EFFECT OF LIME AND FARM YARD MANURE ON PHOSPHORUS ADSORPTION CHARACTERISTICS IN AN INCEPTISOL

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

By

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BHUBANESWAR-751 003
2007

THESIS ADVISOR: DR. H. K. SENAPATI

Dedicated to my
Dearest
Baba & Mamma

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF LIME AND FARM YARD MANURE ON PHOSPHORUS ADSORPTION CHARACTERISTICS IN AN INCEPTISOL"** submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)** of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of *bona fide* research work carried out by **SRI DILLIP KUMAR BEHERA** under my guidance and supervision. No part of the thesis has been submitted for the award of any other degree or diploma.

It is further certified that the assistance and help availed by him from various sources during the course of investigation has been duly acknowledged.

Bhubaneswar
31st August, 2007

31.8.07
(H. K. Senapati)

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ABSTRACT

A field experiment was undertaken in the Central Research Station of Orissa University of Agriculture and Technology to study the impact of farm yard manure (FYM) and lime on phosphorus availability and adsorption parameters in rice-rice cropping sequence. The treatments comprised of the inorganic macro, secondary(s), micro (B, Zn) nutrients alone and in combination with FYM and lime compared against an absolute control. The experimental acid laterite soil responded to the application of phosphatic fertilizers by increasing the crop yield. By addition of FYM or lime along with recommended doses of fertilizers increased the yield of rice. But highest grain yield of 29.7 and straw yield of 34.0 q ha^{-1} were obtained in the treatment, supplied with recommended doses (100% NPK) of fertilizers along with FYM and lime. The same treatment also recorded the highest agronomic efficiency (AE) at 21.5. The uptake of phosphorus was also encouraged by the application of FYM and lime along with the inorganic fertilizers. There was marked improvement in the soil quality parameters by application of FYM and lime which was observed from the post harvest properties of the soil.

To study the phosphorus adsorption behaviour and characteristics the soil samples were collected from some of the selected treatment plots prior to the imposition of the treatments in the rice crop. The soil samples were incubated in the laboratory condition with the addition of known concentration of phosphorus. At the end of the equilibration period the concentration of the phosphorus in the filtrate was determined and the amount of phosphorus adsorbed were expressed. From this study it was observed that the highest of 80% P adsorbed in control where the concentration of P added was 0.5 $\mu g\ ml^{-1}$ as against 20 % P adsorbed in 100% NPK + FYM + Lime treatment where the concentration of P added was 12.0 $\mu g\ ml^{-1}$. Phosphorus adsorption at different concentration of added phosphorus was maximum in the control and decreased in the order of control >100 % NPK > 100 % NPK + FYM > 100 % NPK + lime > 100% NPK + FYM + lime.

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CHAPTER-I

Introduction

INTRODUCTION

Long term effect of different nutrient management practices for different crops are important to understand the soil nutritional and environmental interaction.The dynamics of soil phosphorus gives an idea about the phosphorus supplying capacity of soil to plant.

Chemical fertilizers along with organic manures viz., farm yard manure (FYM), crop residues, green manure and lime help in improving soil physical, chemical and biological properties on long term basis. The role of organic matter in improving soil fertility status can be attributed to the fact that complex formation and chelation by various organic acids tend to accelerate the decomposition process and also enhance the release of soluble nutrients. The solubility of Al-PO_4, Fe-PO_4 or Ca-Po_4 is expected to increase considerably by complex formation with humic compounds and/or organic compounds.

Phosphorus is an important essential nutrient next to Nitrogen for plant growth and development. External phosphorus fertilization in intensive cropping systems often exceeds P demand by crops, which leads to P accumulation in soils. Levels of different pools of soil P have been affected not only by soil properties and climatic conditions but also by rate and type of P applied. Soil usually contains 0.1 to 0.25 percent of P_2O_5 and rarely exceed 0.5 percent. It is great importance to note that most of the phosphorus present in soils is unavailable to plants. The recovery of fertilizer phosphorus by the crops that is planted immediately after the fertilizer application amounts to only 10-30 percent of the quantity added to the soils, the remaining 70-90 percent has been assumed to be consumed by micro-organisms, precipitated by soluble cations in the soils or sorbed by soil complex. It is now generally accepted that the role played by microorganisms is relatively minor and the chemical precipitation and physico-chemico sorption plays the major role.

Under field condition, where P fertilizers are applied to soil, the adjacent soil is contacted by the soil solution containing very high concentration of P and accompanying cations. P retention reaction begins in this environment, which often initially favours in situ precipitation of phosphorus compounds. Retention of phosphorus is most frequently a problem in acid soils high in finely divided sesquioxides . The acid soil complex, generally contribute in large measure to the locking up of applied phosphorus in soil.

Liming in acid soil is the traditional method used to reduce P sorption and to increase its plant availability. However, liming is an expensive input, often giving contradictory results and is less effective on high P fixing soils . There has been renewed interest in the past 10 years on use of organic amendments to increase P efficiency and availability to plant.

Phosphorus adsorption by soil is important because adsorbed phosphate equilibrates with P in the soil solution and this P in turn is the immediate source of P for plant. Phosphorus adsorption isotherm integrates P intensity capacity and quantity parameters of soil and these factors play an important role in controlling the P flux to roots of growing plant.

A multitude of factors influence P adsorption and it is difficult to make valid comparison among soil unless conditions have been standardized. The mobility of soil phosphate is controlled by sorption capacity of soils, which in turn is related to the characteristics of the reacting surface.

Crop uptake of fertilizer P rarely exceeds 20 to 25 per cent in a single cropping season and this is due to the various physico-chemical and biological transformations that revert the soluble P into insoluble forms. Transformations of P, both native and applied, vary with crop, fertilizer, soil and crop management practices. The soil factors that affect transformations are pH, organic matter, temperature, minerological composition, free sesquioxide content, microbial population and root exudates. In soils with acid to neutral pH, the highest amount of applied P is recoverable in Fe and Al-P fractions after 20 days. The clay content, pH and ratio of Fe_2O_3 to Al_2O_3 also control the transformation of P. In *Alfisols* the order is Fe-P > Ca-P > Al-P. In acid soils, the increase in Al and Fe-P is less than the decrease in Ca-P, mainly because of the predominance of reductant-soluble and occluded forms. The increase in Fe-P was very conspicuous in different soils after a crop of rice and accounted for 20 to 32 per cent of the applied P (Singhania and Goswami, 1978b).

Moisture regime influences transformations of both soil and applied phosphorus. Flooding of soils sets off a series of reactions, which usually result in better availability of phosphorus mainly through increase in the amounts of water soluble P and Fe-P. It is mainly due to reduction of ferric P to ferrous P, the chief source of phosphorus for wetland rice. Flooding of soils results in formation of organic acids, which help in solubilization of phosphorus. Low E_h values in lowland soils also help in the release of phosphorus from organic phosphorus, mainly iron phytates. Increase in availability of P due to flooding is also caused by displacement of phosphate from aluminium and ferric phosphates by the organic anions produced in soil. A cycle of drying and flooding before reflooding of the acid soils increased availability of the native phosphorus. Alternate flooding and drying increased the amounts of Fe-P and reductant soluble P fractions but decreased those of water soluble and Al-P.

The clay fraction in soils seems to be the site of phosphate fixation. Organic matter in soils influences P fixation directly and indirectly. Directly, phosphate can be adsorbed by organic matter, the clay complex and the chelating compounds; indirectly, the organic acids released during the decomposition of organic matter affect phosphate solubilization and fixation. Free $CaCO_3$ present in calcareous soils adsorbs phosphate. Oxides of iron and aluminium rather than the respective ions of these metals combine with phosphates to form metal phosphates and cause reversion of soluble P into insoluble products. *Vertisols* are having higher phosphate-fixing capacity than *Alfisols*. The adsorption curves for these soils constructed by equilibrating the soil samples for six days with different rates of phosphate indicated that to obtain a concentration of 0.2 ppm of P in solution (Considered to be optimum for field crops) application of 20 to 40 ppm of P to these soils could be required (K.L.Sahrawat, unpublished).

The reduction of ferric oxyhydrates to more soluble and amorphous ferrous hydroxide allows the occluded forms of phosphate to come into soil solution. In addition to discrete compounds, P can also be present in an adsorbed form. Much of this adsorption generally occurs on surfaces of oxides and hydroxides of iron and aluminium. The crop uptake of P under liming or fertilizer application is further enhanced in lime + NPK treatment. The time interval between application of liming material and seeding should be carefully determined for maximum benefits from the added as well as native phosphate carriers.

There is decrease in Al-P, Fe-P and organic P during the period of rice growth with a consequent increase in available P, to the extent of 64 per cent, from transplanting to the pre-flowering stage. This is attributed to reduction in P fixation, faster rate of P release than that of its absorption by rice roots, presence of continuous stream of water resulting in increased P availability due to hydrodynamic dispersion, hydrolytic dissolution of Al-P and reductive solubilisation of Fe-P. With the addition of lime, there is a considerable decrease in Fe-P, slight increase in Al-P and increase in Ca-P, possibly because of hydrolysis and conversion of Fe-P to Ca-P. There is increase in available P with the addition of organic materials and the increase is more in sandy loams than in alluvial and black soils.

The amount of added water soluble P in equilibrium solution decreased with time, this being dependent on the active Fe content rather than on the pH. Transformations of the added P into Al-P and Fe-P depend upon their amounts already present in the soil. Moist treatment of the soil before application of P and submergence gives higher available P and greater response in rice yield. Application of organic matter and lime lowers fixation to Al-P and Fe-P; and lime increases transformation to Ca-P. Addition of organic matter increases the intensity of soil reduction under submerged conditions, as a result of which there is increase in available P, Fe and Mn.

Rice plants grown in such a system give higher grain yields and uptake of these nutrients. Decomposition of farmyard manure (FYM) causes immobilization of phosphorus but a mixture of FYM and calcium salts have a better effect. Maximum phosphate fixing capacity is in the order: red soil > medium black > heavy black > alluvium grey brown > alluvial soils.

In strongly acid soils having pH less than 5.5 the concentration of Fe and Al ions in solution exceeds that of H_2PO_4 ions. Consequently the latter are precipitated as insoluble phosphates of Al or Fe. The reaction becomes the exposed OH groups on the mineral surface and H_2PO_4 ions also results in fixation of applied P. The important measures to reduce P-fixation are application of suitable liming material in proper quantity, addition of adequate amount of organic material, intimate mixing of water soluble P-fertilizer with FYM, cow dung or biogas slurry just before application of the fertilizer to soil, use of proper placement technique for applying water-soluble P-fertilizer i.e., thorough mixing of the material with the soil by ploughing and use of an intimate mixture of SSP and MRP in suitable proportion such as 2:1 or 1:1 on P basis for both *Kharif* and *Rabi* crops.

