INFLUENCE OF FORM OF ORGANIC MATTER ON THE MINERALISATION OF APPLIED PHOSPHORUS IN SUBMERGED RICE SOILS

By

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DECLARATION

I hereby declare that the thesis entitled "Influence of form of organic matter on the mineralisation of applied phosphorus in submerged rice soils" 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, associateship, fellowship, or other similar title, of any other University or Society.

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Certified that this thesis entitled "Influence of form of organic matter on the mineralisation of organic phosphorus in submerged rice soils" is a record of research work done independently by Sri. ... [illegible], under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Introduction

INTRODUCTION

Phosphorus being one of the major plant nutrients plays a vital role in the nutrition of the rice plant. Its role in crop production is well known and needs no special emphasis. However, the different aspects of phosphorus nutrition, such as its availability to plants and the response of crops to its application [illegible] under those are investigated. The availability of this nutrient in the soil is governed by a large number of factors such as particle size, soil reaction, moisture status, content of organic matter, soluble iron and aluminium etc. in the soil. It would appear therefore, that the status of this element in the soil can hardly be used as a criterion of plant response.

Soils in India, particularly that of Kerala State though reported to be poor in total and available P, do not generally respond to application of phosphorus. The recovery of applied phosphatic fertilizers by most of the crops ranges between 20 and 30 per cent ([illegible], 1977). This is because when soluble phosphatic fertilizers are applied to the soil, a large portion is converted into insoluble iron, aluminium and calcium phosphates. The nature of fertilizer [illegible] ment adjacent to [illegible] the nature of reaction products formed in the soil which, in turn, serve as potential source of available phosphorus to the plant with passage of time. Transformation of added P into Fe-P and Al-P fractions are related to pH, clay, organic matter, sesquioxides and P fixing capacity of soils.

The behaviour of phosphate in waterlogged soils is markedly different from that in upland soils. This difference in behaviour is of greatest practical significance in the phosphatic nutrition of rice grown in low land soils. The unique soil conditions created by waterlogging influence the transformation and availability of both native and applied phosphates. Several workers have studied the transformation of phosphorus in submerged rice soils and they reported that the soil conditions ensuing the submergence of soil result in an increase in the content of available phosphorus in soil.

Availability and forms of phosphorus in soils, to a large extent, are influenced by organic matter application. Application of farm yard manure has been reported to enhance the efficacy of phosphorus utilisation and absorption by plants. This may be through the effects of the action of carbon dioxide in solubilising phosphorus compounds or the formation of phospho-humic complexes which are more assimilable by plants or the formation of humus colloids which form a protective coating over the colloidal sesquioxides. Although the beneficial role of organic matter application to the soil is well known, quantitative data on the extent to which the applied phosphorus will continue to become available to rice crop under submerged conditions particularly under the influence of different types of organic matter are not available. A knowledge of the extent and pattern of phosphorus transformation as influenced by organic matter will help us to find out how best the applied phosphorus can be made available to the plant enabling better phosphorus management in lowland rice soils. The present investigation, thus, was undertaken with the following objectives.

1. To study the effect of submergence on the transformation of phosphorus in rice soils.

2. To study the effect of different forms of organic matter and different forms of P fertilisers on the transformation of soil phosphorus into different forms under waterlogged condition.

3. To find out the effect of organic matter and phosphorus on the release of exchangeable iron under submerged conditions of the soil and

4. To find out the effect of application of phosphorus and organic matter on growth and yield of lowland rice.

Review of Literature

REVIEW OF LITERATURE

Fixation of fertilizer phosphorus into less soluble forms of iron and aluminium phosphates due to soil reactions leads to low recovery of applied phosphatic fertilizers by crops. In submerged soils organic matter may be present in the partially humified forms and phosphorus mineralisation is not likely to be as fast as in uplands. Although the beneficial role of organic matter application to the soil is well known, quantitative data on the extent to which the applied phosphorus will continue to become available to rice crop under submerged conditions, particularly under the influence of organic matter are not available. A knowledge of the extent and pattern of phosphorus mineralisation as influenced by organic matter will be useful to find out how best the applied phosphorus can be made available to the plant. A brief review of the research work carried out on the availability of phosphorus and its transformation in soils under the influence of organic matter is presented below.

1. Effect of phosphorus in the nutrition of the rice plant.

As a major plant nutrient, phosphorus is involved in many vital growth processes in rice. If phosphorus is limiting, plants fail to grow satisfactorily and yields are depressed. High rice yields by P application to soils have been attributed to stimulation of root development, making plants more resistant to drought, promotion of early flowering and ripening by means of which the unfavourable influence of late transplanting is eventually reduced or neutralised, development of more active tillering which enables rice plants to recover more rapidly and more completely after any adverse situation and higher food value of rice grains owing to higher P content of the grain (De Geus, 1954). Phosphorus also helps to strengthen the stem of cereals, thus reducing their tendency to lodge (Anonymous, 1961).

Low phosphorus supply suppresses early nitrogen uptake and prevents the synthesis of proteins from nitrogenous substances. Phosphorus is essential for the synthesis of nucleic acids and phospholipids. Nucleic acids can actually promote heading in rice; as it controls the vegetative growth through protein biosynthesis and reproductive growth through flower initiation (Fugiwara, 1964). Phosphorus increases the ratio of grain to straw in cereals resulting in greater yield of grain. Phosphorus is also reported to impart disease resistance to plants as it enhances normal cell development resulting in vigorous growth (Tamhane et al. 1966). Bhattacharya (1970) revealed that P manuring increased early tiller formation, a greater part of which ultimately provided more grains of heavier weights. There was early and synchronous flowering as well. Other beneficial effects of phosphorus include the formation of new cells, promotion of root growth (particularly the development of fibrous roots), formation and setting of seeds and grains and improvement in the quality of grain.

2. Effect of submergence on the availability of added and native soil phosphorus

Waterlogging markedly increases the availability of native and applied P as compared to upland soils. In low land rice soils, the water and acid soluble phosphorus increase on flooding and P uptake by rice plants is enhanced.

The increase in the availability of phosphate on submergence of a soil was reported as early as 1940 (Mold, 1940; Mortimer, 1941). Kawaguchi (1944) concluded that in submerged soil the solubility of soil phosphorus increased with the development of reducing conditions when iron phosphate was the main constituent of soil phosphorus. Chin (1939-50) observed that the amount of water soluble phosphorus increased with the development of reducing condition in soil. Similar observations have been reported by Ogawa et al. (1951), Islam and Elahi (1954), Patrick

(1964) and Davant and Ellis (1964). Basak and Bhattacharya (1962) studied the transformation of phosphorus in rice soils of Bengal and found that there was an increase of 64 per cent in available phosphorus from planting to tillering stage and a gradual decrease after pre-flowering stage to the original level. They also observed a release of about 420 kg P_2O_5/ha from the mineralisation of organic phosphorus in the course of a rice growing season.

However, submergence does not invariably lead to an increase in phosphate solubility and availability (Ponnamperuma, 1969). Several factors obviously affect the release and re-fixation of phosphate in a flooded soil. He pointed out that phosphate availability may be considerably reduced as a result of the precipitation of $FePO_4$ in the oxidised rhizosphere of the rice roots. Fe^{2+} ion is oxidised to Fe^{3+} and combines with the phosphate ion.

Broeshart et al. (1965) observed that flooding significantly increased the availability of phosphate in rice soils in which free $CaCO_3$ was absent. Purnachandra Rao (1966) noted that availability of phosphorus increases with flooding due to solubilization of ferric phosphate to ferrous phosphate associated with a lowering of oxidation-reduction potential of the soil. Mahapatra and Patrick (1969, 1971) stated that available soil phosphorus was known to increase when a soil was submerged. The increase in water soluble phosphorus has been attributed to the release of phosphorus from organic matter. Chakravarti and Kar (1970) reported that water soluble phosphate increased in all soils gradually with the period of submergence. Islam and Islam (1973) reported that the concentration of water soluble phosphorus increased upon submergence, reached a maximum and then decreased. Mandal and Khan (1975) reported that the availability of native soil phosphorus in acid soils increased appreciably consequent to continuous waterlogging. Chang (1976) noted that during submergence crystallised iron phosphate tends to change into colloidal iron phosphate through solution and precipitation resulting in its greater availability.

Karwar (1976) has reported that the increase in available phosphorus on submergence of a soil could be attributed to the following mechanisms:-

(i) release of P from mineralisation of organic matter,

(ii) reduction of insoluble ferric phosphate ($FePO_4 \cdot 2H_2O$) to the more soluble ferrous phosphate ($Fe_3(PO_4)_2 \cdot 8H_2O$) (Islam and Elahi, 1954),

(iii) release of occluded phosphate by reduction of hydrated ferric oxide coating (Chang and Jackson, 1958; Mahapatra, 1966),

(iv) anion exchange between clay and organic anion (Russel, 1962),

(v) displacement of phosphate from ferric and aluminium phosphates by organic anion (Savant and Ellis, 1964; Mandal and Mandal, 1973),

(vi) increase in solubility by hydrolysis of $FePO_4.2H_2O$ and $AlPO_4.2H_2O$ caused by the increased pH accompanying reduction of acid and strongly acid soils (Ponnamperuma, 1965) and

(vii) increase in solubility of phosphate associated with the decrease in pH caused by accumulation of CO_2 in calcareous soil (Ponnamperuma, 1965; Khan and Mandal, 1973). These mechanisms may not all be important at any one time or under the same situation. The nature and magnitude of such transformations are influenced more by the chemical characteristics of the soils than by their reaction.

Singh and Sahasan (1976) obtained an increase in available phosphorus after 10 days of incubation when clay loam acid soils with pH 5.7 and organic carbon 0.9 were kept waterlogged. They also recorded a decrease in available phosphorus after 20 days of incubation. Mohanti and Patnaik (1977) observed that on submergence, the available increased during the first 20 to 30 days because of reduction of iron and manganese compounds, afterwards there was a decrease because of the precipitation as phosphates. Singh and Ram (1977) found that available P increased during tillering stage of wet land rice and that it tended to decrease after that stage. They related the increase in available P in slightly acid soil (pH 6.6) to a decrease in Fe-P and Ca-P concentrations. The decrease in available P might be due to the re-formation of Fe-P and Ca-P. Katyal and Venkataramayya (1983) reported that soil solution phosphorus was influenced slightly, by submergence and increased due to the addition of fertilizer P. Its concentration was about 2.9 times more in wet season than in dry season, regardless of the fertilizer application or time of submergence. The increase in water soluble P was attributed to the higher temperature in the first two months of the wet season than in the corresponding periods of dry season. Mathew and Jose (1985) studied the release of available P from rock phosphate and super phosphate during incubation under submergence and observed that the concentration of available P in the soil was not significantly affected by the variations in the form of applied P. Sudhir et al. (1987) found that Al-P was the more important fraction contributing towards the availability of phosphorus in soils followed by Red-P and Calcium-P.

3. <u>Transformation of inorganic phosphate in submerged soils</u>

Phosphate ion in the soil forms a wide array of compounds with varying solubility. According to Chang and Jackson (1957) inorganic phosphate in the soil can be fractionated into six forms:

(1) Saloid bound phosphate,
(2) Aluminium bound phosphates,
(3) Iron bound phosphates,
(4) Reductant soluble phosphates,
(5) Occluded phosphates and
(6) Calcium bound phosphates.

The behaviour of phosphate in waterlogged soils is remarkably different from that in upland soils. This difference in behaviour is of greatest practical significance in the phosphate nutrition of rice grown in low land soils. The unique soil conditions created by waterlogging influence the transformation and availability of both native and applied phosphates. Various research workers have studied the distribution pattern and plant availability of different phosphate fractions in submerged soils.

In the main rice tracts of different climatic zones of West Bengal, Basak and Bhattacharya (1962) observed that iron and aluminium phosphates represented 4[illegible] per cent [illegible] phosphate. These fractions decreased gradually from planting time to post harvest time and then increased by the planting time of the next season. Jesse ([illegible]) observed that there occurred a loss of aluminium phosphate and a gain in iron phosphate with time when excess soluble phosphate was not continuously present. The change of Al-P to Fe-P was due to the lower solubility product of Fe-P. Chiang (1963 a, b) reported that in soils that became less acid as a result of waterlogging, Ca-P and Fe-P increased and Al-P decreased, whereas when alkaline soils were waterlogged, Ca-P and Al-P increased and Fe-P decreased. Mahapatra (1966) studied the transformation of inorganic phosphate in an acid clay soil as a result of waterlogging and found that the greatest change was the conversion of phosphate from the reductant soluble fraction to ferrous phosphate. [illegible] (1967) studied the changes in forms of inorganic phosphorus in four rice soils and showed that on submergence and development of anaerobic condition, aluminium phosphate, alkali extractable iron phosphate and calcium phosphate increased but reductant soluble phosphate decreased. Mahapatra and Patrick (196[illegible]) observed that on waterlogging, aluminium and iron phosphates increased with a decrease in reductant soluble phosphate while calcium phosphate remained relatively unchanged. Islam ([illegible]) reported that the increase in soluble phosphorus in acid soils was due to a decrease in calcium, iron and reductant soluble phosphate concentrations in neutral soil. Increased with decrease in Fe-P and Al-P. Hong and Yoo (1970) observed that in normal paddy soils, the main form was iron phosphate and aluminium phosphate and the transformation of phosphate from ferric to ferrous type under waterlogged condition was remarkable. Mahapatra and Patrick Jr. (1971) found that when Al-P increased by 35% and Fe-P by 64%, Ca-P did not undergo much change due to waterlogging, the reductant soluble P decreased. Part of the increase in Fe-P was apparently at the expense of reductant soluble iron P and in certain soils, part of the increase in Fe-P apparently came from Ca-P. Mandal and Chatterjee (1972) reported that the transformation of P into Al-P and Fe-P appeared to be directly related to the quantity of these inorganic forms of P already present in the soils, proportionate to the total amount of inorganic soil phosphate. Patrick et al. (1974) found that flooding increased the transformation of all the P sources into Fe-P fraction. Gupta and Narain Sayan (1975) studied the transformation of native inorganic phosphates in red soils of Mirzapur under waterlogged condition and observed that Al-P decreased whereas Fe-P and Reductant soluble P increased with increase in time. Mandal and Khan (1975) reported that under continuous waterlogging Al-P recorded an initial increase followed by a decreasing trend while a less acid soil comparatively rich in Al-P recorded progressive decrease. Continuous waterlogging for 110 days caused an increase in Fe-P in all soils, but did not bring about any decrease in Reductant soluble P and the Ca-P decreased. Singh and Singh (1976) also observed in Dhankar soil of Mirazpur a decreasing trend of Al-P and Ca-P and increasing trend of Fe-P with age of rice crop under waterlogging. Rajukkannu and Ravikumar (1978) studied the transformation of phosphorus in rice soils under flooded conditions and observed that consequent to flooding Fe-P and Al-P increased and Reductant soluble iron phosphate decreased and that there was no change in Ca-P. Verma and Tripathi (1982) observed that all the native inorganic phosphorus fractions increased upon waterlogging with the maximum increase of 70.7 per cent in Fe-P. Sundaresan Nair and Aiyer (1983) found that consequent to waterlogging Fe-P, Al-P, Ca-P and Saloid-P increased while Reductant soluble P and Occluded P decreased. Harikrishnan Nair (1986) found that on waterlogging, lateritic alluvium soil of Vellayani registered an increase in all the inorganic fractions of phosphorus. The average percentage increase due to submergence was lowest for Occluded P and highest for Fe-P. Sah and Mikkelsen (1986) observed significant changes in the inorganic P fractions due to submergence of soils. They found that the Fe-P fractions increased and Al-P fractions decreased when soils were submerged. The Ca-P fractions increased during flooding in soils that had initially high levels of Ca-P but was almost unchanged in soils with lower Ca-P content. The reductant soluble fractions decreased during flooding in the soils subjected to annual flooding for rice.

4. Influence of organic matter on phosphorus transformation

Addition of oxidisable materials like green manures increased the availability of phosphorus by promoting the process of conversion of ferric to ferrous phosphate (Islam and Elahi, 1954). Shapiro (1958) concluded that organic matter effects phosphate transformation in waterlogged soils through mechanisms of reduction and chelation. Both processes lead to increase in the solubility and availability of phosphate. Mandal (1964) observed that in presence of starch, 0.5 N acetic acid extractable showed a considerable increase with a decrease in Ca-P fraction. It was thought that the large amount of CO_2 formed due to the decomposition of starch might have converted some of the insoluble tricalcium phosphate to mono and dicalcium phosphates. Mandal and Chatterjee (1972) observed in a laboratory incubation study that organic matter addition resulted in a higher percentage of added P remaining in soluble form during the initial period of incubation but it significantly increased the content of [illegible] [illegible] by [illegible] [illegible] and the amounts of [illegible] in all the soils. It also [illegible] [illegible] transformation [illegible] inorganic phosphorus [illegible] [illegible] phosphorus and [illegible] soluble iron phosphate in [illegible] soils. [illegible] not show any significant influence on the [illegible] formation into calcium phosphate. They concluded that [illegible] addition of organic matter reduced very considerably [illegible] the added [illegible] aluminium phosphate in all the soils. [illegible] and [illegible] (1975) observed that application of organic matter significantly increased the fixation of [illegible] phosphorus both as aluminium phosphate and iron phosphate [illegible] [illegible] low land rice soils. This was possibly [illegible] formation of complexes by the decomposition [illegible] organic matter with [illegible] [illegible] [illegible]. [illegible] and [illegible] (1976) reported that addition [illegible] matter in submerged soil resulted in significant [illegible] in [illegible] after [illegible] months, whereas increased [illegible] [illegible] were observed after [illegible] days of its addition. [illegible] (1977) conducted a laboratory [illegible] lateritic soil of [illegible] to study the influence of organic matter on the transformation of inorganic [illegible] [illegible] and found that [illegible] amounts of [illegible] [illegible] were observed [illegible] and also the conversion of [illegible] [illegible] was found lowered in the soil. He also suggested that the transformation of added P into different fractions in laterite soil may be arranged in the descending order Al-P > Fe-P > Ca-P. Hajra and Debnath (197) studied the effect of some chelating agents on the transformation of native inorganic fractions in soil and found that addition of some chelating agents like humic acid, ... and oxine did not have any influence on the saloid bound-P in laterite soils. There was an overall increase in Al-P on addition of the complexing agents. The Fe-P fraction increased due to application of ... . Native Ca- fraction was not much affected by the application of complexing agents. Mukhopadhyaya and Mandal (197) studied the effect of addition of farm yard manure (FYM) on available phosphorus in acidic soils (pH 5.1) and found that addition of FYM increased the availability of phosphorus. This increase was attributed to mineralisation of some organic phosphorus of the farm yard manure.

In general, application of organic matter to submerged soil increases the availability of phosphorus due to the following reasons (Sarwar, 1976):-

(i) the organic colloids preventing the soluble P from coming into contact with active iron and aluminium,

(ii) the action of CO_2 produced by decomposing organic matter in dissolving some phosphatic material or in tying up active iron,

(iii) the formation of organic phosphates (phospho-humic complexes) which are less firmly fixed in soil and

(iv) the mineralisation of organic phosphorus by bacteria and its release for use by the plants.

Broadbent (1953) pointed out that in addition to releasing phosphorus from the organic form such as phosphorus esters of inositol, organic matter influences phosphorus supply indirectly by influencing the growth of microorganism which produce organic acids capable of solubilizing inorganic phosphates. Hajra and Debnath (1987) studied the effects of humic acid and some synthetic chelating agents, viz. EDTA and oxine on the transformation of added water soluble P in acidic soil and found that application of chelating agents increased the amount of added P retained in saloid bound form and decreased the transformation of added P to Al-P and Fe-P. They also attributed the better efficiency of applied phosphorus in presence of chelating type complexing agents to the retention of greater quantity of added phosphate in saloid bound form.

V. <u>Effect of added phosphate on the transformation of inorganic phosphate</u>

Any form of phosphate applied to soil undergoes a series of changes and except a nominal fraction, plants absorb phosphorus from the reaction products, the chemistry of which is yet to be clearly understood. Available data show that percentage utilisation of applied phosphate may vary from 10 to 40 per cent only. The more soluble phosphate are transformed into a series of reaction products of iron, manganese, aluminium, calcium etc. depending upon soil reaction and these newly formed compounds are precipitated. These reactions are very rapid and take place within a few days (Arambarri and Madrid, 1971; Mandal and Khan, 1972; Mandal and Chatterjee, 1972).

According to Hsu and Jackson (1960) applied P will be retained in soil as Ca-P, Fe-P and Al-P. Chang and Chu (1961) found that in acid soils, 80% of the added P was retained by the soil as Al-P and Fe-P. In 1962, Chu et al. reported that the breakdown of rock phosphate into both aluminium and iron fractions decreased with increasing pH. Manning and Salomon (1965) observed that the continuous application of super phosphate increased the Al-P than Fe-P and Ca-P fractions. Similar were the observations of Mandal and Das (1970) and they further concluded that the dynamics and the magnitude of transformation are more influenced by Fe_2O_3 and active iron rather than pH of the soils. Debnath and Hajra (1972) found that within 24 hours most of the added [illegible] under waterlogged conditions was recovered in different [illegible] in the order Al- > Fe- > [illegible]. Reductant soluble [illegible] increased in red, laterite and hilly soils with no significant changes in alluvial soil and saline soils. [illegible] in quantity of [illegible] increased and that of [illegible] decreased irrespective of soil characteristics. [illegible] (1 7[illegible]) concluded that the transformation of water soluble phosphate into Al- and Fe- is directly related to quantity of these forms present in the soil in proportion to the total amount of inorganic soil [illegible]. They also stated that transformation of [illegible] Fe- and reductant soluble [illegible] more [illegible] into occluded iron and aluminium phosphate [illegible] 19[illegible]. [illegible] showed that [illegible] application, more than [illegible] of the [illegible] super phosphate was converted to [illegible] unavailable [illegible] acid soils whereas under [illegible] maintained a higher amount of available [illegible] super phosphate. [illegible] (19[illegible]) studied the transformation of added phosphates in acid soil under waterlogged conditions and concluded that [illegible] was transformed into [illegible] of incubation. [illegible] converted to unavailable Al, Fe and Ca-phosphates (Mandal and Khan, 1977). Singh and Ram (1977) observed more of Ca-P and Fe-P fractions from the added P than Al-P. Singhania and Goswami (1978) investigated the transformation of applied P in rice-wheat cropping sequence in laterite soils of India and found that P applied to rice increased Al-P, Fe-P and Reductant-P. Sahi et al. (1979) reported that addition of water soluble phosphate to waterlogged calcareous soils caused a considerable decrease in Ca-P and Fe-P and an increase in Al-P at 4 days. Taloshilkar and Patil (1979) studied the fate of applied P at different stages of rice growth under waterlogged condition and observed that Fe-P fraction formed the major portion of native inorganic phosphorus fractions. Al-P, Fe-P and Ca-P fractions increased at both flowering and harvesting stages of rice growth while there was no appreciable increase in the reductant soluble-P fraction. Sharma et al. (1980) conducted an incubation study on the transformation of added P in acid soils of Himachal Pradesh and found that most of the added P was transformed into Al-P, Fe-P and very little to Ca-P fraction at one day interval. The added P which was transformed into Al-P increased upto 7 days and later decreased slowly with time upto 30 days. The conversion of added P into Fe-P fraction increased slowly with time upto 30 days and very little was changed to Ca-P even at prolonged time intervals. Colanandon et al. (1982) studied the transformation and availability of 32P tagged ammonium nitrate phosphate in waterlogged soils and found that most of the added orthophosphates were converted to Al-P and Fe-P in all the soils.

6. Growth, yield and uptake of nutrients by paddy as influenced by organic matter and phosphorus

(a) Influence on nutrient concentration

Experimental evidences in India indicate that the application of phosphate in conjunction with organic manures is beneficial in enhancing the nutrient uptake by plants. Datta and Goswami (1962) in a laboratory study observed that the addition of organic matter (farm yard manure) increased the available phosphorus and its uptake from the alluvial, black, red as well as from the calcareous soils. It has been reported (Anon., 1964) that there was a significant increase in the content of phosphorus in straw and the amount of phosphorus absorbed by the rice plant due to the application of phosphorus. Kusanandana and Wongmaneeroj (1967), Naphade (1969) and Akundov (1969) reported that the phosphorus content in the grain was increased from 0.75 per cent to 0.96 per cent with increased levels of phosphorus (90-150 kg per hectare). Phosphorus content in straw was highly correlated with available phosphorus in the soil, according to [illegible] and Chandrana (1 [illegible]). [illegible] pot culture experiment with rice [illegible] crop observed that [illegible] and potassium uptake by [illegible] phorus and green manure application. [illegible] et al. [illegible] reported that phosphorus uptake [illegible] increasing rates of organic matter and phosphorus [illegible] under submerged conditions [illegible] of field on soils. [illegible] matter also promoted grain phosphorus [illegible] treated with flooding. [illegible] that N and P uptake by the rice crop [illegible] increased by the application of phosphorus [illegible] nitrogen.

(b) Influence on growth and yield

The results of trials with phosphatic fertilizers either alone or in combination with organic or [illegible] fertilizers show that [illegible] generally [illegible] response at most of the places Mahapatra (1961). However, increased yields of [illegible] of phosphatic fertilizers have been reported [illegible] (1 [illegible]) in Andhra, [illegible] in Telangana, [illegible] (1 [illegible]) in Madhya Pradesh [illegible] (1 [illegible]) in Bihar. [illegible] observed [illegible] phosphorus in all Rice Research Stations of Kerala. Gurucharan Singh (1966) recorded from the experiments conducted in Punjab that super phosphate when applied alone had a depressing effect on the yield of paddy. But when it was applied in conjunction with high doses of nitrogenous manures there was a reduction in lodging and increase in the yield. Dubey (1966) reported that there was good response to the application of phosphorus in cultivator's fields in Madhya Pradesh. Chacko (1966) found no response to the application of phosphorus alone either in different forms or at different levels in Kerala though there were indications to show that phosphorus in conjunction with high doses of either green leaf or lime was beneficial in the laterite soils of Kerala. Srinivasulu and Pawar (1969) got no significant effect on plant height, number of ear bearing tillers, length of panicle, 1000 grain weight, number of mature and chaffy grains per panicle and root : shoot ratio by the application of phosphorus for two indica x japonica hybrids. Biswas et al. (1970) studied the effect of long-term application of different bulky organic manures and found that among the different organic manures such as green manure, groundnut cake and farm yard manure, the highest yield of rice was shown under the treatment of farm yard manure which has also raised the organic matter status of the soil to the highest extent. Ramaswamy and

Raj (1972) in a pot culture experiment with rice (I.R. strain as a test crop observed that grain and straw yields of rice were significantly increased due to phosphatic fertilization. Chatterjee et al. (197) studied the effect of different bulky organic substances on rice production and found that application of bulky organic matter (a) 10 t/ha on dry weight basis, 3-4 weeks before transplanting if allowed to decompose under submerged soil condition can replace 20-40 kg N/ha out of 80 to 100 kg N/ha advocated for proper growth and production of high yielding varieties. Tiwari et al. (1980) noticed that green manuring raised the grain yield of rice significantly and there was 27% increase over control. Ahmed et al. (1984) reported that there was significant increase in grain and straw yield of rice under flooded conditions due to the application of phosphatic fertilizers in conjunction with organic matter. Mandal and Chatterjee (1983) observed that added increased the number of tillers per sq.m., dry matter accumulation, number of matured panicles per sq.m., number of filled grain/panicle and 1000 grain weight and markedly increased yield. Reddy and Mitra (1985) found that under waterlogged condition, application of P together with N increased the grain yield of rice 9-14 per cent over nitrogen alone, and by 27 per cent over the unfertilized control. Roy and Jha (1987) studied the effect of phosphorus on lowland rice yield and found that N application increased the grain yield from 3.93 t/ha without N (control) to 4.61 t/ha with N applied basally. Gopalaswamy and Vidhyasekharan (1987) studied the effect of green leaf manure on rice yield and found that application of green leaves of *Glyricidia maculata* before transplanting rice significantly increased rice yield over control.

Materials and Methods

MATERIALS AND METHODS

A field experiment to study the effect of incorporating of different forms of organic matter on the [illegible] transformation of native and applied phosphorus in [illegible] rice soils and their effects on the growth and yield of rice was conducted during the second crop season (Mundakan) of 19[illegible] in the Instructional Farm of College of Agriculture, Vellayani. The experiment was laid out in randomised block design with 12 treatments and three replications. The details of the experiment, treatments adopted, method of collection of soil and plant samples, methods of chemical analysis and the statistical methods adopted for the experiment are given in this chapter.

Details of the experiment

Location : Wetland area of the Instructional Farm on the western side of the College of Agriculture, Vellayani, Kerala.

Soil : The texture of soil was sandy clay loam [illegible] soil [illegible] acidic in [illegible]. [illegible] hydrometer [illegible] composition [illegible] as determined by [illegible] analysis [illegible] given in Table 1.

Table 1. Soil characteristics of the experimental site

A. Mechanical analysis

Coarse sand (per cent)	=	[illegible]
Fine sand "	=	[illegible]
Silt "	=	[illegible]
Clay "	=	[illegible]

B. Chemical analysis

Soil pH	=	[illegible]
Organic carbon (per cent)	=	[illegible]
Total N "	=	0.07
Available N (kg ha^{-1})	=	[illegible]
Total P_2O_5 (per cent)	=	[illegible]
Available P_2O_5 (kg ha^{-1})	=	[illegible]
Total K_2O (per cent)	=	[illegible]
Available K_2O (kg ha^{-1})	=	[illegible]

Forms of phosphatic fertilizers

P_0 - No phosphorus

P_1 - Single super phosphate ([illegible] P_2O_5) to provide [illegible] kg P_2O_5/ha

P_2 - Mussoorie phosphate (21.5 % P_2O_5) to provide [illegible] kg P_2O_5/ha

Forms of organic matter

M_0 - No organic matter

M_1 - Farm yard manure @ 5 t/ha

M_2 - Green leaves (Glyricidia) @ 5 t/ha

M_3 - Composted salvinia @ 5 t/ha

Detailed analysis of the forms of organic matter used in the field experiment is given in Table 2.

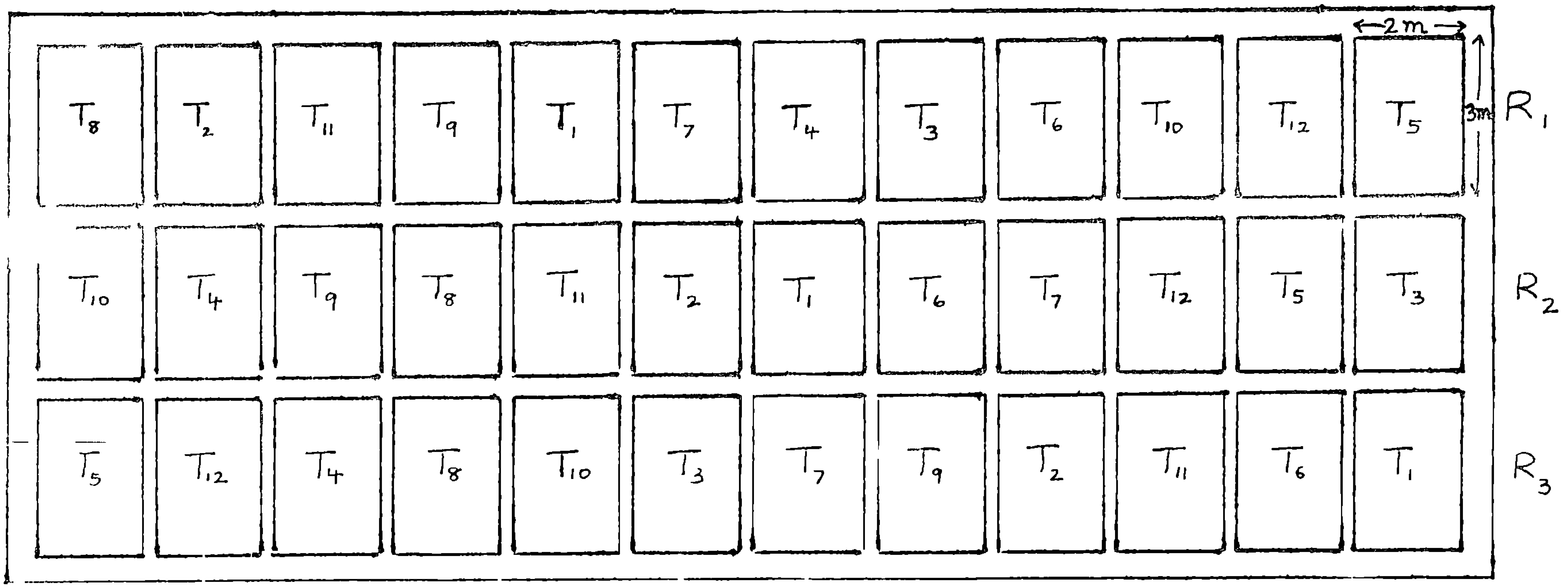
Table 2. Composition of organic matter (on oven dry basis)

	N %	P %	K %
1. Cattle manure (FYM)	0.59	0.2[illegible]	0.39
2. Green leaves (Glyricidia)	3.12	0.21	0.96
3. Composted salvinia	0.21	0.12	0.42

Treatment combinations

No.		Details
T_1 -	P_0M_0	No phosphorus + No organic matter
T_2 -	P_0M_1	No phosphorus + Farm yard manure
T_3 -	P_0M_2	No phosphorus + Green leaves
T_4 -	P_0M_3	No phosphorus + Composted salvinia
T_5 -	P_1M_0	Super phosphate + No organic matter
T_6 -	P_1M_1	Super phosphate + Farm yard manure
T_7 -	P_1M_2	Super phosphate + Green leaves
T_8 -	P_1M_3	Super phosphate + Composted salvinia

FIG. 1. LAY OUT PLAN - RANDOMISED BLOCK DESIGN



T_9 - P_2M_0 Mussoorie phosphate + No organic matter
T_{10} - P_2M_1 Mussoorie phosphate + Farm yard manure
T_{11} - P_2M_2 Mussoorie phosphate + Green leaves
T_{12} - P_2M_3 Mussoorie phosphate + Composted salvinia

Replication 3

All plots received N as urea (46% N) and K as muriate of potash (60% K_2O) at 70 kg N/ha and 35 kg K_2O/ha respectively. Plots except (P_0M_0) which did not receive any organic matter treatment were supplied with equivalent amounts of N, and K in NPK to compensate for the nutrients supplied through the application of organic matter.