Liming acid soils promotes root growth of plants by reduction of toxic levels of Al, Fe and Mn in soil solution and consequently the uptake of nutrients and water from lower depths is increased. Liming acid soils to near neutrality creates a favourable environment for soil microorganisms to carry out the transformation of C, N and P.

The Long Term Fertilizer Experiments in O.U.A.T. Central Research Station is continuing since 1972 with Rice-Rice cropping system. The present investigation was undertaken with the following objectives:

i) To study the effect of continuous applications of N, NP and NPK fertilizer on productivity of the system.

ii) To assess the need of secondary and micronutrient.

iii) To monitor the need of FYM and Lime on P availability of soil .

iv) To investigate the build up of organic matter in the soil.

v) To study the effect of P buildup and depletion on P-adsorption parameters of the soil.

CHAPTER-II

Review of Literature

REVIEW OF LITERATURE

Phosphorus is an essential plant nutrient but it is deficient in most acid and highly weathered soils such as *ultisol* and *oxisol.* Generally the phosphorus is available to plants in very small amounts in acid soils, due to adsorption by Fe or Al oxides or by its precipitation with soluble Al and Fe, whereas in alkaline soils phosphate readily reacts with Ca to form insoluble precipitates. An understanding of the adsorption-desorption behaviour of phosphate in soils a long term fertilization would be an invariable supplement to our knowledge of the chemistry of phosphorus in soils and would assist in developing its application strategies for successive crops. Continuous fertilizer application in an intensive cropping pattern for higher production has rendered the soil to undergo a series of changes both in its physical makeup and chemical properties. The effect of long term manuring in a rice based intensive cropping system on phosphorus adsorption properties of soils has been reviewed in the following few pages.

2.1 EFFECT OF DIFFERENT FACTORS ON PHOSPHORUS ADSORPTION AND AVAILABILITY

The important factors that affect adsorption and desorption of P in soil include pH, $CaCO_3$, organic matter, amount and nature of clay (Prakash *et al.* (1993) and available P etc. Among these factors, clay and available P content of soils play an important role in affecting adsorption and desorption of added residual P in soils.

Phosphorus adsorption in acid soils is mainly attributed to hydrous oxides of Fe and Al and 1:1 layer lattice clays, particularly in tropical soils with low pH (Haynes, 1984)

Milap-Chand *et al.* (1995) observed that phosphorus adsorption in soil decreased with decrease in CEC , amorphous forms of Fe and Al, clay, Organic carbon and $CaCO_3$ contents, while equilibrium solution P concentration decreased significantly with the increase in clay, organic carbon, oxalate extractable Fe and Al in soils. The combined effect of clay and extractable Fe explained about 98 % of the variation both in adsorbed P and in solution P concentration. The differential buffering capacity (DBC) of soils yielded positive and significant correlations with total Fe and Al, organic carbon and clay content in soil. Residual effect of P fertilizer decreased P sorption.

Boparia and Sharma (2006) concluded that Langmuir adsorption maxima values increased with increasing clay content of the soil and decreased with a decrease in the clay content of the soils. The bonding energy values also varied among different textured soils. The bonding energy values were lowest in sandy loam soil whereas these values tended to increase with increasing clay content of soils. Adsorption maxima and bonding energy strongly determine the tenacity with which P is bound to soil particle. Dhilon *et al.* (2004) observed that clay content of soils was one of the most important soil properties affecting phosphorus adsorption.

Dhillon *et al.* (2001) conducted an experiment on P availability to predict P response. Dry matter yield, P concentration and P uptake increased with rise in soil P. Both Al-P and saloid P controlled P availability in these soils as they correlated significantly with various parameters. Among the various methods to extract available P Olsen's method was found to be the most suitable in modified form.

Reddy *et al.* (1980) studying on soil utilized for waste disposal reported that an increase in waste loading rates decreased the adsorption capacity and increased the equilibrium phosphorus concentration. Desorption also increased with organic amendment and showed that same soil amended with swine effluent increased P-desorption with increasing P loading..

Ghosh *et al.* (1997) studied the indices of P availability and fixation of added P in acid *Alfisols*. They observed that organic carbon, clay content and lime potential were the major factors affecting variations in available P status in acid soils and fixation of added phosphorus.

Arai *et al.* (2005) studied on phosphate reactivity in long term poultry litter amended in sandy soil. They investigated on inorganic P speciation, P adsorption capacity and the extent of P desorption. The inorganic P fractionation analysis showed high levels of oxalate extractable P, Al and Fe fractions, which were susceptible to slow release during the long-term P desorption experiments at moderate acidic soil pH water. In the adsorption experiments P was strongly retained in soils at near targeted pH of lime (~6.0), but P adsorption gradually decreased with decreasing pH near the soil pH (~5.0).The overall findings suggested that P losses can be suppressed by an increase in the P retention capacity of soil.

Ige *et al.* (2005) reported the P retention capacity of Manitoba soils and to generate equation that release these capacities to other soil properties .The soil groups were clay: clay soils, regional till loam, high lime till, wet sand soils and dry sand soils. They showed the retention of P in soil was influenced more by Ca and Mg and soil texture.

Ramamurthy and Bisen (1971) have shown that the energy of adsorption of Fe-P is less than that of Ca-P in rice soils. Thakur *et al.* (1977) determined the relationship between inorganic P-fractions and available P and p uptake by rice and observed that Al-P and Fe-P correlated significantly with Olsen's P as well as total uptake of P. Devanath and Mandal (1982) concluded that Fe-P was the main source of P to rice. Sahoo (1984) also arrived at similar conclusions based on the results of multiple regression and path analysis. Mishra and Khana (1982) evaluated the contribution of different soil P-fraction to the labile pool of P by isotopic dilution technique in an acid soil. The results obtained revealed that Fe-P was the dominant source followed by Al-P. The results on inorganic phosphorus fractions in long term experimental plot, with alkaline pH showed that 80 to 85 per cent of the fixed P was transformed as Ca-P, 8-14 per cent as Al-P ,1-5 per cent as saloid-P and 1-2 per cent as Fe-P (Subramanian and Kumarswamy, 1989).

Availability of both native soil phosphorus and the fertilizer phosphorus reaction products, is mostly a diffusion controlled process. The phosphorus in soil solution and the mobility of phosphate ion, therefore, largely depends upon the ease of P desorption from the solid phase depending upon the phosphate adsorption characteristics of the soil.

Kanwar and Prihar (1962) and Maurya and Ghosh (1972) have reported that continuous application of P fertilizer resulted in builed up of soil phosphorus. According to Patnaik *et al.* (1989) and Panda and Sahoo (1989), enrichment of soil with P occurred with balanced or higher doses of NPK and there was depletion of soil reserve P in absence of fertilizer P application at all the Long Term Fertilizer Experiment centres of India. Depletion was more pronounced in 100 % N treatment than that in the unfertilized control because of larger crop removal in the former.

2.2 EFFECT OF ORGANIC ACIDS ON PHOSPHORUS ADSORPTION

The reduction of P-sorption due to organic amendment in soil is undoubtedly the cumulative effect of several mechanisms. However, insight into the relative importance of these mechanisms was reported by Iyamuremye *et al.* (1995a) who compared organic and inorganic amendments. Both the inorganic amendments i.e., $CaCO_3$ and $CaSO_4$ had less effect on sorption constant than P rich organic residues (manure and alfa-alfa) and also did not increase Bray's 1 P or total inorganic P, as did organic amendments. The researchers concluded that the production of organic acids or organic complexing agents and effects on P-fractions were more important than reduction in exchangeable metals in affecting P sorption.

Earlier studies have shown that addition of organic matter to soil prevented P adsorption (Sibanda and Young, 1986). The mechanism for reduction of P adsorption includes. (1) Organic acids can block exposed hydroxyl on the surface of Fe and Al-oxides (Appelt *et al.*, 1975) and decreased P fixation capacities of these soils (Dalton *et al.*, 1952). (2) The competition of organic acids produced during mineralization for same sites of fixation as P and complexation of exchangeable Al by organic acids (Hue, 1991, Sing and Jones, 1976). (3) P returned to the soil by organic residue reacts with the sites of P sorption (Reddy *et al.*, 1980, Iyamuremye 1995a).

Patel *et al* .(1963) reported that combination of organic manure like FYM and P fertilizer had the best effect on the desorption of phosphate. The marked increase in desorption of P with optimum level of NPK plus FYM treatment was attributed to the organic manure maintaining a good level of labile soil P (Subramanian and Kumarswamy, 1989). Decomposition of organic matter produces CO_2 and H_2CO_3 which dissolve the primary phosphate minerals. The activity of phosphate fixing agents like Fe, Al in acid soils are inactivated by formation of stable chelating compounds with organic anions like malate, oxalate and citrate etc., which are products of organic decay.

2.3 EFFECT OF FYM ON PHOSPHORUS ADSORPTION

Anjaneyulu and Omanwar (1979) reported that continuous application of inorganic fertilizers increased the inorganic fraction where as the addition of FYM increased the organic fraction of P in soil.

Chaudhury *et al.* (1981) reported that available P of the soil increased significantly with P and FYM application. FYM alone also increased the available soil P and K indicating its favourable effect on the availability of P and K in soil (Grewal *et al.*, 1981). Patnaik *et al.* (1989) have reviewed the results of several long term fertilizer experiments which show P enrichment in soils with application of balanced or higher doses of NPK and combined use of NPK and FYM and P depletion in absence of P fertilizer addition. Depletion of P was more pronounced with 100 % N dose than that in unfertilized control, possibly because of enhanced crop growth and P removal by the crops.

The effect of P and K fertilizers and FYM application in wheat-maize rotation for 9 years, was studied by Singh *et al.* (1983). They observed that P treatments increased available P in soil only in combination with FYM where K fertilizer did not influence the available K status of soil. Availability of P and K increased in the treatments receiving FYM application. This may be ascribed to the mineralisation of organic P and K contributing to towards their availability (Prasad *et al.*, 1983; Patel *et al.*, 1965 and Mukhapadhaya *et al.*, 1979).