The experiment was conducted in microplots

Plot size	:	3 x 2 m
Gross area	:	6 m^2
Net plot size	:	2.55 x 1.70 m (excluding border and sample rows)
Net area	:	4.34 m^2
Spacing	:	15 x 10 cm
Crop variety	:	Triveni
Duration of the crop	:	110 days
Season/year	:	Mundakan (second crop season)/1986
Date of sowing	:	14-[illegible]-1986
Date of harvest	:	2-1-1987

[illegible]plication of fertilizers and organic man[illegible]

Calculated quantities of P fertilizers based on their P_2O_5 content were applied as basal dose. All the plots received a common dose of 7[illegible] N/ha and [illegible] $_2$O/ha. Half the amount of N and K were applied basally. The remaining N and K were applied as top dressing at panicle initiation stage as recommended in the package of practices recommendations of the K[illegible], 1[illegible].

[illegible]

The seeds were sown in the nursery on 14-[illegible]-1[illegible] and the seedlings were transplanted to main field on 1-1[illegible]-1[illegible] after the application of fertilizers. All the intercultural and plant protection measures were carried out as and when required. Water level was maintained at 1.5 cm during transplanting and gradually increased to 5 cm till one week before harvest.

[illegible]

[illegible] plant and number of tillers per hill were recorded [illegible] tillering and maximum tillering stages. At flowering stage, the number of productive tillers and height of the plant were recorded.

The crop was harvested leaving one border and one sample row on all the sides of each plot. The yield of grain and straw [illegible] har- vested [illegible] cent [illegible].

<u>Collection of soil and plant samples for chemical analysis</u>

Soil samples

Soil samples were initially [illegible] the experiment. From [illegible] plot, [illegible] soil were taken [illegible] collection of [illegible] intervals of [illegible], [illegible], [illegible], 45, [illegible], 7[illegible] days by the [illegible] method [illegible] [illegible] and [illegible] ([illegible]77).

Plant samples

The plant samples from the sampling row were collected at the time of harvest. The grain and straw were separated and air dried and then oven dried at 6[illegible]–7[illegible] for [illegible] hours. The dried samples were ground in a mechanical grinder and preserved in [illegible] [illegible] analysis.

Analysis of soil

The soil samples collected before applying the treatments and at fortnightly intervals after transplanting were analysed for soil reaction, exchangeable iron, available phosphorus and various inorganic fraction of phosphorus.

Soil reaction

The pH of the soil was determined using a Perkin Elmer pH meter and glass electrode in a soil-water suspension of 1:2.5 ratio.

Exchangeable iron

Exchangeable iron was estimated by extracting a known weight of the wet soil with neutral normal ammonium acetate and the colour developed by potassium thiocynate method was read in a Klett-Summerson Photoelectric Colorimeter using green filter (Jackson, 1973).

Available phosphorus

This was estimated colorimetrically by chloromolybdo phosphoric blue colour method (Jackson, 1973) in a Photo electric Colorimeter by extracting the wet soil with Bray extractant No. 1 (0.03 N NH_4F in 0.025 N HCl).

Inorganic P fractions

Inorganic P fractions viz. Saloid-P, Aluminium-P, Iron-P, Reductant soluble P, Occluded-P and Calcium-P were estimated by the procedures of Chang and Jackson after Peterson and Corey as described in Hesse (1976). The details of the procedure are furnished hereunder.

Saloid-P

A weighed quantity of the moist sample to give one gram of dry soil was placed in 100 ml of polypropylene centrifuge tube, 50 ml of 1M NH_4Cl solution was added and shaken for 30 minutes and centrifuged. The supernatant solution was estimated colorimetrically by sulfomolybdo-phosphoric blue colour method suggested by Jackson (1973).

Aluminium-P (Al-P)

To the soil left after the removal of supernatant solution, 50 ml of 0.5 M NH_4F solution adjusted to pH 8.2 with NH_4OH was added and shaken for one hour and centrifuged. Phosphorus in the solution after eliminating fluoride interference by adding boric acid and decolourising with activated carbon was estimated by chloromolybdo phosphoric blue colour method (Jackson, 1973) in a photo-electric colorimeter using 660 nm filter.

Iron-P (Fe-P)

The residue was washed twice with 25 ml portions of saturated NaCl solution and centrifuged each time to recover the soil. The soil was then suspended in 50 ml of 0.1 M NaCl solution and shaken for 17 hours, centrifuged and P was estimated colorimetrically by sulfomolybdo phosphoric blue colour method suggested by Jackson (1973).

Reductant soluble P (Red-P)

The residue was washed twice with 25 ml portions of saturated NaCl solution and discarded the washings. The soil was suspended in 25 ml of 0.3 M Na citrate solution, 1 g of sodium dithionite was added and shaken for 10 minutes. The suspension was heated to 80°C diluted to 50 ml shaken for 5 minutes and centrifuged. The supernatant solution was decanted. The residue was washed twice with saturate NaCl solution and the washings were added to the previous solution and mixed well. To 3 ml of the solution, 1.5 ml of 0.25 N $KMnO_4$ was added to oxidise excess dithionite and citrate. The solution was allowed to stand for 3 minutes and P in the solution was estimated by sulfomolybdo phosphoric blue colour method (Jackson, 1973) and expressed as reductant soluble P.

Occluded-P

To the residue 50 ml of 0.1 N NaOH solution was added, shaken for one hour and centrifuged. The occluded-P was estimated from the supernatant solution by chloromolybdo phosphoric blue colour method (Jackson, 1973) in a photo-electric colorimeter.

Calcium-P (Ca-P)

The residue was washed twice with 25 ml portions of saturated NaCl solution. To this 50 ml of 0.5 N H_2SO_4 was added and shaken for one hour and centrifuged. The residue was discarded. P from the supernatant solution was estimated by sulfomolybdo phosphoric blue colour method (Jackson, 1973) and expressed as Ca-P.

Analysis of plant samples

Total Nitrogen

The total nitrogen content in the straw and grain samples were analysed by Microkjeldhal method (Humphries, 1956).

Total phosphorus

This was estimated in the triple acid extract by the Vanadomolybdate method as described by Jackson (1973).

Total Potassium

The triacid extract prepared was diluted suitably and the total K content was estimated using an EEL flame photometer (Stanford and English, 1949).

Calcium and Magnesium

The content of these elements in the straw and grain was estimated from the triple acid extract after proper dilution using a "Perkin Elmer 305B" Atomic Absorption Spectrophotometer with the respective Cathod lamps.

Statistical Analysis

Analysis of variance technique for groups of experiments as per the method suggested by Panse and Sukhatme (1978) was used for the analysis of the aggregate data to find out the effect of different treatments, periods of submergence and interaction of these factors on the transformation of different P fractions, soil pH and exchangeable iron.

Zero order correlation coefficients were worked out between P fraction, available P and straw and grain yield.

Analysis of variance technique as suggested by Panse and Sukhatme (1978) was used to find out the effect of different treatments on growth and yield characters.

Results

RESULTS

Results on the influence of different kinds of organic matter on the transformation of different forms of P under submerged field condition and their effects on growth characters and yield of rice are presented in this chapter.

<u>Transformation of Phosphorus in Rice soil</u>

Iron-P (Fe-P)

Changes in Fe-P fractions as influenced by treatments and period of submergence are presented in Table 5a and 5b. The data show that the effect of phosphatic fertilisers, organic matter, different periods of submergence and the combinations of treatments and periods are significant.

Among the different forms of organic matter, FYM treatment recorded the lowest Fe-P level which was on par with that in M_2 (green leaves). It was significantly different from composted salvinia in lowering the level of Fe-P fraction. No significant reduction could be noticed by the application of composted salvinia.

Consequent to the addition of P fertilisers, there was a significant increase in Fe-P content of soil. The highest Fe-P content was recorded by super phosphate

Table 3(a) Influence of organic matter and phosphorus on Fe- content on soil (in ppm)

	P_0	P_1	P_2	Mean
M_0	254.72	296.95	262.71	271.46
M_1	237.02	291.31	255.04	297.96
M_2	230.24	291.76	250.77	250.59
M_3	252.60	294.99	257.03	268.20
Mean	245.02	291.15	256.5[illegible]	

CD for M marginal mean = 6.237

CD for P marginal mean = 7.250

Table 3b Changes in [illegible] as influenced by treatments and period of submergence
(Mean values in ppm)

Treatments		Period in days							Mean
		0	15	30	45	60	75	90	
T_1	P_0M_0	212.90	243.22	271.43	235.27	274.30	256.20	227.60	234.72
T_2	P_0M_1	207.30	223.51	251.74	263.40	297.50	253.90	201.76	237.02
T_3	P_0M_2	210.82	231.73	234.66	263.96	215.02	240.05	209.57	239.24
T_4	P_0M_3	211.40	246.00	263.73	232.90	277.41	254.01	227.52	232.60
T_5	P_1M_0	256.76	239.07	311.20	323.36	313.31	330.64	275.21	276.95
T_6	P_1M_1	232.70	265.77	2[illegible]2.12	312.71	370.23	294.05	270.19	281.80
T_7	P_1M_2	240.71	274.53	276.00	310.63	314.10	239.51	272.44	271.76
T_8	P_1M_3	232.40	296.01	300.20	324.11	313.20	293.73	272.01	274.99
T_9	P_2M_0	220.40	254.03	271.20	293.40	287.11	265.42	233.40	252.71
T_{10}	P_2M_1	210.21	233.05	254.21	267.00	270.82	253.70	217.52	240.76
T_{11}	P_2M_2	207.15	250.70	256.10	233.00	273.73	251.94	225.60	250.77
T_{12}	P_2M_3	213.37	250.72	274.02	207.35	235.30	250.33	232.00	237.03
Mean		222.40	255.43	277.31	272.77	230.52	265.47	232.21	

CD period = 9.633
CD treatments = 12.574
CD interaction = 33.267

treatment (P_1) which was significantly higher than the Mussoorie phosphate treatment (P_2).

The interaction effect of organic matter and phosphate fertilizer was not significant. Among the different treatment combination tried, super phosphate plus no organic matter (P_1M_0) recorded the highest Fe-P content of 2[illegible].[illegible] ppm and the lowest Fe-P in P_0M_1.

The changes in Fe-P content was not consistent during the different periods of submergence with respect to various treatments. Submergence of soil caused a significant increase in Fe-P fraction. The Fe-P at different sampling intervals showed an increase upto the 45th day beyond which it significantly decreased. However, the Mussoorie phosphate plus FYM treated plots (P_2M_1) attained maximum Fe-P level (270.82 ppm) on 60th day of waterlogging only, though the difference between the Fe-P content on 45th (26[illegible].[illegible]) and 60th days of submergence was not significant.

Aluminium-P (Al-P)

The mean levels of Al-P in the various treatments are presented in Tables 4a and 4b. From the results it is evident that various treatments, and different periods of submergence brought about significant difference in the levels of Al-P fraction.

Table [illegible]. Influence of [illegible] and [illegible] on the [illegible]
[illegible] of [illegible]

	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	149.[illegible]	[illegible]
[illegible]	[illegible].67	[illegible]	[illegible].61	[illegible]
[illegible]	[illegible]	[illegible]	151.[illegible]	[illegible]
Mean	[illegible].61	[illegible]	[illegible]	

[illegible] [illegible] means = [illegible]

[illegible] [illegible] means = 1.[illegible]

Table 4(b) Changes in Al-P as influenced by treatments and period of submergence
(Mean values expressed in ppm)

Treatments		Period in days							Mean
		0	15	30	45	60	75	90	
T_1	P_0M_0	120.30	140.80	154.60	162.39	156.70	143.70	[illegible]	149.74
T_2	P_0M_1	120.95	130.01	145.81	152.65	140.93	140.32	136.30	139.29
T_3	P_0M_2	126.91	135.82	140.72	156.97	150.15	144.90	142.31	143.67
T_4	P_0M_3	127.13	139.04	153.10	160.21	154.35	147.18	147.00	146.93
T_5	P_1M_0	143.72	151.21	162.23	171.23	165.96	140.67	140.11	155.73
T_6	P_1M_1	134.24	141.13	159.90	161.21	154.04	137.73	132.59	144.42
T_7	P_1M_2	138.80	145.87	155.71	165.24	151.37	145.62	141.21	149.91
T_8	P_1M_2	141.60	140.90	160.16	160.34	163.10	147.11	[illegible]	153.73
T_9	P_2M_0	135.86	148.90	162.11	160.50	164.41	146.33	145.22	152.63
T_{10}	P_2M_1	127.90	140.22	155.70	160.23	154.97	140.24	139.36	145.99
T_{11}	P_2M_2	132.52	145.52	159.79	163.95	153.72	145.72	140.10	149.62
T_{12}	P_2M_3	134.61	146.01	160.72	163.40	160.20	144.90	142.25	151.15
Mean		132.95	142.91	155.64	163.55	157.03	144.95	142.43	

CD Period = 2.326

CD Treatments = 3.045

Application of organic matter significantly decreased the level of Al-P fractions in soil. The maximum decrease in Al-P fraction was observed due to the application of FYM followed by green leaves and composted salvinia treatments.

Phosphatic fertilizer treatments significantly increased Al-P content in soil. There was no significant difference between super phosphate and Mussoorie phosphate in increasing the level of Al-P fraction. However, the highest Al-P content was recorded in super phosphate treatment.

The combined effects of different forms of organic matter and phosphatic fertilizers were insignificant. However, the highest Al-P content (153.73 ppm) was recorded in P_1M_3 and the lowest (139.20 ppm) in P_0M_4.

The changes in Al-P during the different periods of submergence in the various treatments were uniform. Consequent to continuous submergence, there was a significant increase in Al-P fraction. It increased consistently upto 45 days of submergence and started declining thereafter. The trend was unaffected by application of phosphatic fertilizers and different forms of organic matter.

Reductant soluble-P (Red-P)

Tables 9a and 9b present data on the Red-P levels of the various treatments over different periods of submergence. Both treatments and period effects are significant.

When the effects of different forms of organic matter are compared FYM was found to significantly decrease the Red-P. Next in order were green leaves and composted salvinia. No significant change in Red-P fraction could be observed due to the addition of composted salvinia.

Phosphate fertilizer application resulted in a significant increase in Red-P fraction. The increase in Red-P brought about by the addition of super phosphate was significantly higher than that by Mussoorie phosphate.

The interaction effect of organic matter and super phosphate was insignificant. However, the treatment combinations, P_1M_0, P_1M_3 and P_2M_0 recorded the highest Red-P contents of 54.40, 53.20 and 53.05 ppm respectively and the lowest Red-P was recorded in P_0M_1.

Submergence of soil caused a significant decrease in Red-P in all the treatments. The maximum Red-P was noted on the initial day and thereafter it progressively and significantly decreased upto 90th day of submergence.