✓Subehia *et al.(*2005) studied that the addition of lime or FYM , along with recommended doses of chemical fertilizers, significantly improves the soil productivity. Application of lime increased soil pH and significantly reduced all type of soil acidity with most conspicuous effect observed on exchangeable acidity. The use of FYM, on the other hand had a moderate effect on exchangeable acidity as compared to that in treatment of NPK application alone .Both these treatments maintained better nutrient availability and sustained higher grain yields over the soils where only chemical fertilizers were applied. Addition of 100%N alone resulted in maximum phosphorus adsorption (98%) and soils with 100%NPK+LIME resulted in lowest P adsorption. Vyas and Motiramani (1971) reported that organic matter has proved to be effective in increasing the available phosphorus from native as well as added phosphorus.

2.4 EFFECT OF LIME ON PHOSPHORUS ADSORPTION

Khurana *et al.* (2003) reported that phosphate reaction products are the specific identifiable compounds formed as a result of reaction between applied fertilizer P and soil constituents. In the initial stage of reaction, these are metastable and with lime, are converted to more stable P compound. Some of the metastable forms persist for a longer time to act as good source of P for plant (Black, 1967). These reaction product primarily govern the availability of P to plants by controlling soil solution P. The investigations involving identification of these reaction products are therefore important from soil fertility point of view.

Paliyal and Verma (2002) reported that phosphate adsorption showed in case of experimental soil had a greater affinity for P as the P adsorption continue to rise with increase in equilibrium P concentration. The lime applications increased and gypsum application decreased the P adsorption. The lower level of gypsum application was superior in declining the P adsorption of its higher level.

Muralidharan *et al.* (2001) studied the effect of lime and phosphorus application on extractable Al and aluminium potential in acid soils. Application of P did not affect the extractable Al content of soil significantly. Application of P as well as lime considerably reduced the Al content of plants.

Curtin and Syers (2001) observed that the liming generally decreased Olsen bicarbonate values, with the effect being largest at the highest rate of P addition and average across P treatments, the decrease in Olsen P for a unit increase in pH. Liming also depressed water extractable P. Decrease in extractable P suggest that liming increased phosphate adsorption. Phosphate-retention capacity appeared to have a strong influence on the relationship between water-extractable P and Olsen P with the high P retention soils having relatively low proportion of water-extractable P when exchangeable cations were replaced with Na, soil that had been limited released capacity, significantly more P was observed in distilled water than their unlimited counterparts. The results confirm that the nature of the exchangeable cation site has a major influence on pH-dependence of phosphate adsorption desorption equilibrium.

On the contrary, Haynes (1983) suggested that liming increased phosphate adsorption. It is believed that liming results in the formation of new highly active surface in soil due to the precipitation of exchangeable aluminium as amorphous polymeric hydroxyl aluminium cations. The formation of this new surface had the greatest effect on phosphate adsorption and least on molybdate, because, in general, the magnitude of decrease in specific adsorption of anions by soil surface as the pH increases followed the order : Phosphate < Sulphate < Molybdate.

Khan and Roy (1964) studying the phosphate retention and release in some east Pakistan soils reported that $CaCO_3$ treatment increased the release of phosphorus in ferruginous clay. Hall and Baker (1971) reported that effect of liming on P availability is not same for all soils. Addition of lime to soil containing clays that react like montmorillonite would increase P-fixation. JotSmyth and Sanchek (1980) reported that $CaCO_3$ and previous P application decreased P-fixation.

Prasad and Mathur (1997) studied the influence of long term use of fertilizers, manures and lime on phosphate adsorption parameters using Langmuir adsorption equation in six soil samples drawn from the Long Term Fertilizer Experiment of the ICAR. The rate and extent of P adsorption was considerably lower in soils which received recommended NPK +lime or FYM. The adsorption maxima was highest in unfertilized soil and lowest in NPK + FYM plot followed by NPK + lime. The bonding energy constant (K) was highest where nitrogen source was ammonium sulphate in the NPK treatment. Buffering capacity of soils and P supply parameters followed a reverse trend. Buffering capacity was highest and P supply parameter was lowest in unfertilized soil. P supply parameter was highest in soils treated with FYM followed closely by limed soil at different levels of added P.

Liming is the most important practice resorted to in such soils in order to counter acidity and increase phosphorus availability to plants (Sanchez and Uehare, 1980). Liming has always given mixed response and it has been reported to increase , decrease and not to affect the extractable soil phosphorus. Dynia and Camargo (1997) observed that in effect of phosphorus and lime application upon P adsorption both P and P^+ lime treatments significantly reduced the soil maximum adsorption capacity for P, but did not affect the P soil retention energy.

Sova (1996) observed the influence of lime application to the acid soil on the mobility of P in runoff and by simulated rainfall condition. The neutralization of the acid soil by appropriate amounts of lime significantly increased the portion of loosely bound phosphate in runoff sediment. This phenomenon influenced bioavailability of P in runoff, which increased after the lime application.

Alvarado and Cajuste (1993) studied on the liming and P retention on volcanic ash soil. They observed that lime and P had no significant effects on P extractability or on the maximum adsorption capacity parameter but a slight reduction in P adsorption in some soils. Bonding energy decreased with lime and P applications.

Debnath *et al.* (2000) reported that liming increased the saloid bound P, Al-P and Ca-P but decreased the Fe-P fraction with a few exceptions. Incidentally, the relative abundance of different inorganic phosphate fractions in the unlimited samples had no bearing on the magnitude of increase. There was an overall increase in the total extractable inorganic phosphates in the limited soils. The findings of quantitative changes in Al-P and Fe-P on liming the acid soils are in agreement with those of some early workers . The increase in saloid bound P in limed soils was due to release of P by hydrolysis of Fe and Al phosphates and mineralization of organic P at an enhanced rate. The decrease in Fe-P is due to release of P from Fe phosphate by hydrolysis. However, a part of the P released might have been fixed by Ca of lime and Al^{3+} or Al $(OH)_3$ in the clay fraction as evidenced by increase in Ca-P and Al-P fractions in limed soils.

Westermann (1992) suggested the influence of lime on P availability. He observed that plant P uptake was increased by P fertilization and decreased by increasing lime concentration. Phosphorus uptake was curvilinearly related to solution P. Solution P concentration increased linearly as the resin-extractable P. equilibrium buffer capacity (EBC) ratio increased, where EBC is the slope of the P adsorption isotherm at the indigenous equilibrium P concentration. The EBC increased as the lime concentration increased. P application increased solution P and resin-extractable P and decreased EBC with in a given lime concentration. The soil test P concentration or P fertilization rate should increase as the lime concentration increase to provide the same decrease of P availability and plant P uptake in that soil.

2.5 RELATIONSHIP BETWEEN PHOSPHORUS ADSORPTION AND AVAILABILITY

Vig *et al* .(2000) reported that crop responded to both native and applied P. calcium P was dominant inorganic P fraction (92.8 %) followed by Al-P (5.4 %, Fe-P (1.4 %) and Saloid-P (0.4 %). Among different indices of P availability, Olsen's Soil test method was found to be the most suitable. Olsen-P had a significant negative relationship with $CaCO_3$ and clay content. Olsen's P showed significant relationship with Fe-P and this relation improved by 7 % on conclusion of Saloid-P along with Fe-P. Both Fe-P and Saloid-P controlled P availability in these soils. These two fractions of soil P seemed to be important as these correlated significantly with Olsen's P and various yield and P uptake parameters on calcarious soils.

Dhillon *et al.* (2004) suggested that the amount of phosphate sorption and desorption increased with increase in amount of P added and it varied with various soil properties viz .clay,$CaCO_3$, Fe and Al oxides etc. Most of these soil were adsorbing more than 150 mg P kg^{-1} soil. Sorption parameters such as sorption maxima, buffering capacity and bonding energy constant related mainly to $CaCO_3$, free Fe oxides, silt, clay and exchangeable Mg. The values of mobility constant correlated significantly with clay, exchangeable Ca and exchangeable Mg. Organic carbon and exchangeable Fe showed highly significant relationship with maximum phosphate desorption. Supply parameter, maximum buffering capacity and bonding energy constant are important sorption parameters which control P availability in these soils.

Veeresh *et al.* (2001) studied the adsorption of added phosphorus in a vertisol amended with different rates of wet and dry fly ashes. The adsorption data were fitted to Langmuir isotherm. The P adsorption maxima varied greatly with the type of soil-ash mixture. Among fly ashes dry fly ash had more effect on P adsorption than wet fly ash. Fly ashes had little effect on P desorption except at higher ash rates. The soil ash mixtures even though had high P adsorption capacity, because of very low bonding energy most part of the adsorbed P was easily desorbable. Supply parameter values varied with the type of soil-ash mixture and also with the equilibrating P concentration.

Mondal *et al.* (2004) observed the P adsorption characteristics in subtropical soil. They suggested that P adsorption isotherm integrates intensity, capacity and quantity parameters of P in soils and these factors play key role in controlling P-flux to the roots of growing plants. Adsorption of P by soils from dilute solution has shown closer agreement with the Langmuir isotherm than several other isotherms. Interaction of at least 3 factors namely the quantity, intensity and buffering capacity expressed as dimension less supply parameter determines the ability of the soils to supply P to growing plant roots.

Van Uexkull (1985) has presented a comparative picture of the effect of traditional rice-culture and high yielding double cropping rice-culture on nutrient balance over a period of 5 years. The latter has almost 4 times larger demand on soil as compared to the former under unfertilized condition. The demand for P and K increased with application of N. Continuous cropping with application of chemical fertilizers and organic manures had shown variable influence on the status of available and total P in soils (Suba Rao and Ghosh, 1981)

Verma *et al.* (1987) observed 48.8 % depletion or available P in control plots as against 8.8-25.9 % enrichment in NP treatment over a period of 7 years in rice-wheat cropping sequence at Masodha. In another Long Term Fertilizer Experiment the level of initial soil test P declined from 7 kg/ha to about 2.8 kg/ha in plots not receiving phosphate fertilizer during continuous cropping (Biswas and Benbi, 1989). Swarup and Chillar (1986); Kanwar and Prihar (1962) and Mandal *et al.* (1985) reported that continued application of nitrogenous fertilizers alone decreased the available P content. Rana *et al.* (1993) reported that application of P fertilizers some times increased the available P or at least decreased the possible adverse effect of nitrogenous fertilizer on available P.

Chang and Chu (1961) observed that phosphorus was fixed mainly as Al-P followed by Fe-P and Ca-P in soils with pH 5.3 to 7.3 kept at field capacity for 3 days. After 100 days the amount of Fe-P increased and those of Ca-P and Al-P decreased. Yaduvanshi *et al.* (1985) while studying the effect of continuous cropping on some soil properties on an *Alfisol* reported that conspicuous accumulation of available P is due to P fixation in form of Al and Fe phosphate. Kuo and Mikkelsen (1979) reported that higher P adsorption in the rice top soil was attributed to higher content of amorphous iron resulting from reduction caused by seasonal soil submergence. Subramanian and Kumarswamy (1989) reported that most of the applied P was fixed as Ca-P and fixation was greater in soils that had not received phosphorus fertilizer. Rao *et al.* (1972) studied the reaction products following application of ammonium phosphate and superphosphate. Al-P was found in soils treated with superphosphate. Singhania and Goswami (1978) reported that application of monocalcium phosphate to rice increased Al-P and Fe-P in all soils. Verma and Singh (1978) found that saloid-P decreased when water logging prevailed without added P. With added P, Al-P increased up to 2 weeks of water-logging and then decreased. Venkatreddy *et al.*(1981) analysed the surface and sub-surface for P fraction in a Long Term Fertilizer Experiment which received varying doses of P for 12 years. The results revealed that saloid-P was higher in surface soil but Al-P and Fe-P were more in sub-soil.

Phosphate adsorption character although largely depends on the chemical properties, is also modified favourably or unfavourably by intensive cropping and soil fertility management practices adopted over a period.

Subramanian and Kumarswamy (1989) reported that P fixation was greater in soils that had not received phosphorus fertilizer for a long time. According to Abdou and Osman (1967) soils with higher binding energy could eb expected to supply lesser amount of P for plant growth. Thus, the treatment receiving 100 per cent N has undergone maximum depletion and more adsorption of phosphorus. Kanwar and Grewal (1960) working with soil fractionation data of Punjab soils were of the opinion that phosphate absorption decreased with the increase in pH and degree of base saturation in acid soils.

2.6 METHODOLOGY OF PHOSPHORUS ADSORPTION STUDY

Majumdar *et al.* (2005) studied the effect of liming on phosphate sorption and desorption behaviour of two acidic *Alfisols* and one *Entisol* of Meghalaya . phosphate sorption data was described successfully by Freundlich and Langmuir adsorption isotherms. *Alfisols* showed greater affinity for P as compared to *Entisol.* Lime application increased P adsorption in all these soils. Lime application had little impact on adsorption maxima while bonding energy increased with increasing lime levels. The Freundlich coefficient decreased with lime application while Freundlich K did not show any definite trend. Phosphorus desorption was very low in these soils, but was more in *Entisol* (3.52-5.53 % of adsorbed P) as compared to *Alfisols* (0.27-0.94 % of adsorbed P). Lime application slightly improved P desorption in *Alfisols* where as it decreased the same in *Entisol.* Phosphorus supply parameter of soil increased with increasing P level and decreased with lime application in both *Alfisols* and *Entisol.*

Vig and Dev (1984) suggested that acid soils adsorbed more P as compared with the alkaline ones irrespective of concentration of P in the equilibrium solution, P adsorption showing a straight line. Langmuir relationship was limited to a known solution concentration which varied with the soil. The treatment of citrate dithionite resulted in maximum reduction of P adsorption in acid soils and similar effect was found with ammonium acetate treatment in alkaline soils. In former group of soils, more than 90 % of adsorbed P was as Fe and Al phosphate and in alkaline ones, about 40 % was saloid bound. Phosphorus was adsorbed at two energy levels, the values of which varied with the nature of the soil. Sesquioxides in non-calcareous and calcium carbonate in alkaline soils among others are known to be largely responsible for adsorption of P.

Reddy *et al.* (1979) studied the phosphate sorption behaviour of a typic Haplustert in relation to rates of fertilizer P and manure applied regularly during the previous five cycles of soyabean-wheat annual rotation. The extent of P sorption was relatively higher in control plot soil and progressively decreased with increasing rates of fertilizer P in both unmanured and manured plots. The P sorption data for all samples were found to fit best in the classical Langmuir isotherm equation. The values of P sorption maxima, bonding energy constant, maximum phosphate buffering capacity and standard P requirement were highest for control plot soil and decreased with increasing rates of P fertilization. But the P supplying parameters followed a reverse trend. Effects of fertilizer P rates on sorption parameters were more pronounced in manured plots than in the unmanured ones.

Milap-Chand *et al.* (1995) reported that the phosphate sorption increased with increasing equilibrium period from 12 hours to 48 hours. Adsorption was nearly complete after 48 hours of equilibrium suggesting achievement of equilibration between solution and solid phase.

Toor *et al.* (1977) suggested that P adsorption data were fitted to Langmuir, Freundlich and Tempkin adsorption equations. Freundlich equation explained better P adsorption behaviour than the Langmuir equation as evidenced by higher correlation coefficient values. Adsorbed P increased with the increase in equilibrium P concentration. P desorption was far less compared to P adsorption. The soils having higher clay content, $CaCO_3$ or extractable Fe and Al exhibited high P adsorption but low P desorption indicating lower P concentration in soil solution for plant use at a point of lime application.

Mallikarjuna *et al.* (2003) suggested two methods for evaluation of P fixation capacity of soil. P fixation capacity of soils exhibited rise with increase in the levels of applied P.P fixation capacity of soil showed significant and positive correlation with organic carbon and available P content.

Serrao (1998) observed the effect of $CaCO_3$ application to increase soil pH on soil phosphate sorption characteristics. Sorbed P was lower in the samples treated with $CaCO_3$ for each level of applied P, with the corresponding higher P concentrations remaining in solution. Liming decreased P adsorption capacity.

Amrani *et al.* (1999) reported the phosphate sorption in calcareous soils as affected by soil properties. They observed the Langmuir and Cooke equations accurately described P sorption isotherms in calcareous soils. The determination of buffer indices requires the establishment of P sorption isotherms, which are difficult to adapt to routine analysis. Therefore, these relationships predict these indices for inclusion in P recommendation models.

Langmuir adsorption parameter *viz.,* absorption maxima (q_m) constant related to bonding energy (k) and their product (q_m x k) are used as an index to characterize the potential P-adsorptivity (Wuzhong *et al.* (1995) . Organo-inorganic fertilization and organic manuring decreased q_m and k, while minimum P application had little effect on them. The isothermal desorption of P was significantly correlated with initially added and isothermally adsorbed-P. The content of soil available P had a significant negative correlation with q_m x k and fixed P. The conclusion was that organic manure could increase P-availability of paddy soil derived from red earth by decreasing q_m, k, maximum buffering capacity (q_m x k) and fixation capacity. Lemare *et al.* (1987), however, observed that buffer power increased with lime, with or without green manure, but it was less in presence of organic matter indicating that phosphate was less strongly held and would be labile in soil in the field. Further, adsorption measurement showed that green manure increased the proportion of added phosphate that become isotopically exchangeable; 99 % of the adsorbed added phosphate was exchangeable in soil with green manure, but 89 % was exchangeable without it.

Senapati and Panda (1976) studied the adsorption behaviour of added phosphates by equilibrating the soil with various concentration of KH_2PO_4 solution and the solution P was determined at the end of the equilibration period. The amount of phosphate adsorbed by the soil was plotted against an equilibrium concentration which could be represented by a Freundlich adsorption equation having the form $x/m = KC^{1/n}$. Where x /m is amount of P_2O_5 fixed, C is the equilibrium concentration and K , 1/n are constants. The adsorption isotherm clearly showed three distinct reasons .The amount of fixation increased up to an equilibrium concentration of about 75 ppm P_2O_5 and then remained constant. At low concentration phosphate is probably adsorbed in highly reactive sites by exchange with OH and other specifically adsorbed anions with increase in concentrations probably less reactive sites Adsorbed phosphate with same mechanism, on further increase in concentration P probably would have been adsorbed by other mechanism like disruption of hydrous oxide polymers in addition to sample exchange phenomenon.

CHAPTER-III

Materials and Methods

MATERIALS AND METHODS

3.1 LOCATION OF THE EXPERIMENTAL FIELD

The field experiment was conducted in 'E' block of the Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar, which lies between the longitude of 85°48′ to 85°49′ and latitude of 20°16′ to 20°17′ N and comes under agroecological 12.2. In this particular location the trials of All India Coordinated Research Project on Long Term Fertilizer Experiments were being conducted since 1997-98. The type of land is medium, irrigated with lift irrigation facility from tube well. The soil is sandy loam in surface but clay loam to clay in lower depth. The soil of the experimental site is lateritic *Inceptisol* (*Udic ustochrept*). The soil profile has been studied and the morphological and some physico-chemical characteristics were examined and presented in Table 2 and 3, respectively.

3.2 TREATMENT DETAILS

The following treatments (Table 1) were undertaken to study the impact of farmyard manure (FYM) and lime on phosphorus adsorption, availability, and uptake to crops influencing the yield of rice.

3.3 EXPERIMENTAL DESIGN

The experiment was designed with randomized block design (RBD) having 12 treatments and 4 replications. The size of sub plot was 15 x 10 m and the surrounding buffer strip was 2.8m.The lay out diagram of the field experiment was presented in Fig.1.

Table 1. Treatment details

T_1	50 % NPK
T_2	100 % NPK
T_3	150% NPK
T_4	100 % NPK +Zn
T_5	100 % NPK +FYM
T_6	100 % NPK + Lime +FYM
T_7	100 % NPK + B + Zn
T_8	100 % NPK + S + Zn
T_9	100 % N
T_{10}	100 % NP
T_{11}	100 % NPK + Lime
T_{12}	Control

100 % = 80:40:60 kg ha^{-1} ($N:P_2O_5:K_2O$)
FYM = 10 t ha^{-1}
Lime = 1 t ha^{-1}
S = 30kg S ha^{-1} as gypsum
Zn = 12.5 kg ha^{-1} from$ZnSO_4$
B = 0.25 % as borax

WEST

SOUTH

R_4T_7 100% NPK + B + ZN	R_4T_1 50% NPK	R_3T_4 100% NPK + ZN	R_3T_1 50% NPK	R_2T_{11} 100% NPK + Lime	R_2T_7 100% NPK + B + ZN	R_1T_8 100% NPK +S+ ZN	R_1T_5 100% NPK + FYM
R_4T_{11} 100% NPK + lime	R_4T_6 100% NPK + Lime+ FYM	R_3T_2 100% NPK	R_3T_3 150% NPK	R_2T_1 50% NPK	R_2T_{12} Control	R_1T_3 150% NPK	R_1T_9 100%N
R_4T_{12} Control	R_4T_9 100%N	R_3T_{10} 100% NP	R_3T_8 100% NPK +S+ ZN	R_2T_5 100% NPK + FYM	R_2T_6 100% NPK + Lime+ FYM	R_1T_7 100% NPK + B + ZN	R_4T_{11} 100% NPK + Lime
R_4T_4 100% NPK + ZN	R_4T_8 100% NPK +S+ ZN	R_3T_6 100% NPK + Lime+ FYM	R_3T_{11} 100% NPK + Lime	R_2T_9 100%N	R_2T_4 100% NPK + ZN	R_1T_{10} 100% NP	R_1T_6 100% NPK + Lime+ FYM
R_4T_5 100% NPK + FYM	R_4T_{10} 100% NP	R_3T_9 100%N	R_3T_7 100% NPK + B + ZN	R_2T_{10} 100% NP	R_2T_8 100% NPK +S+ ZN	R_1T_2 100% NPK	R_1T_1 50% NPK
R_4T_3 150% NPK	R_4T_2 100% NPK	R_3T_{12} Control	R_3T_5 100% NPK + FYM	R_2T_2 100% NPK	R_2T_3 150% NPK	R_1T_4 100% NPK + ZN	R_1T_{12} Control

NORTH

EAST

Design-RBD , Replication - 4 , Plot size – 15 m x 10 m , Spacing 10 cm x 20 cm , Rice cv – *Swarna*

Fig. 1 Layout diagram of the field experiment

3.4 STUDY OF SOIL PROFILE

A soil profile in the experimental site was prepared. The morphology and important physico-chemical characteristics were studied and presented in Table.2 and 3, respectively.