Table 5a Influence of organic matter and phosphorus on Reductant-P content of soil (in ppm)

	P_0	P_1	P_2	Mean
M_0	48.03	54.40	53.03	51.82
M_1	42.19	49.37	46.04	45.87
M_2	45.73	51.88	48.99	48.87
M_3	46.86	53.28	52.88	51.01
Mean	45.70	52.23	50.23	

CD for P Marginal means = 0.8940

CD for M Marginal means = 1.0323

Table 5b Changes in Reductant Soluble P as influenced by treatments and period of submergence (Mean values expressed in ppm)

Treatments	Period in days							Mean
	0	15	30	45	60	75	90	
T_1 P_0M_0	57.60	55.48	50.10	49.72	46.69	42.10	38.59	48.03
T_2 P_0M_1	50.10	47.30	42.41	38.47	40.73	38.06	31.73	42.10
T_3 P_0M_2	54.22	52.70	47.62	44.15	45.01	40.00	39.51	45.75
T_4 P_0M_3	56.31	54.10	48.25	44.60	46.11	41.25	37.27	46.36
T_5 P_1M_0	64.92	60.12	56.75	52.11	53.91	48.91	40.10	54.40
T_6 P_1M_1	58.23	57.64	52.50	46.44	48.21	42.92	39.37	49.34
T_7 P_1M_2	61.17	58.70	54.11	49.91	50.20	45.66	43.41	51.86
T_8 P_1M_3	63.52	59.10	55.51	51.00	52.21	46.85	44.60	53.28
T_9 P_2M_0	61.26	59.04	55.30	51.20	51.76	47.80	44.88	53.05
T_{10} P_2M_1	50.00	53.05	48.91	42.30	43.11	40.04	35.76	46.94
T_{11} P_2M_2	59.25	56.21	51.75	46.20	48.40	42.50	39.50	49.90
T_{12} P_2M_3	60.71	58.51	54.27	50.81	51.18	48.90	45.77	52.03
Mean	58.85	56.03	51.45	45.92	48.12	43.75	40.55	

CD Period = 1.3656

CD Treatments = 1.7830

It could also be observed that there was a drastic decrease in Red-P during the initial 40 days of submergence and thereafter the decrease was gradual. The interaction between periods and treatments was not significant.

Occluded-P

Tables 6a and 6b present the mean data on Occluded-P in the various treatments submerged continuously for 90 days. The effects of periods of submergence and treatments were significant.

Organic matter treatments significantly lowered the level of occluded-P fraction in soil. The maximum decrease in occluded-P fraction was observed in FYM treatment followed by green leaves treatment. No significant effect was observed due to the addition of composted salvinia.

The content of occluded-P in soil was significantly increased by the application phosphatic fertilizers. The effect of super phosphate was significantly higher than that of Mussoorie phosphate in increasing the level of occluded-P fraction.

The effect of different treatment combinations was also insignificant. However, the highest mean levels of occluded-P over different periods were recorded in T_1M_3 and

Table 6a Influence of organic matter and phosphorus on [illegible] content of [illegible] (in ppm)

	[illegible]	[illegible]	[illegible]	Mean
[illegible]	37.73	[illegible]	[illegible]	[illegible]
[illegible]	37.06	[illegible]2.59	37.19	35.[illegible]
[illegible]	[illegible].41	[illegible]	30.[illegible]	37.7[illegible]
[illegible]	35.35	[illegible]	[illegible]	[illegible].77
Mean	[illegible].31	41.19	37.33	

CD for [illegible] [illegible] .343

CD for [illegible] [illegible] 1.[illegible]7

Table 5b. Changes in [illegible] as influenced by treatments and period of submergence
(Mean values expressed in ppm)

Treatment No.		Period in days							Mean
		1	15	30	45	60	75	90	
T1	0 0	53.61	41.57	37.11	35.12	[illegible]	[illegible]	[illegible].15	[illegible]
T2	0 1	47.72	35.41	31.32	[illegible]	27.50	24.25	[illegible].15	[illegible]
T3	0 2	50.75	34.59	[illegible]	[illegible]	[illegible].17	27.41	[illegible]	35.41
T4	0 3	52.91	37.71	35.91	34.15	[illegible]	20.71	[illegible].24	[illegible]
T5	1 0	61.20	[illegible].62	[illegible].11	43.72	[illegible].45	[illegible]	[illegible]	[illegible]
T6	1 1	56.52	42.75	33.75	[illegible]	[illegible].52	31.37	[illegible].37	[illegible]
T7	1 2	[illegible]	[illegible]	40.55	[illegible]	34.76	[illegible]	[illegible]	[illegible]
T8	1 3	60.47	[illegible].21	42.71	[illegible]	36.54	33.1	[illegible].41	[illegible]
T9	2 0	55.43	[illegible]	[illegible]	[illegible]	[illegible].12	[illegible]	[illegible]	44.21
T10	2 1	59.75	[illegible]	[illegible]	[illegible]	32.41	32.1[illegible]	[illegible]	37.1[illegible]
T11	2 2	54.15	[illegible].15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T12	2 3	[illegible]	47.1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean		[illegible]	[illegible]	37.[illegible]	[illegible]	[illegible]	[illegible]	31.1	

[illegible]

[illegible]

173. The lowest level was recorded i [illegible] 4.

The maximum occluded- was [illegible] on the [illegible] day of submergence and thereafter i[illegible] progressive[illegible] significantly decreased upto [illegible] day of waterlogging. [illegible]he maximum decrease in [illegible] was [illegible] during the initial [illegible] days of submergence. [illegible] not influenced by the treatments and there [illegible] significant effect due to the interaction between [illegible] of submergence and treatments.

[illegible]alcium-? (Ca-)

Changes in Ca- fraction as influenced by periods of submergence and different treatments are presented in Tables 7 and 7b. [illegible] results show that the effects of periods of submergence and treatments are significant.

Organic matter application significantly increased the Ca- contents of soil. [illegible]reen leaves caused greater decrease in the level of Ca- than [illegible]. [illegible]he effect of composted salvinia was insignificant.

The basic fertilizer application resulted in significant increase [illegible] contents of soil [illegible] to [illegible] [illegible] efficient.

[illegible] was no significant [illegible] to the different

Table [illegible]. Influence of [illegible] and [illegible] on [illegible] of soil [illegible]

	[illegible]	[illegible]	[illegible]	Mean
[illegible]	25.44	62.78	[illegible]	[illegible]
[illegible]	[illegible].01	[illegible]	57.33	[illegible]
[illegible]	32.35	[illegible]	[illegible]	4[illegible]
[illegible]	[illegible]	62.71	[illegible]	[illegible]
Mean	33.12	[illegible]	57.[illegible]	

[illegible] for [illegible] means = 1.[illegible]

[illegible] for [illegible] means = 1.4[illegible]

Table 7b Changes in [illegible] as influenced by treatments and period of submergence
(Mean values expressed in ppm)

Treatments		Period in days							Mean
		0	15	30	45	60	75	90	
T_1	P_0M_0	35.41	32.14	35.25	37.14	40.71	30.15	36.31	36.44
T_2	P_0M_1	32.60	31.07	35.50	39.36	34.71	35.14	34.21	34.61
T_3	P_0M_2	32.33	30.00	31.43	32.76	35.34	37.15	32.11	33.83
T_4	P_0M_3	34.39	31.39	34.26	36.72	38.00	37.35	35.73	35.61
T_5	P_1M_0	51.24	57.40	62.17	65.41	71.79	67.21	65.21	62.92
T_6	P_1M_1	50.64	56.13	59.77	69.57	65.42	65.24	60.95	60.39
T_7	P_1M_2	49.75	54.21	57.49	60.72	62.75	63.30	62.16	58.60
T_8	P_1M_3	50.72	57.23	61.27	64.98	70.12	60.72	60.75	62.71
T_9	P_2M_0	46.75	52.54	58.65	62.13	63.93	63.23	59.42	58.77
T_{10}	P_2M_1	45.04	46.95	57.27	60.70	56.24	53.47	58.71	57.03
T_{11}	P_2M_2	44.22	51.77	55.52	59.47	54.35	62.14	60.32	56.50
T_{12}	P_2M_3	46.10	52.03	57.80	61.72	67.25	62.57	59.65	53.19
Mean		43.38	46.12	50.21	55.52	57.75	55.43	52.76	

CD (Period) = 1.9347

CD (Treatments) = 2.4676

[illegible]

[illegible]

[illegible] of soil [illegible] fraction. [illegible] level [illegible] significant [illegible] of [illegible].

[illegible]

[illegible] data on the effect [illegible] matter and phosphatic fertilizers on the [illegible] and [illegible] the influence of [illegible] show [illegible] effects of [illegible] significant.

Organic matter [illegible] significant [illegible] the [illegible] content of soil. [illegible] on [illegible] soil [illegible] solution [illegible] significant.

[illegible] and [illegible] of soil significantly. [illegible] super[illegible]

Table 6a Influence of organic matter and phosphorus on Saloid-P content of soil (in ppm)

	P_0	P_1	P_2	Mean
M_0	1.5791	2.1526	1.6260	1.7859
M_1	1.8226	2.6341	1.9691	2.1419
M_2	1.7407	2.5113	1.8299	2.0272
M_3	1.6396	2.2373	1.7096	1.8655
Mean	1.6955	2.3862	1.7836	

CD for P marginal means = 0.0805

CD for M marginal means = 0.0930

Table 8b Changes in [illegible] as influenced by treatments and period of submergence (Mean values expressed in ppm)

Treatments		Period in days							Mean
		0	15	30	45	60	75	90	
T_1	P_0M_0	1.115	1.312	1.485	1.567	1.712	1.987	1.876	1.5791
T_2	P_0M_1	1.235	1.921	1.824	1.810	1.940	2.107	1.971	1.8226
T_3	P_0M_2	1.217	1.871	1.712	1.732	1.817	1.926	1.910	1.7407
T_4	P_0M_3	1.197	1.532	1.671	1.693	1.734	1.852	1.738	1.6306
T_5	P_1M_0	1.624	2.013	2.085	2.271	2.409	2.513	2.149	2.1526
T_6	P_1M_1	1.990	2.721	2.621	2.695	2.714	2.878	2.812	2.6341
T_7	P_1M_2	1.954	2.929	2.407	2.517	2.623	2.765	2.735	2.5110
T_8	P_1M_3	1.895	2.112	2.195	2.314	2.515	2.425	2.273	2.2473
T_9	P_2M_0	1.324	1.527	1.673	1.759	1.804	1.680	1.531	1.6260
T_{10}	P_2M_1	1.497	1.878	1.921	1.979	2.121	2.201	2.187	1.9691
T_{11}	P_2M_2	1.431	1.712	1.829	1.812	1.936	2.194	1.985	1.8299
T_{12}	P_2M_3	1.405	1.631	1.712	1.812	1.779	1.813	1.615	1.7096
Mean		1.5077	1.8965	1.9353	1.9969	2.1103	2.1715	2.0678	

CD for Period = 0.1230

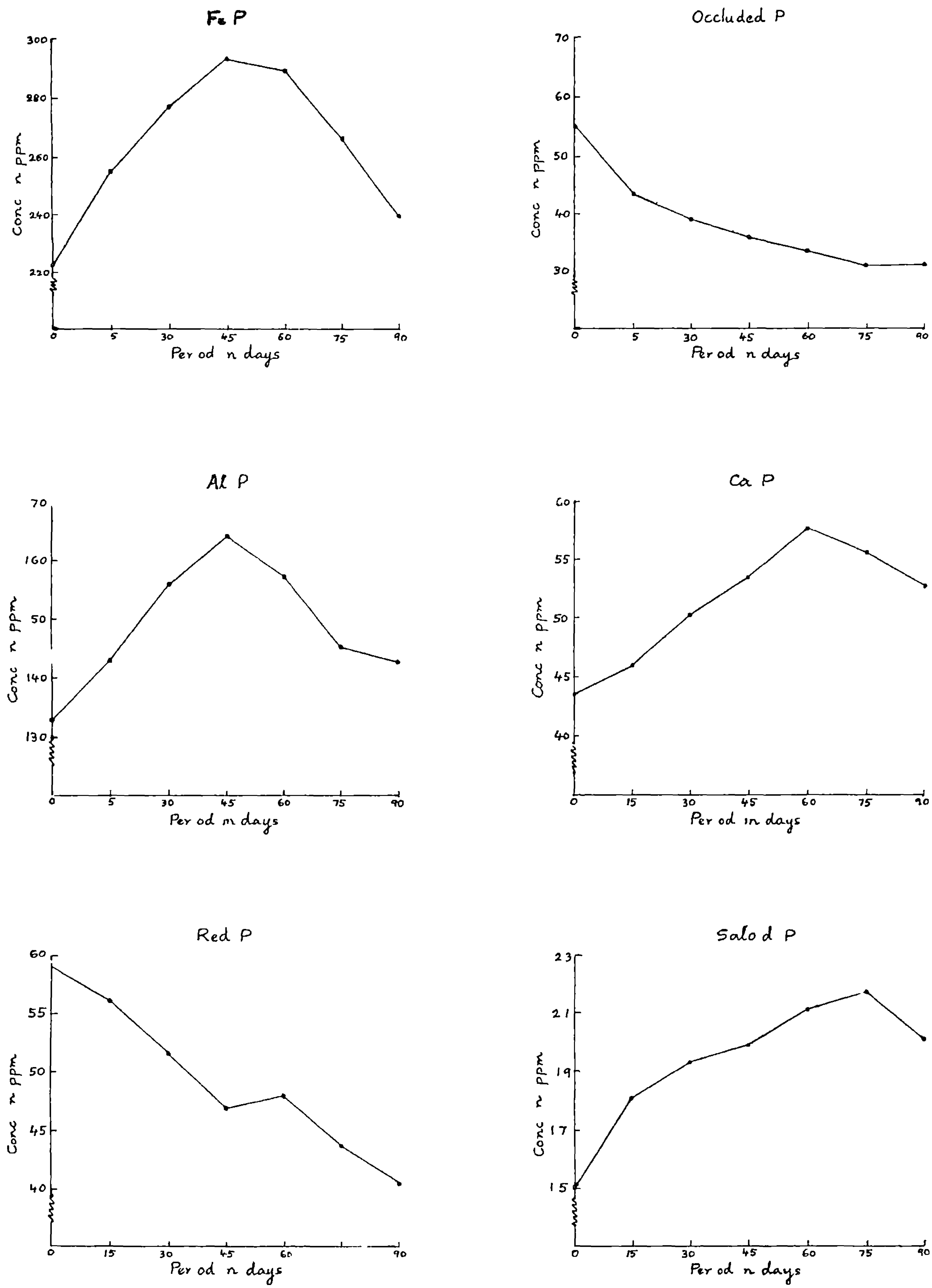
CD for Treatments = 0.1631

in increasing the content of saloid-P fraction and both the treatments significantly increased the saloid-P fractions.

The effect of combined application of organic matter and phosphatic fertilizer was insignificant. However, among the various treatment combinations tried, super phosphate plus farm yard manure (P_1M_1) recorded the highest saloid-P content of 2.6 ppm followed by super phosphate plus green leaves (P_1M_2) which recorded 2.5 ppm saloid-P fraction. The lowest saloid-P content of 1.6 ppm was recorded in P_0M_0.

There was a significant increase in saloid-P content of soil due to periods of submergence. Consequent to submergence, there was a gradual increase in saloid-P and the maximum level was recorded on 75th day, which was statistically on par with the saloid-P content on 60th day. Beyond 75 days of submergence, there was a gradual decrease in saloid-P level. The interaction effect of period and treatment was not significant. However, with continuous submergence, saloid-P fraction increased upto 75 days except in the case of P_1M_0, P_1M_3, P_2M_0 and P_2M_3 where the maximum value was recorded on 60th day of waterlogging.

FIG. 2. EFFECT OF SUBMERGENCE ON INORGANIC P FRACTIONS IN SOIL



Available-P

Tables 9a and 9b present data on available-P levels in the various treatments over different periods of submergence. The effect of periods of submergence, treatments and their combinations are significant (Fig. 5).

Application of different forms of organic matter produced significant increase in available-P. The maximum increase in available-P was obtained by the addition of FYM followed by green leaves and composted salvinia.

Phosphatic fertilizer application also caused significant increase in available-P content of soil. Though the highest levels of available-P were recorded in super phosphate treated plots (P_1M_0 to P_1M_3), there was no significant difference between super phosphate and Mussoorie phosphate in increasing the content of available-P.

The effect of combined application of organic matter and phosphate fertilizer was also significant. The highest available-P content of 111.3 ppm was recorded in super phosphate plus FYM treated plots (P_1M_1) which was statistically on par with P_2M_1, P_2M_2 and P_1M_2 and significantly higher than the other treatments. The lowest available-P content of [illegible]2.6 ppm was recorded in untreated plots (P_0M_0).

The submergence of soil resulted in an appreciable increase in available-P content of soil. The highest

Table 7a Influence of organic matter and phosphorus on available [illegible] content of soil (ppm)

	P_0	P_1	P_2	Mean
[illegible]	[illegible]	1[illegible]5.72	1[illegible].6	10[illegible].25
[illegible]	[illegible]7.77	111.[illegible]	110.97	1[illegible]6.[illegible]
[illegible]	97.30	1[illegible]7.37	1[illegible].2[illegible]	1[illegible]4.6[illegible]
[illegible]	[illegible]5.03	102.[illegible]	10[illegible].24	1[illegible].31
Mean	[illegible]	1[illegible].3[illegible]	1[illegible]7.23	

C.D. for Organic means = 1.4[illegible]2

for [illegible] means = 1.[illegible]13[illegible]

for [illegible] Interaction = 2.[illegible]

Table 16 Changes in available[illegible] as influenced by treatments and period of submergence (Mean values expressed in ppm)

Treatments		Period in days							Mean
		0	15	30	45	60	75	90	
1	[illegible]	74.3[illegible]	31.02	[illegible]3.05	77.32	1[illegible]2.27	1[illegible]0.35	101.21	[illegible]2.33
2	[illegible]	76.35	35.56	[illegible]3.32	1[illegible]	111.35	10[illegible].72	1[illegible]6.51	[illegible]7.77
3	[illegible]	75.47	33.17	[illegible]5.53	107.41	1[illegible].1[illegible]	10[illegible].16	1[illegible]9.32	[illegible]7.3[illegible]
4	[illegible]	74.21	34.36	[illegible]5.17	1[illegible]1.32	1[illegible].34	1[illegible]6.31	104.26	[illegible]9.33
5	[illegible]	[illegible]7.31	3[illegible].25	104.17	115.[illegible]	117.33	117.26	11[illegible].35	1[illegible]5.72
6	[illegible]	[illegible]2.9[illegible]	[illegible]4.37	110.22	125.21	123.10	11[illegible].24	12[illegible].13	111.[illegible]
7	[illegible]	81.53	[illegible]3.46	1[illegible].25	12[illegible].10	11[illegible].21	115.17	11[illegible].25	1[illegible]7.57
8	[illegible]	81.13	[illegible].49	10[illegible].17	11[illegible].21	12[illegible].17	12[illegible].51	110.72	1[illegible]3.5[illegible]
9	[illegible]	77.23	36.10	1[illegible]3.26	112.44	112.[illegible]	113.4[illegible]	11[illegible].73	10[illegible].63
10	[illegible]	81.23	[illegible].35	111.34	12[illegible].25	124.7[illegible]	1[illegible]1.[illegible]	120.76	11[illegible].57
11	[illegible]	[illegible].51	[illegible].51	123.21	11[illegible].72	123.17	12[illegible].7[illegible]	122.42	1[illegible].2[illegible]
12	[illegible]	7[illegible].14	[illegible].27	109.37	115.2[illegible]	11[illegible].74	110.01	11[illegible].25	1[illegible]6.24
Mean		7[illegible].72	[illegible].2[illegible]	102.40	11[illegible].76	11[illegible].3[illegible]	11[illegible].[illegible]	11[illegible].3[illegible]	

Period = .2571
CD Treatment = [illegible].037
Interaction = 7.[illegible]

available-P content was observed by submerging the soils for a period beyond 60 days and upto 75 days. However, there was no significant difference between the levels of available-P on 60th and 75th days of submergence. During the initial 45 days of submergence, there was a drastic increase in available-P and thereafter the increase was gradual upto 30 days beyond which it started declining. The trend was unaffected by different treatments except in P_1M_1 and P_1M_2 where the highest available-P was recorded on 45th day of submergence itself.

Soil reaction

Tables 10a and 10b present mean data on soil pH values as influenced by various treatments and period of submergence. The effects of treatments, periods of submergence and the combinations are significant (Fig. 4).

Consequent to organic matter application, there was a significant decrease in soil pH. Green leaves treatment recorded the lowest pH values followed by farm yard manure and composted salvinia.

Among the different forms of P fertilizers, Mussoorie phosphate treatment caused a significant increase in soil pH. But super phosphate did not produce any significant increase in pH.

Table 19a Influence of organic matter and phosphorus on soil pH

	P_0	P_1	P_2	Mean
M_0	6.16	6.21	6.21	6.19
M_1	5.65	5.72	5.74	5.70
M_2	5.47	5.54	5.55	5.52
M_3	5.99	5.89	6.23	6.04
Mean	5.82	5.84	5.93	

SE P marginal means = 0.0646

SE M marginal means = 0.07457

Table 10b Changes in soil pH as influenced by treatments and period of submergence (Mean values)

Treatments		Period in days							Mean
		0	15	30	45	60	75	90	
T_1	P_0M_0	5.18	5.90	6.18	6.42	6.53	6.48	6.58	6.16
T_2	P_0M_1	5.08	5.53	5.65	5.93	5.88	5.79	5.75	5.65
T_3	P_0M_2	4.88	5.10	5.35	5.77	5.76	5.70	5.75	5.47
T_4	P_0M_3	5.15	5.53	5.89	6.40	6.32	6.33	6.33	5.99
T_5	P_1M_0	5.27	5.90	6.23	6.55	6.48	6.52	6.55	6.21
T_6	P_1M_1	5.17	5.92	5.63	5.93	6.02	5.87	5.88	5.72
T_7	P_1M_2	4.87	5.12	5.40	5.73	5.95	5.90	5.92	5.54
T_8	P_1M_3	5.10	5.40	5.73	6.20	6.20	6.27	6.23	5.90
T_9	P_2M_0	5.17	5.92	6.17	6.53	6.50	6.58	6.52	6.21
T_{10}	P_2M_1	5.22	5.72	5.72	5.95	5.90	5.85	5.85	5.74
T_{11}	P_2M_2	4.90	5.29	5.42	5.95	5.70	5.92	5.87	5.53
T_{12}	P_2M_3	5.10	5.93	6.33	6.52	6.50	6.50	6.57	6.23
Mean		5.09	5.36	5.82	6.14	6.13	6.13	6.16	

CD Period = 0.0905
CD Treatments = 0.1271
CD Interaction = 0.3417

FIG. 3. EFFECT OF SUBMERGENCE ON AVAILABLE P IN SOIL

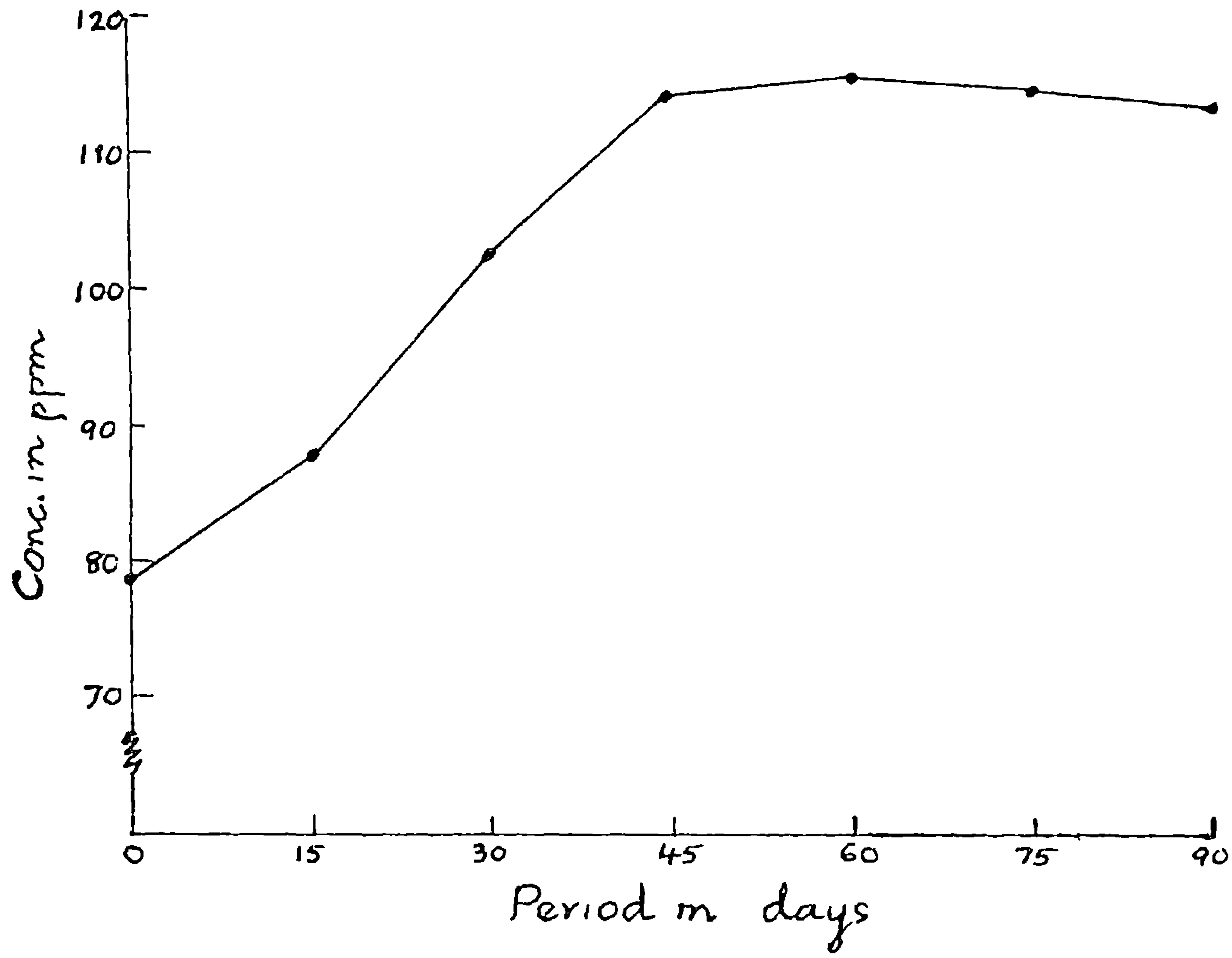
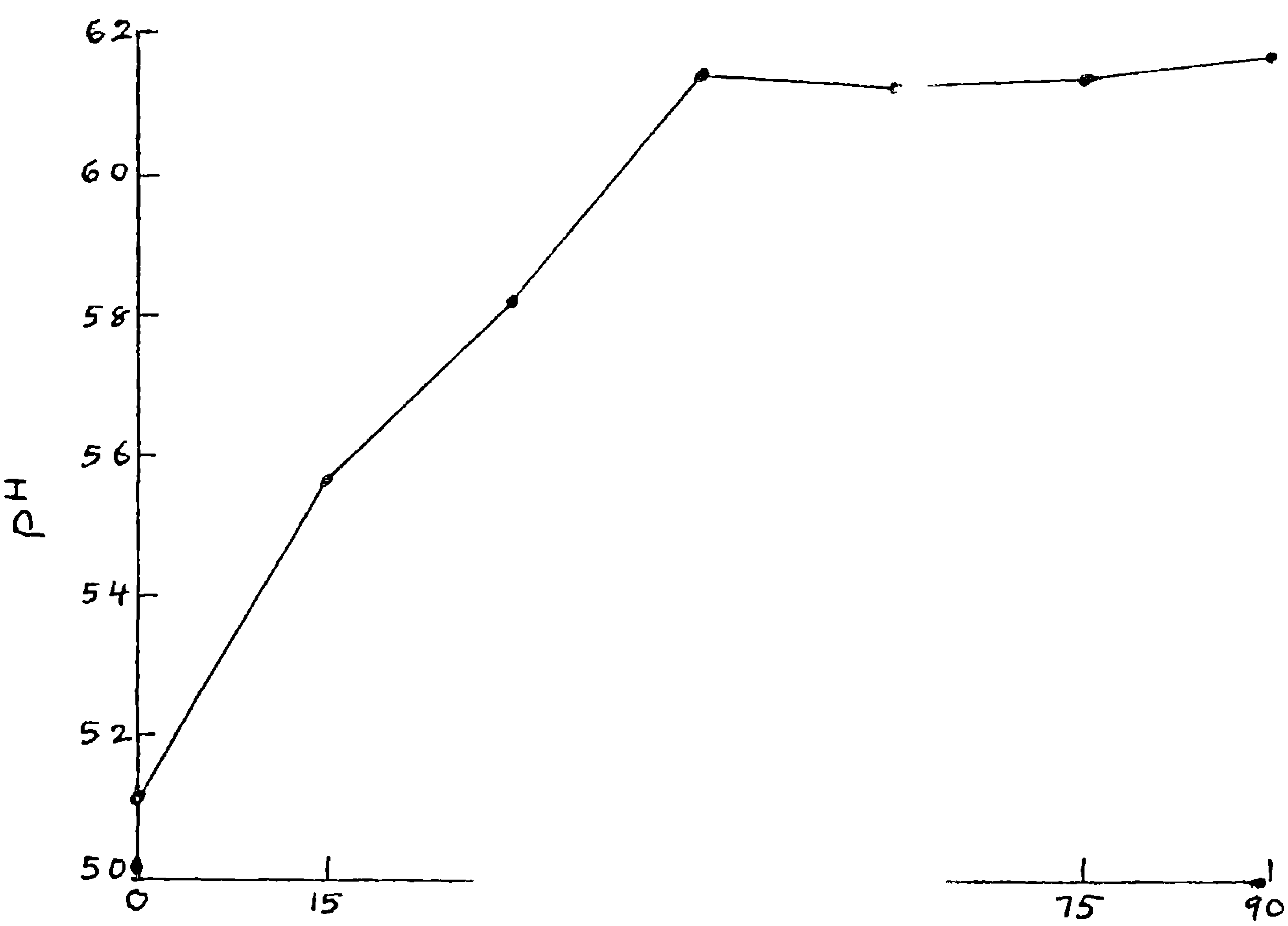


FIG. 4. EFFECT OF SUBMERGENCE ON SOIL pH



The treatment combinations did not have any significant effect on soil pH. However, the lowest pH value of 5.47 over different periods was observed in P_3M_2 and the highest (6.23) in P_2M_3.

The influence of submergence on soil pH was more during the initial periods. There was a significant increase in soil pH upto 45th day of submergence beyond which the pH values remained more or less constant. The highest pH value was attained on 45th days of submergence in all the treatments except in P_1M_1 and P_1M_2 where the peak pH value was recorded on 60th day of waterlogging.

Exchangeable iron (exch. iron)

The data presented in Tables 11a and 11b show the influence of periods of submergence and different treatments on the exchangeable iron content of soil. The results showed that both the period and treatment effects are significant.

Application of different forms of organic matter caused a significant increase in exchangeable iron contents in soil. Among the different forms of organic matter, green leaves treatment recorded the highest exchangeable iron content (459 ppm) followed by farm yard manure (406 ppm) and composted salvinia (366 ppm).

Table 11a Influence of organic matter and phosphorus on exchangeable iron content of soil (ppm)

	P_0	P_1	P_2	Mean
M_0	265.99	133.71	216.57	204.43
M_1	406.43	364.42	377.43	397.43
M_2	430.29	370.29	346.43	383.07
M_3	356.14	293.23	322.57	331.73
Mean	368.96	302.19	300.03	

CD 0 Marginal mean = 18.8422

CD 1 Marginal mean = 21.7117

Table 11b Changes in Exchangeable iron as influenced by treatments and period of submergence (mean values expressed in ppm)

Treatments		Period in days							
		0	15	30	45	60	75	90	Mean
T_1	P_0M_0	266	474	245	193	130	174	192	240.00
T_2	P_0M_1	526	730	432	316	272	248	252	406.43
T_3	P_0M_2	536	814	560	302	313	288	264	458.23
T_4	P_0M_3	405	724	376	230	267	254	242	366.14
T_5	P_1M_0	212	338	219	156	143	136	135	193.71
T_6	P_1M_1	333	574	402	318	262	272	235	364.42
T_7	P_1M_2	426	623	430	361	230	278	221	376.29
T_8	P_1M_3	298	532	341	234	227	193	201	290.23
T_9	P_2M_0	239	418	226	178	166	142	149	215.57
T_{10}	P_2M_1	344	608	297	269	213	203	210	307.43
T_{11}	P_2M_2	355	632	492	373	256	224	197	347.43
T_{12}	P_2M_3	319	563	333	309	225	232	195	321.97
Mean		304.00	611.95	350.50	290.73	235.33	218.17	205.42	

CD Period = 23.72

C[illegible] = [illegible]

Application of phosphatic fertilizers also produced significant decrease in exch. iron content of soil. Though the maximum decrease in exch. iron was brought about by super phosphate the effect of super phosphate was statistically on par with that of mussoorie phosphate.

The interaction effect of organic matter and phosphatic fertilizers was not significant. However, the lowest exchangeable iron level (193 ppm) was observed in super phosphate treated plots (O_1P_3) and the highest (450 ppm) in green leaves treated plots (O_3P_2).