3.5 ANALYSIS OF THE INITIAL SOIL

The initial soil samples before start of the 2006 *kharif* experiment were collected .The soil samples were processed by drying under shade in laboratory condition, hammered and sieved through two mesh sieve and analysed for different physico-chemical parameters. Among the physical parameters the particle size distribution, bulk density, particle density, pore space, structure and among the chemical parameters soil pH, electrical conductivity(EC), organic carbon, cation exchange capacity(CEC), exchangeable bases (Ca, Mg, K, Na), base saturation, and available macro and micro nutrients were determined as per the procedure (Jackson , 1973) and the results were presented in Table 4.

Method of analysis

The soil samples were analysed for different parameters following standard methods as given below.

i) **Particle size distribution:** The particle size distribution was estimated by Bouyoucos hydrometer method as described by Piper (1950).

ii) **Bulk Density (B.D.):** The bulk density was determined by core method as described by Black (1965).

iii) **Particle Density :** The particle density was determined by Pycnometer method as desired by Black *et al.*,1965.

iv) **Pore space** = The pore space of the given soil sample was determined by the following formula.

$$\text{Pore space (\%)} = \left(1 - \frac{\text{B.D}}{\text{P.D}}\right) \times 100$$

v) **Soil pH (w):** The soil pH was estimated in 1:2 soil water suspension by means of a systronics pH meter using glass electrode(Jackson ,1973)

vi) **Electrical conductivity (EC) :** The electrical conductivity was determined by the Elico conductivity meter (Jackson ,1973).

vii) **Organic carbon :** The organic carbon content in soil was determined by oxidation method of Walkley and Black as described by Page *et al.*, 1982.

viii) **Cation exchange capacity (CEC) and exchangeable cations**: The CEC of the soil was determined by saturating the soil exchange complex with neutral normal ammonium acetate solution and distilling the soil for NH_4^+-N. During saturation process, the equilibrium solution were saved and used for the estimation of exchangeable cations by following the methods as described by Jackson (1973). Exchangeable Ca^{2+}, was determined by EDTA (Versenate) complexometric titration method using calcon indicator by Page *et al.* (1982).

ix) **Available nitrogen** : Available nitrogen was determined by extracting the soil with alkaline KMnO4 as described by page *et al.*(1982).

x) **Available phosphorus (Bray's 1):** The Bray's 1 available P was determined following the method of Bray and Kurtz as described by Page *et al.* (1982).

xi) **Available potassium :** Available potassium was determined by extracting the soil with neutral normal ammonium acetate solution and estimated by flame photometer(Jackson, 1973)

xii) **Available sulphur :** Available sulphur was determined by extracting the soil with 0.15 per cent $CaCl_2$ solution (1:5 soil to solution ratio). Sulphur in the clear extract was determined colorimetrically by turbidimetric method using $BaCl_2$ (Chesin and Yien, 1951).

xiii) **Available micronutrients :** The Zn, Fe, Mn, Cu were estimated by extracting with DTPA and B by hot water as per the standard procedure of Jackson , 1973.

3.6. CROP MANAGEMENT

The experimental site was completely designed for rice-rice cropping system. Transplanted medium duration high yielding rice variety *Swarna* was taken during *kharif* (wet season) from July 2006- November 2006. Farmyard manure (FYM) was incorporated in the particular treatments at the time of first puddling and quantities of nutrients added from these sources was estimated and recorded.

Urea, diammonium phosphate (DAP) and murate of potash (MOP) were used as inorganic sources for N, P, K, respectively in various treatments. Nitrogen was applied in 3 splits i.e. 25 % as basal, 50% at 15 days after transplanting (DAP) and 25 % at panicle initiation stage. Total phosphorus was applied as basal and potash was applied 50 % as basal and 50 % at panicle initiation stage. Gypsum and zinc sulphate were applied as sources of sulphur and zinc, respectively at the time of planting and Borax was sprayed twice as source of boron. Paddy seedlings were transplanted at a spacing of 20 x 10 cm with 2-3 seedlings per hill. Necessary intercultural, water management and plant protection measures were taken until the crop was matured for harvesting.

The mean grain and straw yield and yield attributing characters of grain and straw were observed and presented in Table 5. The grain, straw yields and soil parameters were statistically analysed (Gomez and Gomez, 1967).

3.7 POST HARVEST ANALYSIS OF SOIL AND PLANT SAMPLES

The post harvest soil samples were subjected to analysis for important physico-chemical characteristics (Jackson, 1973) and the results were presented in Table 7. The uptake and uptake rate of phosphorus of the grain and straw was assessed through the chemical analysis of respective grain and straw samples by digesting with diacid mixture (HNO_3:$HClO_3$) in the proportion of 3:2 following the standard method advocated by Black, 1968 and the results were presented in Table 6 and Fig.3.

3.8 PHOSPHATE ADSORPTION STUDY IN SOIL

Phosphate adsorption study was conducted in the laboratory condition as an incubation experiment. The soil samples were collected from selected treatments like control, 100 % NPK, 100 % NPK + FYM,100 % NPK + LIME, 100 % NPK + FYM + LIME from the All India Coordinated Research Project on Long Term Fertilizer Experiments trial site. Duplicate soil samples of 5 g were taken in a series of 100 ml conical flask. To this 50 ml of 0.01M $CaCl_2$ containing 0,0.5,1,2,4,6,8,10,12, μg P ml^{-1} as KH_2PO_4 were added. In order to check the microbial activities two drops of tolune was added. The flasks were tightly covered with polythene to check evaporation of the added phosphate solutions. The contents were shaken in a reciprocating shaker for continuous by 2 hours and equilibrated for 48 hours at 25^0C in a BOD incubator with intermittent shakings. At the end of equilibration period the suspensions were filtered and the concentration of phosphorus in the filtrate was determined by developing blue colour with stannous chloride ($SnCl_2$). Intensity of colour was measured at 660 mμ wavelength in a UV-VIS spectrophotometer. The amount of phosphate adsorbed was calculated as follows.

P adsorbed μg g^{-1}= concentration of P added (μg ml^{-1}) – Equilibrium concentration of P (μg ml^{-1}) x 10

The results were presented in Table 8, 9 and Fig.5.

CHAPTER-IV

Results and Discussion

RESULTS AND DISCUSSION

4.1 STUDY OF SOIL PROFILE

4.1.1 Morphological characteristics of soil profile

The soil profile has been studied and the morphological characteristics were described in Table 2.

4.1.2 Physico-chemical characteristics of soil profile.

The important physico-chemical characteristics presented in Table 3 revealed that, the composition of sand of the profile was 53-82.6 % and highest quantity was observed in 11 to 16 cm layer of A_1 horizon. The highest amount of silt of 24.8 % was observed in 89-150 cm depth of BW_4 horizon. The soil profile at the depth of 41-89 cm of BW_3 horizon accounted for highest quantity (25.2 % clay). The textural class of the horizons of Ap, A_1, BW_1, were sandy loam where as BW_2 and BW_3 were sandy clay loam and BW_4 was sandy loam. The bulk density of profile varied from 1.38 to 1.54 g cc^1 and particle density varied from 2.37 to 2.54 g cc^{-1}. The lowest bulk density of 1.38 g cc^{-1} was observed in the A_1 horizon. The pH varied from 5.3 to 6.9 and with increase in depth of profile the pH was increased. There was marginal fluctuation of the electrical conductivity (EC) and with increase in depth it was decreased. The organic carbon percent varied from 0.19 to 0.44 g kg^{-1}. The highest amount was observed on the surface horizon of Ap and A_1 and the amount decreased with increase in depth. The cation exchange capacity varied from 3.9 to 14.9 cmole (p^+) kg^{-1}.

4.2 PHYSICO-CHEMICAL PROPERTIES OF THE INITIAL SOIL.

The physico-chemical properties of the initial soil presented in Table 4 revealed that , the sand , silt and clay composition of the soil was 71 ,12 and 17 percent ,respectively. The soil was grouped under sandy loam textural class. The bulk density, particle density and pore space were 1.55 g cc^{-1}, 2.68 g cc^{-1} and 42.20 g cc^{-1} , respectively. The soil structure was single grained.