Submergence of soil resulted in a significant increase in exchangeable iron content of soil. Drastic and significant increase in exch. iron was noticed during the initial 15 days of submergence and a corresponding significant decrease below the initial level was observed beyond 15 days and upto 30th day of submergence. Beyond 30 days of submergence the exch. iron content was decreased progressively and significantly.

Correlation studies

Simple correlations were worked out between different P fractions of soil, available P and pH. The correlation matrices are presented in Table 12.

Table 12 Zero order correlation matrix of soil-P fractions and soil pH

	S-P	Al-P	Fe-P	Rs-P	O-P	Ca-P	Av-P	Soil pH
S-P	1.000	0.2310**	0.5817**	-0.2313**	-0.3437**	0.6008**	0.6383**	0.1900
Al-P		1.000	0.7006**	-0.0670	-0.2336**	0.4459**	0.9664**	0.5714**
Fe-P			1.000	0.0433	-0.1059	0.6004**	0.5657**	0.4291**
Rs-P				1.000	0.9059**	0.1017	-0.6033**	-0.4654**
O-P					1.000	-0.0201**	-0.7004**	-0.6228**
Ca-P						1.000	0.6705**	0.3715**
Av-P							1.000*	0.6447**
Soil pH								1.000

It may be seen from the table that saloid-P fraction was positively and significantly correlated to Al-P (r = 0.2818), Fe-P (r = 0.9317), Ca-P (r = 0.6090) and available-P (r = 0.6303), whereas it was significantly and negatively correlated with Red-P (r = 0.2313) and occluded-P (r = -0.3437) fraction.

A significant positive correlation was observed between Al-P with Fe-P (r = 0.7836), Ca-P (r = 0.4493) and available-P (r = 0.9664). The Al-P was negatively correlated with occluded-P (r = -0.2836) while there was no significant correlation between Al-P and Red-P. Significant correlations were also observed between Fe-P, Ca-P and available-P. The correlation coefficients were 0.6094, and 0.5697 respectively. No significant correlation was obtained between Fe-P and Red-P.

There was significant positive correlation between Red-P and occluded-P (r = 0.9039) while Red-P was negatively correlated with available-P (r = -0.6033). No significant correlation was observed between Red-P and Ca-P fraction. The occluded-P was significantly and negatively correlated with Ca-P (r = -0.0201) and available-P (r = -0.7004).

There was significant correlation between soil pH and soil P fractions excepting saloid-P fraction. Soil pH was positively correlated with Al-P (r = 0.5714), Fe-P (r = 0.4231), Ca-P (r = 0.3715) and available-P (r = 0.5447), whereas it was negatively correlated with Red-P (r = -0.4634) and occluded- (r = -0.6228) fractions.

Growth characters

The data on the various growth characters of the rice plant as influenced by phosphorus and organic matter application are presented in Tables 13 to 13.

No. of Tillers

The tiller count at various growth stages of rice plant is presented in Table 13. The effects of phosphorus and organic matter were significant. The interaction effect was, however, not significant.

The maximum tiller count was obtained in M_2 in all stages of growth which was significantly superior to M_1, M_3 and M_0. It was closely followed by M_1 which was significantly superior to M_3 and M_0. M_3 and M_0 were par.

Among the forms of phosphorus tried, P_1 and P_2 were significantly superior to P_0 with respect to tiller count at all growth stages. No significant difference could, however, be observed between the different forms of P fertilizers.

Table 13 Influence of phosphorus and organic matter on the mean number of tillers/hill at different growth stages of rice

	Active tillering stage					Maximum tillering stage					Flowering stage			
	P_0	P_1	P_2	Mean		P_0	P_1	P_2	Mean		P_0	P_1	P_2	Mean
M_0	8.2	9.3	10.7	9.4	M_0	9.3	11.7	12.5	11.2	M_0	9.2	9.9	11.2	10.1
M_1	11.7	12.5	11.7	12.0	M_1	12.2	13.8	13.9	13.2	M_1	12.0	13.3	12.2	12.5
M_2	11.5	13.6	13.7	12.9	M_2	13.2	16.5	17.1	15.6	M_2	12.8	15.2	16.1	14.7
M_3	7.8	10.5	7.8	9.4	M_3	10.4	12.9	11.6	11.6	M_3	9.7	11.1	10.7	10.5
Mean	9.3	11.5	11.5		Mean	11.3	13.7	13.7		Mean	10.9	12.4	12.6	

CD P marginal means = 1.0329
M marginal means = 1.2477
P x M Interaction = NS

CD P marginal means = 0.7753
M marginal means = 1.1255
P x M marginal means = NS

CD P marginal means = 0.8594
M marginal means = 0.9693
P x M Interaction = NS

Though the interaction effect of phosphorus and organic matter on tiller count was not significant, increased trend could be observed in the treatment P_2 [illegible] at all growth stages.

Height of plant

Table 14 presents data on the influence of treatments on the height of plant. There was significant increase in the height of rice plants due to the application of organic matter and phosphorus. The interaction effect was, however, not significant.

The maximum plant height was obtained in M_2 in all growth stages which was significantly superior to M_1, M_3 and M_0. The next in order were M_1 and M_3 but no significant increase in plant height could be noticed in M_3. M_1 was on par with M_3 and superior over M_0.

Among the forms of phosphorus applied P_1 was significantly superior to P_2 and P_0 with respect to plant height at all growth stages. P_2 was significantly superior to P_0 at all growth stages.

The interaction effect of phosphorus and organic matter was not significant. However, P_1M_2 performed better.

Table 14 Influence of phosphorus and organic matter on the mean height of plants at different growth stages of rice (in cm)

	Active tillering stage					Maximum tillering stage					Flowering stage			
	P_0	P_1	P_2	Mean		P_0	P_1	P_2	Mean		P_0	P_1	P_2	Mean
M_0	48.4	56.4	53.2	52.7	M_0	50.2	59.4	55.7	55.1	M_0	59.2	71.1	65.9	65.4
M_1	51.1	59.7	57.2	56.0	M_1	53.0	62.5	59.6	58.4	M_1	60.5	74.6	71.4	68.8
M_2	55.8	65.2	60.9	60.6	M_2	53.4	63.9	63.4	63.6	M_2	67.5	78.9	73.2	73.1
M_3	49.3	58.1	54.2	54.0	M_3	52.5	62.1	55.9	56.9	M_3	61.5	74.2	65.5	66.9
Mean	51.3	59.9	56.4		Mean	53.5	63.2	58.7		Mean	62.2	74.7	69.0	

CD P marginal means = 3.6307   CD P marginal means = 3.1935   CD P marginal means = 0.8875

M marginal means = 4.2333   M marginal means = 3.6923   M marginal means = 0.7633

P x M interaction - NS   P x M interaction - NS   P x M interaction - NS

Yield of grain and straw

The data relating to the mean yield of grain and straw from the different treatments are presented in Table 15 and 16 respectively (Fig. 5). The effects of organic matter and phosphorus were significant while the interaction effect was not significant.

Among the different forms of organic matter M_2 gave significantly higher grain yield over M_3 and M_0 and was on par with M_4. However, M_3 failed to give significant increase in grain yield over control (M_0). The application of phosphorus also resulted in significant increase in grain yield over the control but no significant difference was observed between the forms of phosphorus, P_1 and P_2. Though the interaction effect of phosphorus and organic matter was not significant with respect to grain yield, the maximum yield trend could be noticed in P_2M_2.

The straw yield was also influenced significantly by the application of organic matter and phosphorus. The interaction effect was, however, not significant. Among the different forms of organic matter M_2 was significantly superior to M_4, M_3 and M_0 with regard to straw yield. The treatments M_1 and M_3 gave no significant increase in straw yield over control (M_0). Among the different forms of P tried P_2 was significantly superior to P_1 and P_0 which were

Table 15 Influence of phosphorus and organic matter on grain yield of rice (kg/ha)

	O_0	O_1	O_2	O_3	Mean
P_0	2373	2142	2212	2131	21[illegible]
P_1	225[illegible]	2253	2240	2234	225[illegible]
P_2	2[illegible]32	2372	2444	22[illegible]	2371
Mean	2[illegible]03	227[illegible]	2292	2241	

O marginal mean = 69.773

P marginal mean = 72.12

P x O interaction = [illegible]

Table 16 Influence of phosphorus and organic matter on the straw yield of rice (kg/ha)

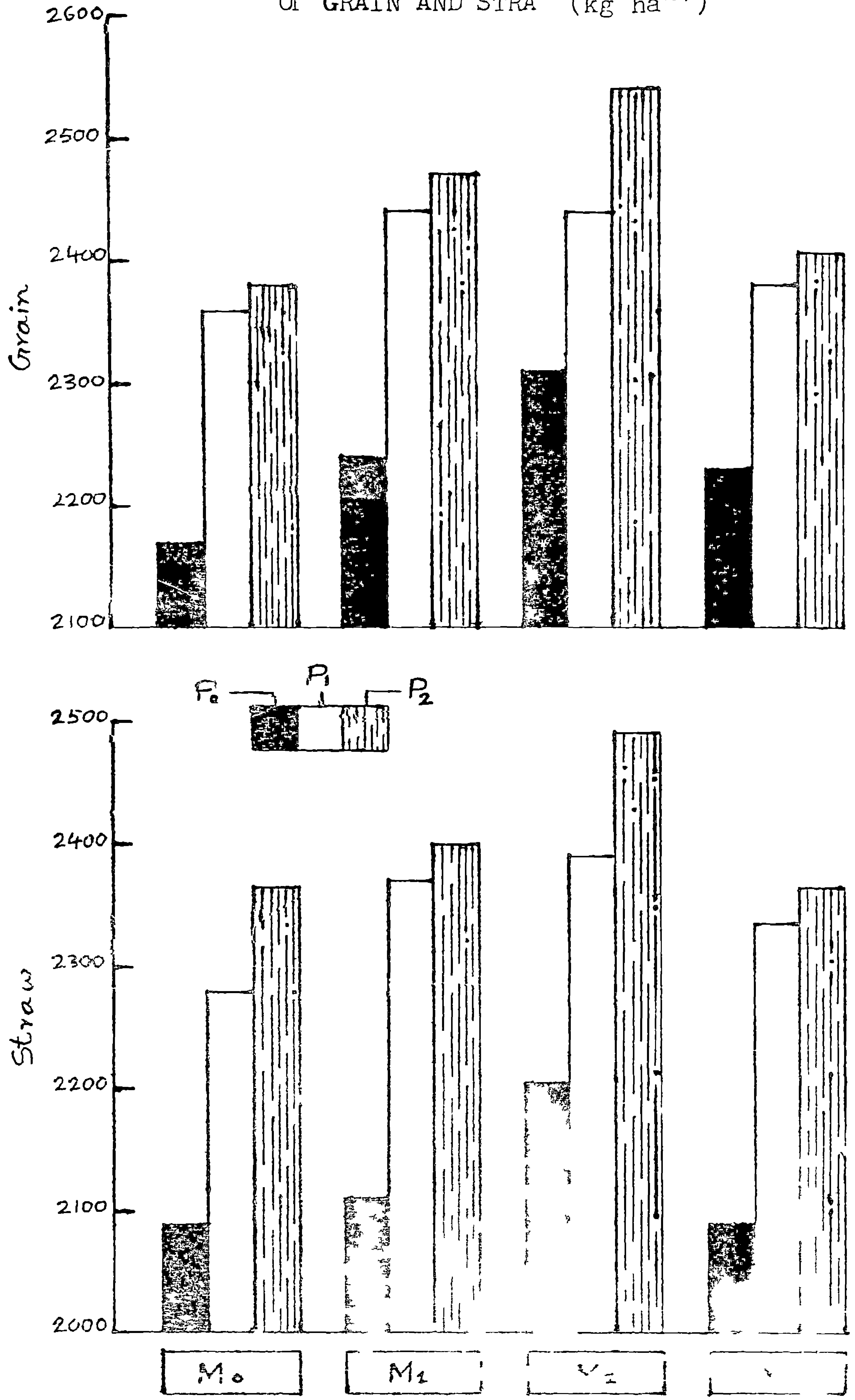
	O_0	O_1	O_2	O_3	Mean
P_0	2[illegible]	[illegible]	22[illegible]	2[illegible]	[illegible]
P_1	257[illegible]	[illegible]472	2433	[illegible]	2444
P_2	2[illegible]	[illegible]	2[illegible]	[illegible]	2[illegible]
Mean	2[illegible]	[illegible]	2461	[illegible]2	

O marginal mean = 40.44

P marginal mean = 53.16

P x O interaction = [illegible]

FIG. 5. EFFECT OF ORGANIC MATTER ON YIELD OF OF GRAIN AND STRA (kg ha^{-1})



to straw yield. P_1 also gave significant increase in straw yield over control (P_0). Though the interaction effect was not significant, enhanced straw yields of 2040 kg/ha and 2500 kg/ha were noticeable in the treatments P_2O_2 and P_2O_1 respectively.

Nutrient composition of grain and straw

Data pertaining to the percentage content of N, P, K, Ca, Mg and Fe on grain and straw are presented in Tables 17 to 22(a) and (b).

Nitrogen

The effect of phosphorus on nitrogen content of straw was not significant. The nitrogen content of straw in the control was 0.695 percent which was significantly raised to 0.931 percent by the application of farm yard manure.

With respect to the nitrogen content of grain, there was no significant difference between different forms of fertilizers and organic matter.

Phosphorus

Table 18a presents data on the phosphorus content of straw as influenced by the treatments. Significant increase in phosphorus content of straw was recorded by the application of both forms of fertilizer. The mean values varied from 0.192 percent in P_0O_0 to 0.321 percent in the super phosphate treated plots (P_1O_0 to P_1O_3). The ...

Table 17a Influence of phosphorus and organic matter on the nitrogen content (%) of straw

	N_0	N_1	N_2	N_3	Mean
P_0	0.672	0.896	0.784	0.712	0.766
P_1	0.725	0.971	0.840	0.767	0.827
P_2	0.675	0.926	0.812	0.752	0.791
Mean	0.693	0.931	0.812	0.738	

CD P marginal means - NS

N marginal means - 0.0935

P x N Interaction - NS

Table 17b Influence of phosphorus and organic matter on the nitrogen content (%) of grain

	N_0	N_1	N_2	N_3	Mean
P_0	0.721	0.862	0.786	0.722	0.773
P_1	0.687	0.732	0.751	0.694	0.724
P_2	0.700	0.798	0.746	0.711	0.741
Mean	0.705	0.797	0.754	0.709	

CD P marginal means - NS

N marginal means - NS

P x N Interaction - NS

Table 10a Influence of phosphorus and organic matter on the phosphorus content (%) of straw

	M_0	M_1	M_2	M_3	Mean
P_0	0.179	0.177	0.207	0.196	0.192
P_1	0.204	0.232	0.236	0.211	0.221
P_2	0.191	0.214	0.225	0.199	0.207
Mean	0.191	0.214	0.222	0.193	

CD P marginal means - 0.0167

M marginal means - 0.0192

Table 10b Influence of phosphorus and organic matter on the phosphorus content ( ) of grain

	M_0	M_1	M_2	M_3	Mean
P_0	0.141	0.238	0.211	0.159	0.187
P_1	0.179	0.204	0.250	0.174	0.217
P_2	0.152	0.259	0.229	0.199	0.204
Mean	0.157	0.250	0.229	0.174	

CD P marginal means = 0.0043

CD M marginal means = 0.0050

matter application also significantly increased P content of straw over the untreated plots. The maximum P content of 0.222 percent was obtained with the green leaves treatment (P_3M_2).

In grain (Table 10b) the phosphorus content was increased by the application of P fertilizers and it varied from 0.187 percent in P_0M_0 to 0.217 percent in the plot treated with super phosphate. Significant increase in phosphorus content of grain was also obtained by organic matter treatment. The maximum P content of 0.259 percent was recorded by farm yard manure treatment followed by green leaves (0.220 percent) and composted salvinia (0.174 percent) treatments.

Potassium

Application of phosphorus had no significant effect on the potassium content of straw (Table 10c). Application of farm yard manure along with phosphate fertilizers increased the potassium content of straw.

The potassium content of grain (Table 10b) was also significantly influenced by phosphorus and organic matter. The mean potassium content of grain varied from 1.095 percent to 1.150 percent in treatments with P fertilizers and from 1.037 percent to 1.220 percent with the organic matter

Table 19a Influence of phosphorus and organic matter on the potassium content (%) of straw

	N_0	N_1	N_2	N_3	Mean
P_0	1.690	1.871	1.793	1.669	1.759
P_1	1.574	1.861	1.765	1.632	1.733
P_2	1.992	1.879	1.805	1.697	1.735
Mean	1.590	1.877	1.737	1.662	

CD P marginal means - N.S.

N marginal means - 0.0707

Table 19b Influence of phosphorus and organic matter on the potassium content (%) of grain

	N_0	N_1	N_2	N_3	Mean
P_0	1.009	1.106	1.120	1.064	1.095
P_1	1.067	1.255	1.104	1.126	1.130
P_2	1.036	1.219	1.151	1.094	1.125
Mean	1.037	1.220	1.192	1.095	

CD P marginal means - 0.0195

N marginal means - 0.0225

treatments. The maximum values were obtained with the super phosphate and farm yard manure treatments.

Calcium

Table 20a and b give data on the calcium content of straw and grain respectively. The calcium content of grain and showed no significant difference by the application of phosphorus. There was significant increase in the calcium content of straw and grain by the application of different forms of organic matter. The mean calcium content of straw varied from 0.103 to 0.145 percent and that of grain from 0.313 and 0.401 percent.

Magnesium

Data on the magnesium content of straw and grain as influenced by phosphorus and organic matter application are presented in Table 19a and b respectively. No significant difference could be noticed by the application of phosphorus on the content of magnesium. Organic matter application had significant effect on the magnesium content of straw and grain. The mean magnesium content of straw was increased from 0.120 in P_0M_0 to 0.140 percent by the application of farm yard manure whereas the maximum content of 0.714 percent in the grain was obtained from the green leaves treatment. There was significant difference between farm yard

Table 20a Influence of phosphorus and organic matter on the calcium content (%) of straw

	M_0	M_1	M_2	M_3	Mean
P_0	0.106	0.122	0.142	0.114	0.121
P_1	0.111	0.128	0.143	0.115	0.126
P_2	0.108	0.121	0.145	0.116	0.123
Mean	0.108	0.124	0.143	0.115	

CD P marginal means - NS

M marginal means - 0.0082

Table 20b Influence of phosphorus and organic matter on the calcium content (%) of grain

	M_0	M_1	M_2	M_3	Mean
P_0	0.276	0.300	0.372	0.281	0.30[illegible]
P_1	0.349	0.3[illegible]	0.421	0.358	0.375
P_2	0.314	0.344	0.409	0.302	0.342
Mean	0.313	0.347	0.401	0.314	

CD P marginal means - NS

M marginal means - 0.005

Table 21a Influence of phosphorus and organic matter on the magnesium content (%) of straw

	N_0	N_1	N_2	N_3	Mean
P_0	0.124	0.143	0.129	0.125	0.130
P_1	0.132	0.152	0.137	0.134	0.139
P_2	0.130	0.149	0.133	0.131	0.136
Mean	0.129	0.148	0.134	0.130	

CD P marginal means = NS

N marginal means = 0.0087

Table 21b Influence of phosphorus and organic matter on the magnesium content (%) of grain

	N_0	N_1	N_2	N_3	Mean
P_0	0.523	0.571	0.663	0.518	0.569
P_1	0.598	0.650	0.749	0.577	0.643
P_2	0.591	0.632	0.735	0.564	0.629
Mean	0.572	0.618	0.714	0.551	

CD N marginal means = 0.0073

manure and green leaves with respect to their effects in increasing magnesium content of both grain as well as straw.

Correlation between available P and rice yield

Simple correlations were worked out between available phosphorus content of soils at different periods of submergence and straw and grain yield. The correlation matrices are presented in Table 22. All the correlations were significant. Available P at different periods of submergence were positively and significantly correlated with straw and grain yield.

Table 22 Zero order correlation matrix of Available P at different periods of submergence, straw yield and grain yield

Available P (Periods in days)	Straw yield	Grain yield
0	0.8111**	0.8240**
15	0.7037**	0.7326**
30	0.9005**	0.9313**
45	0.8654**	0.8942**
60	0.8767**	0.9273**
75	0.9145**	0.9277**
90	0.9323**	0.9204**

** indicates significant at 1 % level

Discussion

DISCUSSION

The changes in inorganic P fractions and available P in the soil under the influence of different organic materials (farm yard manure, green leaves, and composted salvinia) and P fertilisers (super phosphate and Mussoorie phosphate) and their effects on the yield, growth characters and nutrient composition of rice plant were studied by conducting field and laboratory studies. The results obtained from the studies are discussed here.

Transformation of phosphorus in Rice soil

Among the different inorganic P fractions the most abundant fraction was Fe-P and the least abundant was Saloid-P. The transformation of added and native P into these fractions in the soil may be arranged in the order Fe-P > Al-P > Red-P > Occluded-P > Ca-P > Saloid-P.

It was found that organic matter treatments significantly decreased Fe-P fractions in the soil. The farm yard manure treatment registered the maximum decrease while the effect of green leaves was statistically on par with that of FYM. Mandal and Chatterjee (1972), Mandal and Mandal (1973) and Singh and Hariram (1977) have also recorded decreases in Fe-P levels of acidic low land rice soils due to the addition of organic matter. Singh and Hariram (1977) concluded that the decomposition of organic matter might have created an intense anaerobic condition causing reduction of ferric to ferrous compounds. According to [illegible] et al. (1974), the decrease in Fe-P upon the addition of organic matter to soil was possibly due to the formation of complexes by the decomposition products of organic matter with Fe. Comparing the effects of phosphate fertilizer treatments on Fe-P fraction super phosphate treatment recorded significantly higher Fe-P content than Mussoorie phosphate. Mandal and Khan (1977) observed that more than 86% of the phosphorus added as super phosphate was converted to the unavailable forms of iron and aluminium phosphates in acid soils whereas basic slag and rock phosphate maintained a lower amounts of Fe-P and Al-P than super phosphate. Super phosphate contains more of water soluble phosphorus than Mussoorie phosphate and the major portion of the water soluble P present in the super phosphate might have been transformed into Fe-P. The results of the present study are in agreement with the finding of these workers. It was observed that the Fe-P levels at different sampling intervals showed an increase up to 45 days of submergence beyond which they were significantly decreased. Mahapatra and Patrick (1969) and Singh and Singh (1970) however found an increase in Fe-P in alluvial soils at flowering and harvesting stages of rice. The results o the present study were in agreement with those workers. The increase in Fe-P may be attributed to the binding of P with soluble iron that is produced by the reduction of ferric forms of iron.

The results showed that different periods of submergence and treatments significantly influenced the Al-P fraction of the soil. The organic matter treatments significantly decreased Al-P content and the farm yard manure treated plots recorded the lowest Al-P levels. Mandal and Chatterjee (1972) showed that application of organic matter reduced very prominently the fixation of added P as aluminium phosphate in all the soils. Mandal and Mandal (1973), Singh and Singh (1976) and Singh and Rattan (1977) have also recorded the same trend. Somnath et al. (1974) attributed this decrease to the formation of complexes by the decomposition products of organic matter with Fe and Al. Addition of fertiliser P significantly increased the Al-P content of soil. Similar results have been reported by Singhania and Goswami (1978), Hati et al. (1979), and Sadanandan and Patil (1979). The results of the present study showed that among the two forms of fertiliser P, addition of superphosphate has given higher level of Al-P in soil. This result is in conformity with the findings of Mandal and Khan (1972). Continuous submergence has markedly increased the Fe-P fraction and the highest level was obtained at 45 days of submergence. Ahmed (1967) and Mahapatra and Patrick (1969) have recorded an increase in aluminium phosphate content of rice soils upon waterlogging.

It was observed from the results that both treatments and periods of submergence had significant effect on the Red-P and Occluded-P. The phosphate fertilizer treatments significantly increased the level of these 2 fractions over control. [illegible] and [illegible] (197[illegible]) also obtained an increase in the levels of Red-P and Occluded-P consequent to the addition of phosphatic fertilizers to rice soils. Treatments with FYM and green leaves significantly increased Red-P and Occluded-P contents in soil. Mandal and Chatterjee (1972) have also reported that organic matter addition favoured the transformation of added inorganic phosphates into reductant soluble and occluded iron phosphates. The maximum content of Red-P and Occluded-P fractions was recorded on the initial day of submergence and thereafter they progressively and significantly decreased upto 90th day of submergence. These observations are in agreement with similar studies of Mahapatra and Patrick (1969 and 1971). The decrease observed may be attributed to the reducing conditions that make iron more active to combine with soil phosphates which is released by mineralisation of organic-P as well as solubilization.

Ca-P content of soil was significantly influenced by both the treatments and period of submergence. Both the phosphatic fertiliser treatments significantly increased the Ca-P fractions in soil over control. The highest Ca-P fraction was recorded in soils treated with super phosphate. Addition of organic matter significantly decreased the Ca-P content of soil over control. Similar results have been obtained by workers like Singh and Singh (1976) and Singh and Hariram (1977).

The highest Ca-P fraction was observed by submerging the soils for a period beyond 45th days and upto 60th days. Beyond 60th days the Ca-P levels decreased gradually. Similar results have been recorded by Mandal and Khan (1975). Sah and Mikkelson (1986) also reported a significant increase in Ca-P content in soils subjected to annual flooding for rice. The CO_2 released by microbial activity might be having a solubilising effect both on the native Ca-P in soils as well as the Ca-P in the added phosphate. The decrease in Ca-P beyond 60 days may be attributed to the decrease in CO_2 concentration as a result of which some of the ferrous compounds, formed earlier undergo oxidation and changes to ferric oxide, resulting in the absorption of some of the soluble phosphates.

The transformation of P into saloid-P fraction was significantly influenced by period of submergence and different treatments. Application of organic matter and phosphatic fertilizers significantly increased the saloid-P content of soil. Organic matter application, in general, increased the amount of P retained in saloid bound form. Singh and Hariram (1977) and Hajra and Debnath (1987) have also reported a similar trend. Compared to Mussoorie phosphate, effect of super phosphate was more significant in increasing the saloid-P content in soil. There was a gradual increase in saloid-P with periods of submergence and the highest level was attained on 75th day of submergence. Submergence of acid soil has led to an increase in soil pH which may favour the anion exchange process leading to the release of more amounts of saloid-P from exchange sites. Similar increases in saloid-P fraction due to submergence of soil have been reported by Gupta and Singh (1967) and Sahay et al. (1969).

Available phosphorus

It was observed that addition of phosphatic fertilizers significantly increased the available P content of soil. However, there was no significant difference between super phosphate and Mussoorie phosphate in increasing the available P content of soil. This observation is in line with that of Mathew and Jose (1985).

Addition of organic matter increased the availability of P considerably. Among the different forms of organic matter, the effect of farm yard manure was significantly superior to that of green leaves and composted salvinia. Mukhopadhyaya and Mandal (1979) observed that addition of FYM increased the availability of phosphorus in acidic soil. The decomposition of organic matter under anaerobic condition lowers the redox potential to a great extent and the resulting reducing condition favours the solubilization of more ferric phosphates in the form of ferrous phosphates. Under favourable reducing condition organic acids released from the decomposition of organic matter may stabilise ferrous ions by complex formation (Savant and Ellis, 1964 and Purnachandra Rao, 1966) and maintain P in an available form. Islam and Elahi (1954) observed that addition of oxidisable material like green manures increased the availability of phosphorus by promoting reducing condition which favour the process of conversion of ferric to ferrous phosphates. The results of the present study are thus confirmed. It was also observed that addition of farm yard manure in conjunction with either of the phosphatic fertilisers maintained the highest available-P level in soil over different periods of submergence.

The results of the present study show that available P content was significantly increased by submergence. The highest available P level was recorded by submerging the soils for a period beyond 60 days and upto 75 days. Beyond 75 days available P decreased gradually. Several workers have reported that flooding significantly increased the availability of phosphate in rice soils. (Aoki, 1940; Mortimer, 1941; Islam and Elahi, 1954; Savant and Ellis, 1964; Mahapatra and Patrick, 1969, 1971; Mandal and Khan, 1975). The increase in the content of available P on submergence is due to the reduction and enhanced solubility of Fe-P caused by the reducing conditions as well as increased pH (Ponnamperuma, 1965). In addition to this phenomenon, mineralisation of organic P would also have contributed to the pool of available P (Kanwar, 1976). Basak and Bhattacharya (1962) observed an increase in available P with waterlogging of rice soils of West Bengal upto the flowering stage. Singh and Ram (1977) have also recorded a similar trend in the available P content of submerged rice soils.

The significant positive correlation of available P to pH observed in the present study suggests that the P increase can also be due to pH effect. The increase in pH on submerging the soil favours solubility of Al and Fe phosphates and desorption of P from surfaces of clay and oxides of Al and Fe (Stumm and Morgan, 1970). It may be noted that available P also showed a significant positive correlation with Fe and Al phosphate fractions which signifies the contribution from these fractions to the pool of available P.

The peak value of available P was observed on 60th day of submergence and thereafter a gradual decrease was observed. The decrease in available P during the later stages of submergence might be due to the re-oxidation of ferrous to ferric and the re-formation of Ca-P (Singh and Ram, 1977).

Soil reaction

Soil pH was significantly increased by addition of Mussoorie phosphate. However, no significant increase in pH could be noticed by the application of super phosphate. The increase in soil pH due to the addition of Mussoorie phosphate may be due to the higher basicity of Mussoorie phosphate imparted by the calcium content.

Organic matter treatment significantly decreased soil pH which was lowered from 6.16 in untreated plots (T_1) to 5.99 in composted salvinia treated plots, 5.65 in FYM treated plots and 5.47 in green leaves added plots. The decrease in soil pH upon the addition of organic matter may be attributed to the release of organic acids and phenols (Mung and Ponnamperuma, 1966) from decomposing organic matter which keep the pH at a low level.

Submergence of soil brought about significant rise in pH upto the 45th day beyond which it was maintained constantly. The peak pH values were observed between 30 and 45 days of submergence. The increase in pH consequent to submergence might be due to an increase in ammoniacal nitrogen (Karunakar and Daniel, 1950). Reduction of ferric and inorganic compounds and release of bases like potassium, calcium and magnesium due to hydrolysis (Ponnamperuma, 1955; Mahapatra, 1968).

Exchangeable iron

The treatments with organic matter and phosphatic fertilisers influenced iron content in soil significantly. Phosphate application significantly reduced exchangeable iron content in soil. The maximum decrease of 21 per cent was observed in super phosphate treatment (P_1M_0) and Mussoorie phosphate treatment (P_2M_0) recorded a 12 per cent decrease in exchangeable iron content over unfertilised control (P_0M_0). The decrease in exchangeable iron content in soil upon the addition of phosphatic fertilizers may be due to the formation of iron phosphates.

There was a significant increase in exchangeable iron level consequent to the addition of organic matter. The effect of green leaves was more significant followed by the effects of FYM and composted salvinia. Takkar (1968) studied the effect of organic matter on iron under waterlogged condition and observed a marked increase in exchangeable iron with the addition of organic matter in acidic soil. Mandal (1960) observed that the exchangeable Fe formed in the presence of organic matter on any day of submergence was considerably greater than the corresponding amount in the control soil. In the presence of organic matter the reduction process is more intense and CO_2 production is greater such that under these conditions more iron will be released into exchangeable forms at a faster rate, than in the soils unamended with organic materials (Mandal, 1960; Takkar, 1968). The results of the present study thus confirm the positive influence of organic materials in releasing more of exchangeable Fe under submerged conditions.

Consequent to continuous submergence there was a significant increase in the exchangeable iron content of soil upto 15th day and thereafter it decreased gradually. During the initial 15 days of submergence a seventy per cent increase in iron content was observed. The increase in the content of exchangeable iron could be the direct result of the massive reduction of the oxides of iron that has taken place immediately after the onset of anoxic conditions (Takkar, 1968). The decrease in the content of exchangeable iron beyond the period of its peak level might be due to the re-oxidation of ferrous iron at the interface of water and atmosphere and consequent precipitation (Singh and Ram, 1977).

Growth characters of rice

The results of the present study have revealed that application of organic matter and P fertilizers significantly increased the tiller counts and plant height. Among the different forms of organic matter, green leaves treatment recorded the highest tiller number of 13.2 at maximum tillering stage and the maximum plant height of 67.3 cm at flowering stage. Green leaves when allowed to decompose under waterlogged condition release fairly good amount of nitrogen throughout the course of its decomposition as compared to FYM and composted salvinia, where the nitrogen present might have suffered a loss through denitrification process (Chatterjee et al., 1979).

Application of phosphatic fertilizer significantly increased the tiller counts and plant height. However, there was no significant difference between the effects of super phosphate and Mussoorie phosphate on tiller production and height of plant. Mandal and Chatterjee (1985) also reported a significant increase in tiller number and plant height by the application of P fertilizers to rice.