Table-2 Morphological characteristics of the soil profile

Horizon	Depth (cm)	Morphology
Ap	0-11	Pale brown (10Y R 6/3). Sandy loam, moderate, very coarse, Granular; dry, slightly hard, moist, very friable, wet, non sticky, common, fine, faint, light red (2.5 YR 5/8) mottles.; common, very fine, discontinuous, imped and tubular pores; few concretions, many, very fine to fine roots, clear smooth boundary.
A1	11-16	Brounish yellow (10 YR 6/6); loamy sand, weak medium, subangular blocky, dry, slightly hard, moist, very friable, wet nonsticky; many , fine distinct, red (2.5 YR 5/8) mottles; common, very fine, discontinuous, random, imped tubular pores, few concretion, many very fine, roots; gradual smooth boundary.
BW_1,	16-26	Grey (10 YR 6/1) Sandy loam, strong, coarse, angular blocky; dry, very hard, moist, firm, wet non-sticky,: common, fine, yellowish red (5YR 5/8) , mottles, common, very fine to fine, discontinuous, random, imped irregular pores, plentiful, medium, ferruginous, soft concretion few, very fine roots, gradual, smooth horizon boundary.
BW_2	26-41	Grey (10 YR 6/1); sandy clay, strong, coarse, angular blocky, dry· very hard, moist extremely firm, wet, slightly sticky, common, fine distinct, yellowish red (5 YR 5/6) mottles; few, very fine to fine, discontinuous, random, imped, irregular pores, plentiful coarse, ferruginous soft; gradual wavy, horizon boundary.
BW_3	41-89	Grey (10 YR 6/1); Gravelly clay loam, strong coarse, sub-angular blocky, dry, extreme hard moist extremely firm, wet very sticky; few very fine, discontinuous, random, imped, irregular pores, plentiful, medium ferruginous, hard, concretion and plentiful, medium, calcium, soft concretion gradual, wavy boundary.
C	89-150	Dark grey (10 YR 4/1); clay loam; moderate, coarse, sub-angular, blocky, dry very hard, moist firm, wet very sticky; few very fine, discontinuous, random, imped irregular pores, plentiful, fine, soft concretion.

Table 3. Physico-chemical characteristics of the soil profile of the experimental site

Sl. No.	Depth (cm)	Horizon	Sand (%)	Silt (%)	Clay (%)	Textural class	B.D. (g/cc)	PD (g/cc)	PH (1:2)	EC (dSm^{-1})	OC (%)	CEC [cmole (p^+) kg^{-1}]
1	0-11	Ap	79.9	8.3	11.8	Sandy loam	1.40	2.37	5.3	0.08	0.44	4.2
2	11-16	A_1	82.6	9.0	8.4	Sandy loam	1.38	2.37	5.8	0.08	0.41	3.9
3	16-26	BW_1	79.0	9.8	10.2	Sandy loam	1.43	2.39	5.9	0.09	0.32	12.0
4	26-41	BW_2	63.0	15.8	21.2	Sandy clay loam	1.51	2.51	6.5	0.07	0.19	14.9
5	41-89	BW_3	53.0	21.8	25.2	Sandy clay loam	1.54	2.54	6.7	0.06	0.23	9.7
6	89-150	BW_4	63.0	24.8	12.2	Sandy loam	1.52	2.50	6.9	0.06	0.36	-

Table 4. Physico-chemical properties of initial soil

Sl.No.	Properties	Quantities
1	Mechanical composition	
	% sand	71
	% silt	12
	% clay	17
2.	Textural class	Sandy loam
3	Bulk density (g cc^{-1})	1.55
4	Particle density (g cc^{-1})	2.68
5	Pore space (%)	42.20
6	Structure	Single grained
7	pHw (1:2)	5.80
8	EC (dSm^{-1})	0.12
9	Organic carbon (g kg^{-1})	4.30
10	CEC [cmol(p^+)kg^{-1}],	3.75
11	Exchangeable bases [cmol(p^+)kg^{-1}],	
	Ca	2.25
	Mg	0.65
	K	0.07
	Na	0.05
	Total	3.02
12.	% BS	80.3
13.	Available nutrients (kg ha^{-1})	
	N (Alkaline $KMnO_4$)	187.0
	P (Olsen's)	19.4
	K (NH_4OAC extractable)	43.4
	K (In HNO_3 extractable)	150.0
	S (0.01M $CaCl_2$)	22.0
14.	DTPA extractable micronutrients	
	Zn	1.80
	Fe	33.00
	Mn	7.53
	Cu	3.15
	B (Hot water soluble)	0.46

Among the chemical properties the soil pH 5.80, EC 0.12 (dsm^{-1}), organic carbon 4.3 g kg^{-1}, cation exchange capacity (CEC) 3.75 [cmol(p^+)kg^{-1}], exchangeable bases [cmol(p^+)kg^{-1}], Ca 2.25, Mg 0.65, K 0.07, Na 0.05, total of 3.02 and per cent base saturation of 80.3 were observed. The available nitrogen, phosphorus, potassium and sulphur were 187.0, 19.4, 43.4 and 22.2 kg ha^{-1}, respectively. The HNO_3 extractable potassium was 150 kg ha^{-1}.The DTPA extractable zinc, iron, manganese, copper and hot water soluble boron were 1.80, 33.00, 7.53 ,3.15 and 0.46 ppm, respectively.

4.3 YIELD AND YIELD ATTRIBUTING CHARACTERS OF RICE

The mean yield of grain and straw along with the yield attributing characters for 2006 *kharif* were presented in Table 5, Fig 2. It was observed that there was significant response to application of plant nutrients over the control. The recommended dose i.e. 100 % NPK resulted higher grain yield of 24.3 and straw yield of 28.8 as against 22.5 and 25.0 q ha^{-1} in 50 % NPK treatment respectively. Further application of super optimal dose of nutrients in 150 % NPK, both the grain and straw yields were reduced to 22.1 and 26.4 q ha^{-1}, respectively. By comparing the N and NP treatments, it was observed that by application of N alone there was increase in grain and straw yield more than the control, but with addition of P (T_{10}) the grain and straw yield was further increased to 20.9 and 27.3 q ha^{-1}, respectively as against 19.8 and 25.4 q ha^{-1} grain and straw in N treatment (T_9). The experimental soil responded to the application of P by increasing the crop yield. By addition of FYM (T_5) the grain and straw yields were further increased, which was not so spectacular in comparison to 100 % NPK treatment (T_2).Farm yard manure (FYM) under decomposition and mineralization released the plant available nutrients . There was slow increase in yield parameters due to addition of FYM. Highest grain yield of 29.7 and straw yield of 34.0 q ha^{-1} were obtained in the treatment having 100 % NPK + FYM + lime (T_6) followed by 24.7 and 29.8 q ha^{-1} grain and straw, respectively in 100 % NPK + FYM (T_5) treatment. Since the soil is acid lateritic the application of lime acted as an amendment. The liming could reduce the phosphate fixation and adsorption in such type of soils in form of Fe-P and Al-P. Highest harvest index (HI) of 47.4 % was obtained in the treatment of 50 % NPK (T_1) followed by 46.6 % in 100 % NPK + FYM + Lime (T_6). The highest agronomic efficiency (AE) of 21.5 was observed in the treatment which received 100 % NPK + FYM + Lime (T_6). By the application of FYM and lime there was increase in economic yield (grain) of the crop, which was reflected in the harvest index of the particular treatment.

The application of nutrients through the integrated use of inorganic and organic sources not only increased the yield but also stabilized the yield and maintained sustainability of the crop production. By use of lime as amendment the soil pH was increased from acidity to neutral range in submersed rice soil which encouraged the transformation of organic sources to the inorganic forms. The liming augmented the availability of both macro and micronutrients. The fixed and adsorbed forms of P can be converted to the available forms, which helped in increase of crop yield.

Khurana *et al.* (2003) and Black(1967)reported that, phosphate reaction products are the specific identifiable compounds found as a result of reaction between applied fertilizer P and soil constituents. In the initial stage of reaction, these are metastable and with lime, are converted to more stable P compound. Some of these metastable forms persist for a longer time to act as good source of P for plant. These reaction products primarily govern the availability of P to plants by controlling soil solution P.

Table 5. **Effect of treatments on yield and yield attributing characters of rice**

Tr. No.	Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (HI) (%)	Agronomic efficiency (AE) (kg grain/kg nutrient applied)
T_1	50 % NPK	22.5	25.0	47.4	12.8
T_2	100 % NPK	24.3	28.8	45.8	15.0
T_3	150% NPK	22.1	26.4	45.6	12.3
T_4	100 % NPK +Zn	19.4	25.4	43.3	8.9
T_5	100 % NPK +FYM	24.7	29.8	45.3	15.5
T_6	100 % NPK + Lime +FYM	29.7	34.0	46.6	21.5
T_7	100 % NPK + B + Zn	21.2	26.2	44.7	11.1
T_8	100 % NPK + S + Zn	19.4	24.7	43.9	8.9
T_9	100 % N	19.8	25.4	43.8	9.4
T_{10}	100 % NP	20.9	27.3	43.4	10.8
T_{11}	100 % NPK + Lime	24.1	30.7	43.9	14.8
T_{12}	Control	12.3	18.8	39.5	
	CD (0.05)	3.4	4.1		
	SEm	1.2	1.4		