Yield of grain and straw

The grain and straw yield increased significantly with the application of phosphatic fertilizer and organic matter. There was no significant difference between the two forms of P fertilizers in increasing the yield. However, the highest grain and straw yield of 2351 and 2505 kg/ha respectively were recorded in Mussoorie phosphate treated plots. Increased yields of paddy due to the application of phosphatic fertilizers have also been reported by Krishna Rao (1959), Seshagiri Rao and Krishna Rao (1960), Ramaswamy and Raj (1972), Mandal and Chatterjee (1985) and Reddy and Mittra (1985). Mandal and Khan (1972) reported that rock phosphate was more effective than super phosphate for growing rice in acid soils. It has been observed from the present study that addition of P fertilizers significantly increased the available P status of soil which in turn, has produced a positive effect on grain and straw yield.

Among the different forms of organic matter, green leaves application recorded the highest yield of rice followed by FYM and composted salvinia. Tiwari et al. (1980) have also reported an increased yield of rice by the application of green manure. Biswas et al. (1970) found that between green manure, and FYM, the highest yield of rice was shown under the treatment of FYM. The results of the present study however, are at variance with the observation of Mew... et al. in that the highest rice yield was obtained with green leaves treatment. Gopalaswamy and Vidhyasekharan (1987) found that application of green leaves of glyricidia before transplanting rice significantly increased rice yield over control.

Though the combined effects of P fertilisers and organic manure were insignificant, it was noticed that application of Mussoorie phosphate in conjunction with green leaves recorded the highest grain and straw yield. Ahmed et al. (1984) recorded a significant increase in grain and straw yield under flooded condition due to the application of phosphatic fertilizers in conjunction with organic matter. Deshpande et al. (1988) observed that the utilisation of rock phosphate by rice increased in combination with FYM and green manure which ultimately resulted in an increased yield of the crop.

Nutrient composition of grain and straw

The nitrogen content of the grain were not much influenced by different treatments. However, there was a significant increase in the nitrogen content of straw by the application of FYM or green leaves. This may be attributed to the greater availability of nitrogen from organic matter treated plots.

The phosphorus content of both grain and straw was found to be positively affected by the application of phosphorus and organic matter. The mean value for the phosphorus content in straw varied from 0.192 per cent in unfertilized plots (P_0M_0) to 0.221 per cent in the super phosphate treated plots. The phosphorus content in the grain was also significantly increased by the application of phosphatic fertilizers. Similar results have been recorded by Luecanandana and Suwana Waong (1967), Machado (1969) and Nkuncor (1966). Organic matter application also significantly increased the phosphorus content both in grain and straw. The phosphorus content in the straw was increased by 16 per cent while the content of grain was increased by 6.2 per cent by the application of organic manures. Datta and Goswamy (1962), Ramaswamy and Raj (1973) and Ahmad et al. (1984) have also recorded similar results.

The phosphorus treatment did not show any significant effect on the potassium content of straw while the potassium content in the grain was significantly increased by P application. The potassium content both in grain and straw were significantly influenced by the organic manure treatment. The concentration of potassium in straw ranged from 1.6 per cent to 1.891 per cent and in grain 1.008 per cent to 1.186 per cent.

No significant variation in the calcium and magnesium contents of straw and grain could be noticed by the application of phosphatic fertilizers alone. The concentrations of calcium in straw varied from 0.103 to 0.145 per cent and that in grain from 0.373 to 0.401 by the application of organic manures.

Consequent to the application of organic manures, the magnesium content increased from 0.129 to 0.148 per cent in straw and from 0.057 to 0.071 per cent in grain. The combined effect of organic matter and phosphorus was found insignificant.

The increased content of nutrients in grain and straw in organic matter treated plots may be due to the greater availability of these nutrients under the influence of organic matter. It is well established that organic matter addition enhances fertility of all types of soil.

Summary and Conclusion

SUMMARY AND CONCLUSION

A field experiment was conducted in the instructional farm of College of Agriculture, Vellayani during [illegible] crop season of 1986 with a view to study the influence of forms of organic matter on the transformation of native and applied phosphorus in [illegible] soils and their effects on the growth and yield of rice (variety, Triveni). The treatments included use of different organic manures (farm yard manure, green leaves and composted [illegible]) [illegible] phosphate fertilizers ([illegible] phosphate and [illegible] phosphate) and various combinations thereof.

The cultural operations and application of fertilizers and manures were carried out as per the [illegible] practices recommended by the Kerala Agricultural University. Periodical samples of soil at fortnightly intervals were taken and chemical analysis for inorganic P fractions, available P, soil reaction and exchange acidity were carried out. Observations on the growth characters, [illegible] and grain were taken. Chemical analysis of the plant material for N, P, K, Ca and Mg were also carried out. The main findings of the study are summarised below.

1. Among the inorganic P fractions, [illegible] was found to be the most abundant and soluble P the least abundant.

The transformation of added and native P into different fractions was in the order Fe-P > Al-P > Red-P > Occluded-P > Ca-P > Saloid-P.

2. Fe-P content increased significantly during the initial 45 days of submergence and thereafter it showed a decreasing trend. Organic matter treatments significantly decreased Fe-P fractions in soil. The effect of FYM was on par with that of green leaves. Phosphate application significantly increased Fe-P content in soil and super phosphate treatment recorded significantly higher Fe-P levels than Mussoorie phosphate. The combined effect of organic matter and phosphorus was insignificant.

3. Submergence of soil markedly increased the Al-fraction and the highest level was attained at 45 days of submergence. The organic matter treatments significantly decreased Al-P content and the maximum decrease was recorded in FYM treatment. Addition of P fertilizer significantly increased the Al-P content in soil and the application of super phosphate produced significantly higher levels of Al-P than Mussoorie phosphate

4. Red-P and Occluded-P fractions were decreased progressively and significantly upto 90th day of submergence. Treatments with FYM and green leaves significantly decreased

Red-P and Occluded-P contents. Addition of phosphatic fertilizers significantly increased the level of these P fractions in soil.

5. Ca-P fraction significantly increased by submergence and the highest Ca-P level was observed at 45 days of submergence, beyond which it decreased. Addition of organic matter significantly decreased the Ca-P content in soil. Both the phosphatic fertilizer treatments positively influenced the Ca-P fraction and the highest content was recorded in super phosphate treatment.

6. Saloid-P content was appreciably increased by submergence of soil and the highest level was attained on 75th day of submergence. Application of organic matter and phosphatic fertilizers significantly increased the saloid-P fraction in the soil. Farm yard manure proved more effective than green leaves and composted salvinia in increasing the level of saloid-P in soil. Compared to Mussoorie phosphate, effect of superphosphate was more significant in increasing the saloid-P content.

7. The results showed that even in the absence of added P, the content of available P in the soil significantly increased on submergence. The highest available P was recorded on 75th day of submergence. Addition of

organic matter increased the availability of P considerably. Farm yard manure was efficient than green leaves and composted salvinia in increasing the content of available P. The concentration of available P in the soil was not significantly affected by the variations in the form of applied P. The result suggests that whether the phosphatic fertiliser is applied as super phosphate or Mussoorie phosphate, its contribution to available pool appears to be the same.

8. Submergence of soil has brought about significant rise in pH upto the 45th day beyond which it was significantly decreased. Organic matter treatment significantly decreased soil pH and the green leaves treatment lowered the pH value from 6.16 to 5.47. Addition of P in the form of Mussoorie phosphate significantly increased soil pH. Increase in pH by the addition of super phosphate was not significant.

9. From the correlation studies it was observed that available P was positively and significantly correlated with Fe-P, Al-P, Ca-P and Saloid-P fractions and significantly and negatively correlated with Red-P and occluded-P.

10. Submergence of soil resulted in a significant increase in exchangeable iron content of soil and during the initial 15 days of submergence, more than sixty per cent

increase in exchangeable iron content was observed. Phosphate application significantly decreased exchangeable iron content in soil and the effect of super phosphate was significantly greater than Mussoorie phosphate in this respect. Addition of organic matter markedly increased the exchangeable iron content in soil and the increase was greatest with the addition of green leaves.

11. Application of organic matter and P fertilisers significantly increased the tiller counts and plant height. Treatment with green leaves was found more effective than FYM and composted salvinia in increasing the number and height of tillers. No significant difference was noticed between super phosphate and Mussoorie phosphate in increasing tiller count and plant height.

12. The grain and straw yield increased significantly with the application of phosphate fertilizer and organic matter. Though the highest grain and straw yields were obtained by Mussoorie phosphate treatment, statistical analysis showed that both super and Mussoorie phosphate were equally good in producing high rice yield. Among the forms of organic matter, green leaves application recorded the highest yield followed by FYM and composted salvinia. Application of Mussoorie phosphate plus green leaves recorded the highest grain and straw yield.

13. From correlation studies it was observed that straw and grain yield were significantly and positively correlated with available P at different periods of submergence.

14. The percentage of nitrogen in grain was not significantly influenced by organic matter and phosphorus application. In straw, however, the nitrogen content increased significantly with the application of FYM and green leaves.

15. The phosphorus content of both grain and straw was found to be positively affected by organic matter and phosphorus application.

16. The potassium content in grain was significantly increased by P application while its content both in grain and straw were significantly increased by the organic matter treatment.

17. No significant variation in the calcium and magnesium contents of straw and grain could be noticed by the application of P fertilizers alone. Organic matter application significantly increased the calcium and magnesium contents both in grain and straw.

Organic matter addition, in general, reduced the transformation of added inorganic P into different inorganic

P fractions except saloid-P fraction in soil. It maintained higher amount of added P in the soil in available form during the initial 75 days of submergence which corresponds to the vegetative and reproductive phases of the rice crop. Application of organic matter either alone or in conjunction with P fertilizers resulted in a significant increase in the grain and straw yields of paddy. The present study indicates the beneficial role of organic matter when applied to acid laterite rice soils of Kerala.

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* Originals not seen

Appendices

Abstract of ANOVA - Influence of organic matter and phosphorus on soil phosphorus fractions, available P, exchangeable iron and soil pH

Source	df	Mean Square Error								
		Fe-P	Al-P	Red-P	Occluded P	Ca-P	Saloid P	Available P	Exch. Fe	Soil pH
riod	6	9203**	1355.5**	511.5**	865.5**	312.9**	0.575**	2603.4**	250475**	1.932**
eatment	11	3134**	154.7**	99.3**	75.5**	1023.6**	0.830**	302.5**	42739**	0.544**
teraction	66	143**	3.4	1.3	1.4	6.9	0.009	8.8**	1947	0.015*
P	2	15655**	322.0**	313.0**	278.8**	5589.3**	0.958**	1406.4**	74277**	7.471**
M	3	841**	335.6**	149.0**	91.7**	40.5**	0.537**	132.4**	102817**	1.877**
P x M	6	100	8.4	4.1	0.6	2.0	0.026	9.5	2180	0.463*
Error	154	144	8.4	2.9	2.8	5.5	0.024	8.0	3365	0.015

* Significant at 5% level

** Significant at 1% level

APPENDIX-II

Abstract of ANOVA - Influence of phosphorus and organic matter on the mean number of tillers/hill at different growth stages of rice

Source	df	Mean Square Error		
		Active tillering stage	Maximum tillering stage	Flowering stage
Block	2	0.601	0.847	1.179
P	2	21.717**	23.009**	13.925**
M	3	44.479**	35.041**	90.665**
P x M	6	0.804	1.512	1.029
Error	22	1.636	1.327	1.069

** Significant at 1 % level

APPENDIX-III

Abstract of ANOVA - Influence of phosphorus and organic matter on the mean height of plants at different growth stages of rice

Source	df	Mean Square Error		
		Active tillering stage	Maximum tillering stage	Flowering stage
Block	2	9.684	16.551	16.137
P	2	223.984**	282.219**	472.705**
M	3	108.272**	120.029**	101.184**
P x M	6	0.668	2.541	8.539
Error	22	19.082	14.277	17.268

** Significant at 1% level

APPENDIX-IV

Abstract of ANOVA - Influence of phosphorus and organic matter on grain and straw yield of rice

Source	df	Mean Square Error	
		Grain yield	Straw yield
Block	1	8778	7040
P	2	178515	275000**
M	3	43659	22942**
P x M	6	6630	1422
Error	22	5136	2631

** Significant at 1% level

APPENDIX-V

Abstract of ANOVA – Influence of phosphorus and organic matter on nutrient content of rice straw

Source	df	Mean Square Error				
		N	P	K	Ca	Mg
Block	2	$5.[illegible]\times10^{-3}$	$1.[illegible]\times10^{-3}$	1.98×10^{-2}	1×10^{-4}	9×10^{-5}
P	2	1.1×10^{-2}	2.5×10^{-3}**	$2.[illegible]\times10^{-3}$	7×10^{-5}	2×10^{-4}
N	3	9.45×10^{-2}**	1.9×10^{-3}*	1.492×10^{-1}**	2.3×10^{-3}**	7×10^{-4}
P x N	6	5×10^{-4}	2×10^{-5}	3×10^{-5}	1×10^{-5}	3×10^{-7}
Error	22	1.01×10^{-2}	1×10^{-4}	6.5×10^{-3}	7×10^{-5}	7×10^{-5}

* Significant at 5% level

** Significant at 1% level

APPENDIX-VI

Abstract of ANOVA - Influence of phosphorus and organic matter on nutrient content of rice grain

Source	df	Mean square error				
		N	P	K	Ca	Mg
Block	2	$1.8x10^{-3}$	$1x10^{-4}$	$5.67x10^{-2}$**	$6x10^{-5}$	$6x10^{-5}$
P	2	$2.6x10^{-3}$	$2x10^{-5}$	$1.21x10^{-2}$*	$6.3x10^{-3}$	$1x10^{-4}$
M	3	$1.6x10^{-2}$	$2x10^{-4}$**	$5.53x10^{-2}$*	$1.53x10^{-2}$*	$1x10^{-4}$
P x M	6	$1x10^{-5}$	$3x10^{-5}$	$1x10^{-2}$	$3x10^{-4}$	$1x10^{-6}$
Error	22	$5x10^{-4}$	$2x10^{-5}$	$1.82x10^{-2}$	$2x10^{-4}$	$5x10^{-5}$

* Significant at 5% level

** Significant at 1% level

INFLUENCE OF FORM OF ORGANIC MATTER ON THE MINERALISATION OF APPLIED PHOSPHORUS IN SUBMERGED RICE SOILS

By

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ABSTRACT OF A THESIS

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ABSTRACT

A field experiment to study the effect of incorporation of different forms of organic matter on the transformation of native and applied phosphorus in submerged rice soils and their effects on the growth and yield of rice (Var. Triveni) was conducted in the Instructional Farm of the College of Agriculture, Vellayani during second crop season in 1986. The treatments included the application of three different form of organic materials (farm yard manure, green leaves and composted salvinia) and two phosphate fertilizers (super phosphate and Mussoorie phosphate). Fractionation of soil inorganic phosphorus at fortnightly intervals for a period of 90 days and estimation of available P, exchangeable iron and soil reaction were carried out. Observations on the growth characters were made at active tillering, maximum tillering and flowering and yield of straw and grain were recorded. The chemical analysis of the grain and straw for N, P, K, Ca and Mg was also carried out.

It was found that in general submergence of soil increased the transformation of both native and added . into Fe-P, Al-P, Ca-P and saloid-P. Reductant-P and occluded-P fractions decreased with progressive submergence.

Submergence of the soil markedly increased the available P status of soil. Phosphorus applied as super phosphate and Mussoorie phosphate was recovered in different inorganic fractions in the order Fe-P > Al-P > Red-P > Occluded-P Ca-P > Saloid-P. Organic matter addition suppressed the transformation of native and added inorganic phosphorus into different inorganic P fractions (Fe-P, Al-P, Red-P, Occluded-P and Ca-P) and maintained higher amount of added P in the soil in available form during the initial 75 days of submergence.

A marked increase in exchangeable iron was also observed with continuous submergence. The process was accelerated by the addition of organic matter. Phosphate application significantly decreased exchangeable iron content in the soil. Submergence of soil resulted in a significant increase in soil pH upto 45 days beyond which it remained more or less constant. Organic matter treatment significantly decreased soil pH whereas addition of P in the form of Mussoorie phosphate increased the soil pH.

The growth parameters (tiller count and plant height) recorded a significant increase due to the application of organic matter and phosphorus. The grain and straw yield increased significantly with the application of P fertilizers and organic matter. Application of Mussoorie phosphate plus green leaves recorded the highest grain and straw yield.

There was a significant increase in the mineral contents in the plant by phosphorus and organic matter application. The study highlights the importance of organic matter in producing a better response to phosphatic fertilizers by rice in the submerged paddy fields.