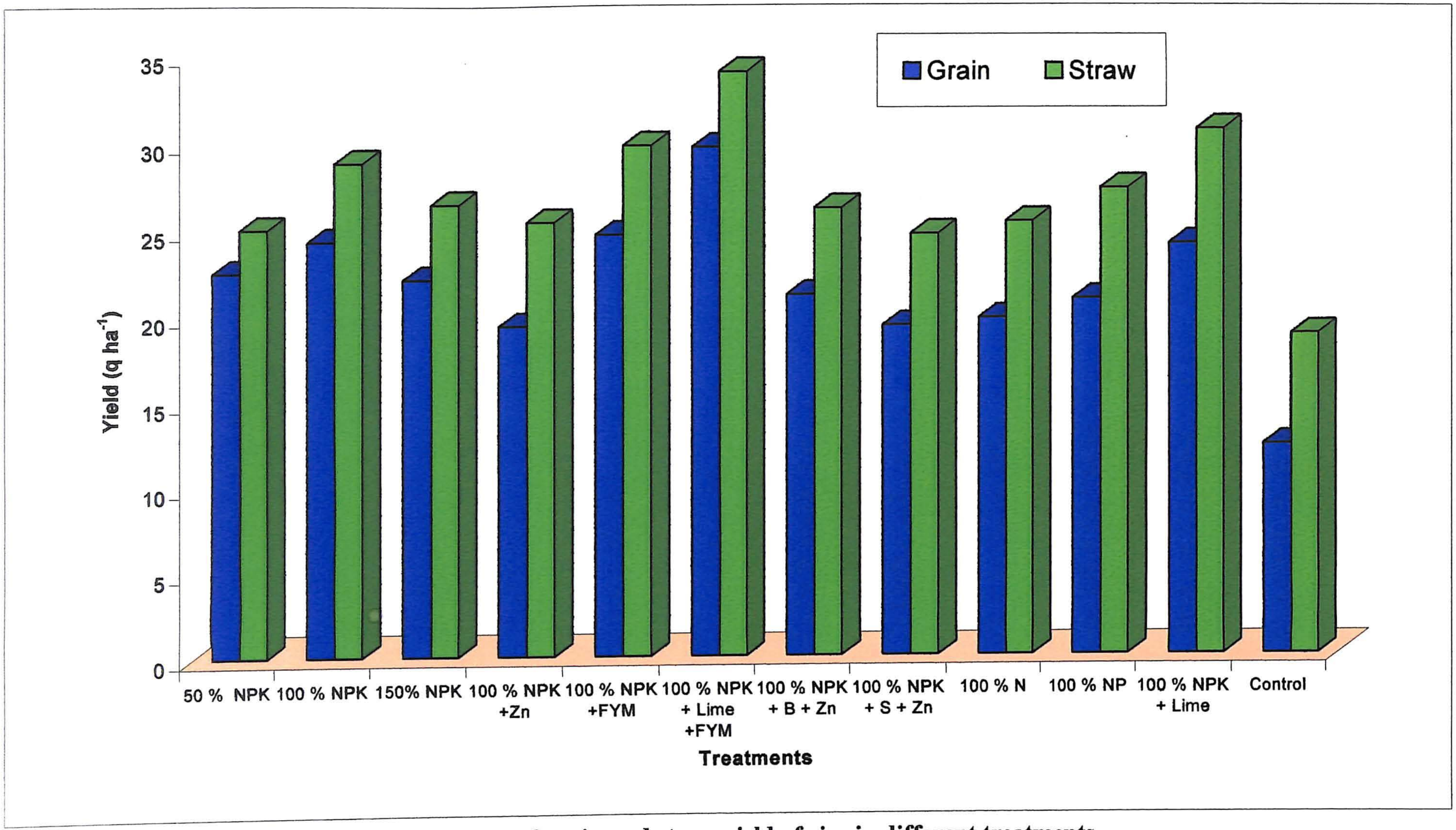

Fig. 2. Variation of grain and straw yield of rice in different treatments

By conducting on-farmed trials in different moisture regimes Senapati *et al.* (2003) reported that integrated use of 100% recommended dose of chemical fertilizer along with 5 t ha^{-1} FYM and in situ green manuring of Dhanicha produced rice grain yield of 5.43 t ha^{-1} at Phulbani and 4.31 t ha^{-1} at Darisahi centres respectively compared to the yield of 3.39 and 1.96 t ha^{-1} with farmers practice and 4.42 and 3.57 t ha^{-1} with 100% recommended dose of fertilizer.

Patnaik *et al.* (1989) have reviewed the results of several long term fertilizer experiments which showed P environment in soils with application of balanced or higher doses of NPK and combined use of NPK and FYM and P depletion in absence of P fertilizer addition. Depletion of P was more pronounced with 100 % dose than that in unfertilized control, possibly because of enhanced crop growth and P removal by the crops. Prasad and Mathur (1997) suggested that, the P supply parameter was highest in soils treated with FYM followed closely by limited soil at different levels of added P.

Subehia *et al.* (2005) studied that the addition of lime of FYM, along with recommended doses of chemical fertilizers, significantly improved the soil productivity. Application of lime increased soil pH and significantly reduced all type of soil acidity with most conspicuous effect observed on exchangeable acidity. The use of FYM, on the other hand had a moderate effect on exchangeable acidity as compared to that in treatment of NPK application alone. Both these treatments maintained better nutrient availability and sustained higher grain yields over the soils where only chemical fertilizers were applied.

Senapati and Dash (2006) observed that the integrated use of organic manure and optimum doses of inorganic fertilizers are necessary for sustained high productivity of rice-rice system.

4.4 UPTAKE AND UPTAKE RATE OF PHOSPHORUS BY RICE

The effect of different treatments on the uptake and uptake rate of phosphorus was presented in Table 6, Fig 3. It was observed that the uptake of P was more in all the treatments than the control. The uptake of P by grain ranged from 5.58 to 9.59 kg ha^{-1}. The treatment receiving 100% NPK with lime and FYM (T_6) recorded the highest value of 9.59 kg ha^{-1} of P by the rice grain. The treatments which received FYM and lime along with 100% NPK (T_5 and T_{11}) resulted almost equal values of 8.24 and 8.22 kg ha^{-1}, respectively. The micronutrient treatments (T_4, T_7 and T_8) were at par ranging from 8.04 to 8.64 kg ha^{-1} of P by the rice grain. The individual and combined effect of P, FYM and Lime were observed which had a positive influence on the uptake of P by the rice grain.

The uptake of P by the rice straw ranged from 1.27 to 2.52 kg ha^{-1}.The highest value of 2.52 kg ha^{-1} was observed in the treatment of 100 % NPK with lime and FYM (T_6). The lime treatment was superior to 100 % NPK (T_2) and FYM treatment (T_5) and was at par with the micronutrient treatments of T_7 and T_8.The application of nitrogen alone (T_9) suppressed the uptake of P both by grain and straw. The total highest uptake of P both by grain and straw was recorded to be 12.11 kg ha^{-1} in recommended dose of fertilizer along with lime and FYM (T_6). The treatments receiving FYM, lime, secondary (S) and micronutrients (Zn, B) resulted almost similar total P uptake values by the rice, grain and straw.

The uptake rate of P by rice grain varied from 2.95 to 4.53 kg t^{-1} and by rice straw it varied from 0.59 to 0.96 kg t^{-1}.

Table 6. **Effect of treatments on uptake (kg ha^{-1}) and uptake rate (kg t^{-1}) of phosphorus by rice**

Tr. No.	Treatments	Uptake of P			Uptake rate of P	
		Grain	Straw	Total	Grain	Straw
T_1	50 % NPK	6.64	1.47	8.11	2.95	0.59
T_2	100 % NPK	7.77	2.12	9.89	3.19	0.74
T_3	150% NPK	8.40	2.37	10.77	3.80	0.89
T_4	100 % NPK +Zn	8.64	2.06	10.70	4.45	0.81
T_5	100 % NPK +FYM	8.24	2.29	10.53	3.33	0.77
T_6	100 % NPK + Lime +FYM	9.59	2.52	12.11	3.23	0.74
T_7	100 % NPK + B + Zn	8.36	2.47	10.84	3.94	0.94
T_8	100 % NPK + S + Zn	8.04	2.38	10.42	4.14	0.96
T_9	100 % N	6.41	1.93	8.34	3.24	0.76
T_{10}	100 % NP	7.52	2.28	9.79	3.60	0.83
T_{11}	100 % NPK + Lime	8.22	2.44	10.67	3.41	0.79
T_{12}	Control	5.58	1.27	6.85	4.53	0.67
	SE m	0.36	0.12	0.53		
	CD (0.05)	1.05	0.33	1.08		

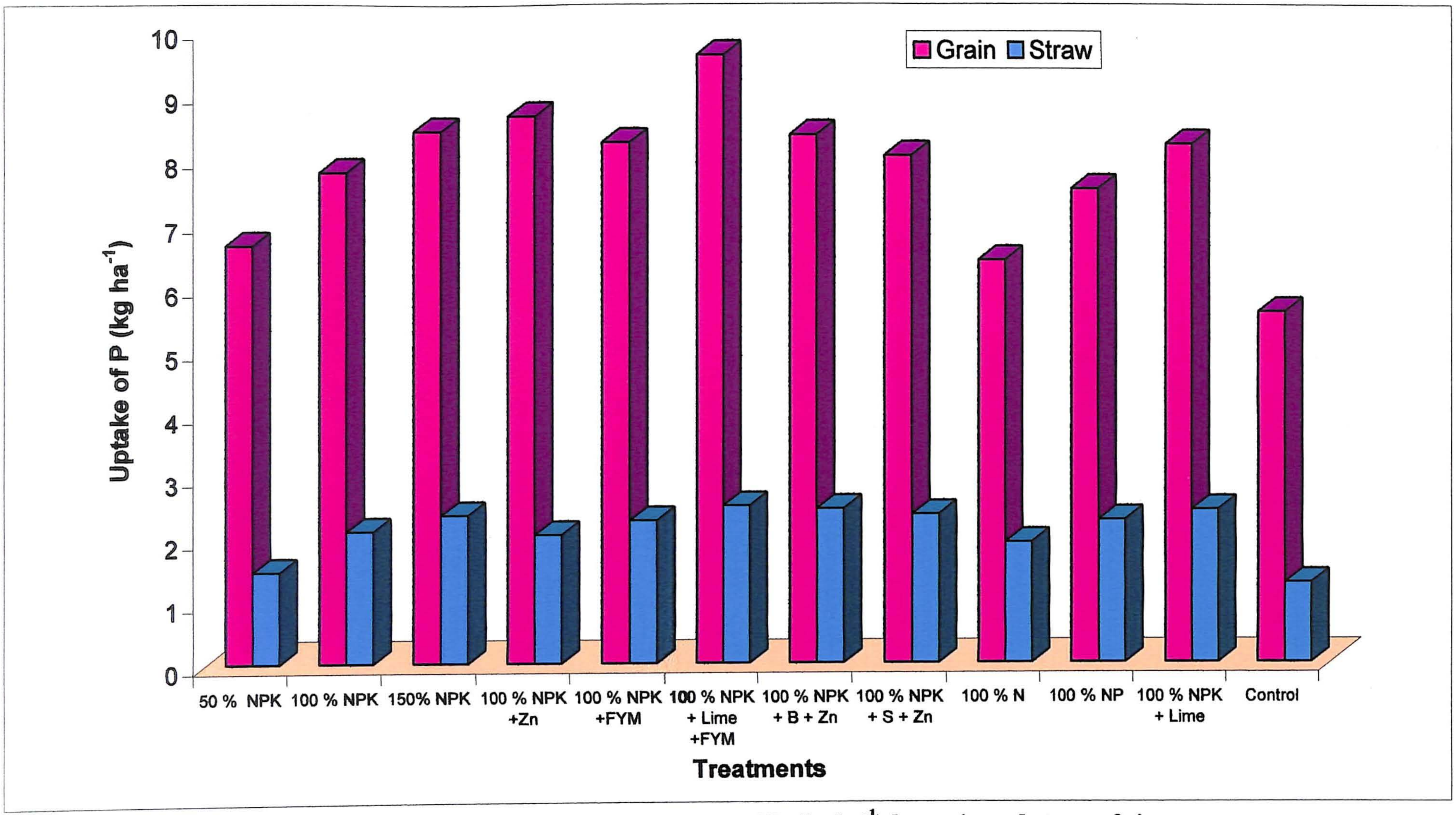

Fig. 3. Effect of different treatments on uptake of P (kg ha^{-1}) by grain and straw of rice

The beneficial effect of soil submergence on the availability of P explains the lack of wide spread response of rice to P fertilizers. In acid soils the moderating effects of submergence on soil pH and E_h influence P availability in two ways. First there is reduction in levels of soluble forms of elements such as Fe, Mn, Al, which rendered P on available. Secondly there is a reduction in the sorption and occlusion of P on soil solids.

4.5 POST HARVEST PROPERTIES OF SOIL

The soil samples were collected and analysed after harvest of the crop in order to assess the effect of treatments on different soil properties and the nutrient availability, which were presented in Table 7.

4.5.1 Soil reaction

Soil pH registered marginal fluctuations ranging from 5.16 to 6.13. In most of the treatments, the values were decreased from the initial soil pH of 5.80.The treatments which received the inorganic chemical fertilizers either suboptimal, optimal or super optimal doses recorded the lower values of pH than the control.. The nutrients applied along or in combination also resulted the lower values. Similarly the secondary (s) and micronutrients (Zn, B) when combined with the inorganic fertilizers also had the lower pH values than the control. The inorganic chemical fertilizers and micronutrient produced acids which decreased the soil reaction. When FYM was applied along with recommended dose of NPK the pH was reduced to 5.22 as against the initial value of 5.80. Farm yard manure on decomposition and subsequent mineralization produced humus and a wide variety of organic acids (the functional group phenolic, hydroxyl or carboxyl) by microorganisms or other process, which helped in reducing the pH . The liming could neutralize the pH dependent acidity. The tests soil is an acid laterite soil and an application of lime the soil pH was increased which was observed from the treatments receiving 100 % NPK with lime (T_{11}) and 100 % NPK, FYM with lime (T_6) representing the pH of 6.12 and 6.13 respectively.

4.5.2 Electrical conductivities

Soil electrical conductivity (EC) registered marginal fluctuations ranging from 0.01 to 0.11 ds m^{-1}. In all the treatments the values were decreased from the initial soil EC of 0.12 dsm^{-1}. Natural salinity levels may increase if the irrigation skims are improperly drained thereby resulting in a rise in the water table. The present experimental site was provided with proper drainage system for which the salinity level to be checked. The rice plants grow on the moderately saline soils if the land is flooded and the EC is less than 4 ds m^{-1} at 25-°C (Mass and Hoffman, 1977). The rice is grown as a 'reclamation' crop to permit the leaching of excess salts from the soils while at the same time produces very good rice yields. The inorganic chemical fertilizers, secondary and micronutrients careers while resulting higher EC values. The addition of FYM and with further addition of lime reduced the EC values.

4.5.3 Organic carbon

The organic carbon content of the soil ranged from 4.12 to 6.15 g kg^{-1}. The treatments receiving 100 % NPK (T_2), 100 % NPK + FYM (T_5), 100 % NPK + Lime (T_6), 100 % NPK + FYM + Lime (T_{11}), 100% NPK + B + Zn (T_7), 100 % NPK + S + Zn (T_8) resulted the higher values than the initial organic status of 4.30 g kg^{-1}. The treatments of control (T_{12}) then 50 % NPK (T_1), 150 % NPK (T_3), 100 % NPK + Zn (T_4), 100 % N (T_9) and 100 % NP (T_{10}) were having lesser organic carbon status than the initial value. The treatment receiving farm yard manure and lime along with recommended dose of NPK recorded the highest value of 6.15 followed by 4.84 (T_5) as against 4.12 and 4.34 in control and recommended doses of NPK (T_2).

4.5.4 Available nitrogen

The available nitrogen content of all the treatments were more than the initial and control treatment. The values varied from 194.14 to 238.94 kg ha^{-1}. The micronutrient treatments (T_7 and T_8) indicated the highest values of 238.94 (T_8) and 238.19 (T_7) followed by 235.74 in lime + FYM treatment (T_6) as against 224.73 kg ha^{-1} in recommended doses of NPK (T_2). The application of FYM, lime and micronutrients encourage the available nitrogen content of soil. Since it is a very poor sandy loam soil the application of well decomposed organic matter in form of FYM can slowly stabilize available nitrogen content of the soil. The available nitrogen content in low range in almost all the treatments.

4.5.5 Available phosphorus

The available phosphorus content of the soil in most of the treatments were lower than the initial status of 19.4 kg ha^{-1}. The control treatment was having only 9.74 kg ha^{-1} which was probably due to the adsorption and fixation behaviour of water soluble phosphates. The treatment supplied with only N (T_9) recapitulated the available phosphorus which was reflected from the lower value of 10.36 kg ha^{-1}. By addition of phosphorus through fertilizer (T_{10}) increased available phosphorus to 13.34 kg ha^{-1} with the supply of NPK at half the recommended dose, although the available phosphorus was increased but it was less than the initial values . The suboptimal, optimal and super optimal doses of phosphorus along with N and K indicated increasing order of available Phosphorus of 14.25, 18.98 and 21.83 kg ha^{-1} , respectively. The secondary micronutrient treatments did not indicate spectacular increase of available phosphorus rather it was at par with the recommended doses of NPK . The addition of FYM with recommended doses of NPK (T_5) recorded higher values of 22.35 kg ha^{-1} phosphorus which was more than the initial and recommended doses of NPK (T_2). The organic matter on decomposition encouraged the available phosphorus content of the soil. With further addition of lime (T_6) the available phosphorus content was increased and it was highest among all the treatments. The result of selected treatments was present in Fig.4. The acid soils on liming could be brought to the neutral to alkalinity range of soil reaction, which was favourable for releasing maximum quantity of phosphorus in available form. The adsorbed and fixed phosphorus could be easily removed by the help of the combined application of lime amendments and FYM along with the recommended doses of N, P and K. Lime alone (T_{11}) did not substantiate the results of the above mentioned treatments of FYM (T_5), FYM and lime (T_6). Excepting control 100 % N, 100 % NP all other treatments showed the available phosphorus in the medium range.

4.5.6 Available potassium

With continuous cropping the available potassium content of soil was increased in all the treatments than the initial figure of 43.4 kg ha^{-1}. The potassium content of the test soil was far below the lower range of the available K of soil. Since the soil is sandy loam in surface and clay to clay loam in subsurface region, there was chance of mining of potassium and the available form represented only the exchangeable form of potassium. The subsurface soil dominated with kaolinite type of mineral enhanced the conversion of exchangeable form to non-exchangeable form of potassium. With continuous application of potassium fertilizer there was increase in available potassium content of soil in different treatments. The value ranged from 57.84 to 70.89 kg ha^{-1}. The treatments receiving super optimal doses of NPK (T_3), FYM, lime and FYM + lime recorded higher figures of 70.89, 69.43, 69.38, 69.64 kg ha^{-1}, respectively.

4.5.7 Available sulphur

The available sulphur content of soil of all the treatments were more than the initial value of 22.2 kg ha^{-1}.The highest value of 57.47 kg ha^{-1} was obtained in the treatment which received recommended doses of NPK + lime (T_{11}) followed by lime + FYM (T_6) and S + Zn (T_8).All the treatments indicated higher values than the critical limit of 20 kg ha^{-1} for available sulphur in soil.

4.5.8 Available micronutrient status of soil

Iron: The available iron content varied from 15.02 to 42.12 ppm in the treatments keeping native source at 20.90 ppm. All the treatments showed a decline mean availability excepting treatment, which received, recommended doses of NPK with FYM (T_5). The highest value of 42.12 ppm was obtained in this particular treatment. The available status of all the treatments was far above than the critical limit of 6 ppm for iron in soil. Since it is an acid laterite soil and in submerged paddy culture due to reduced condition majority of the Ferric (Fe^{+++}) form of iron converted on reduction to Ferrus (Fe^{++}) form. Irons of toxicity are a major problem on this type of soils.

Copper : The available copper content of the soil ranged from 0.40 to 3.17 ppm as against 2.22 ppm in control. There was a marginal fluctuation of available status of copper in all the treatments compared with the initial status. The availability status of all the treatments was above the critical limit of 0.4 ppm.

Manganese : Available manganese status varied from 48.56 to 69.82 ppm as against 46.28 and 7.53 ppm in control and initial soil respectively. The values were far more than the critical limit of 4 ppm. The test soil is dominated in manganese content and due to application of lime and FYM, there was some positive effect.

Table 7. Effect of treatments on post harvest properties of soil

Tr. No.	Treatments	pH	EC (ds m^{-1})	OC (g kg^{-1})	Available macronutrient (kg ha^{-1})				Available micronutrients (ppm)			
					N	P	K	S	Fe	Cu	Mn	Zn
T_1	50 % NPK	5.16	0.096	4.14	217.10	14.25	57.84	40.42	15.00	0.40	66.40	1.78
T_2	100 % NPK	5.20	0.110	4.34	224.73	18.98	66.52	44.43	21.22	2.02	60.96	1.64
T_3	150% NPK	5.18	0.100	4.19	228.47	21.83	70.89	45.37	25.76	3.12	50.08	0.48
T_4	100 % NPK +Zn	5.27	0.091	4.21	208.67	18.93	65.15	43.32	19.34	2.22	69.82	1.98
T_5	100 % NPK +FYM	5.22	0.084	4.84	226.65	22.35	69.43	53.03	42.12	3.17	48.56	2.32
T_6	100 % NPK + Lime +FYM	6.13	0.074	6.15	235.74	25.86	69.64	55.93	28.78	2.98	54.88	2.72
T_7	100 % NPK + B + Zn	5.72	0.086	4.36	238.19	18.15	68.21	48.94	22.72	2.22	50.96	1.78
T_8	100 % NPK + S + Zn	5.39	0.072	4.40	238.94	17.65	64.01	54.35	22.42	1.84	54.50	0.48
T_9	100 % N	5.17	0.076	3.86	227.43	10.36	61.26	39.94	34.84	2.02	63.74	1.40
T_{10}	100 % NP	5.24	0.070	4.29	224.84	13.35	60.82	41.35	29.70	1.26	57.66	2.02
T_{11}	100 % NPK + Lime	6.12	0.083	4.38	228.78	16.14	69.38	57.47	25.40	2.22	50.20	2.22
T_{12}	Control	5.23	0.010	4.12	194.14	9.74	59.84	22.40	20.90	2.22	46.28	0.90
	SE m	5.19	15.77	10.20	10.34	0.33	6.79	6.25				
	CD (0.05)	0.41	0.02	0.66	333.42	0.94	6.40	4.09	5.65	0.43	8.76	0.25
	Initial	5.80	0.120	4.30	187.00	19.40	43.40	22.20	33.00	3.15	7.53	1.80

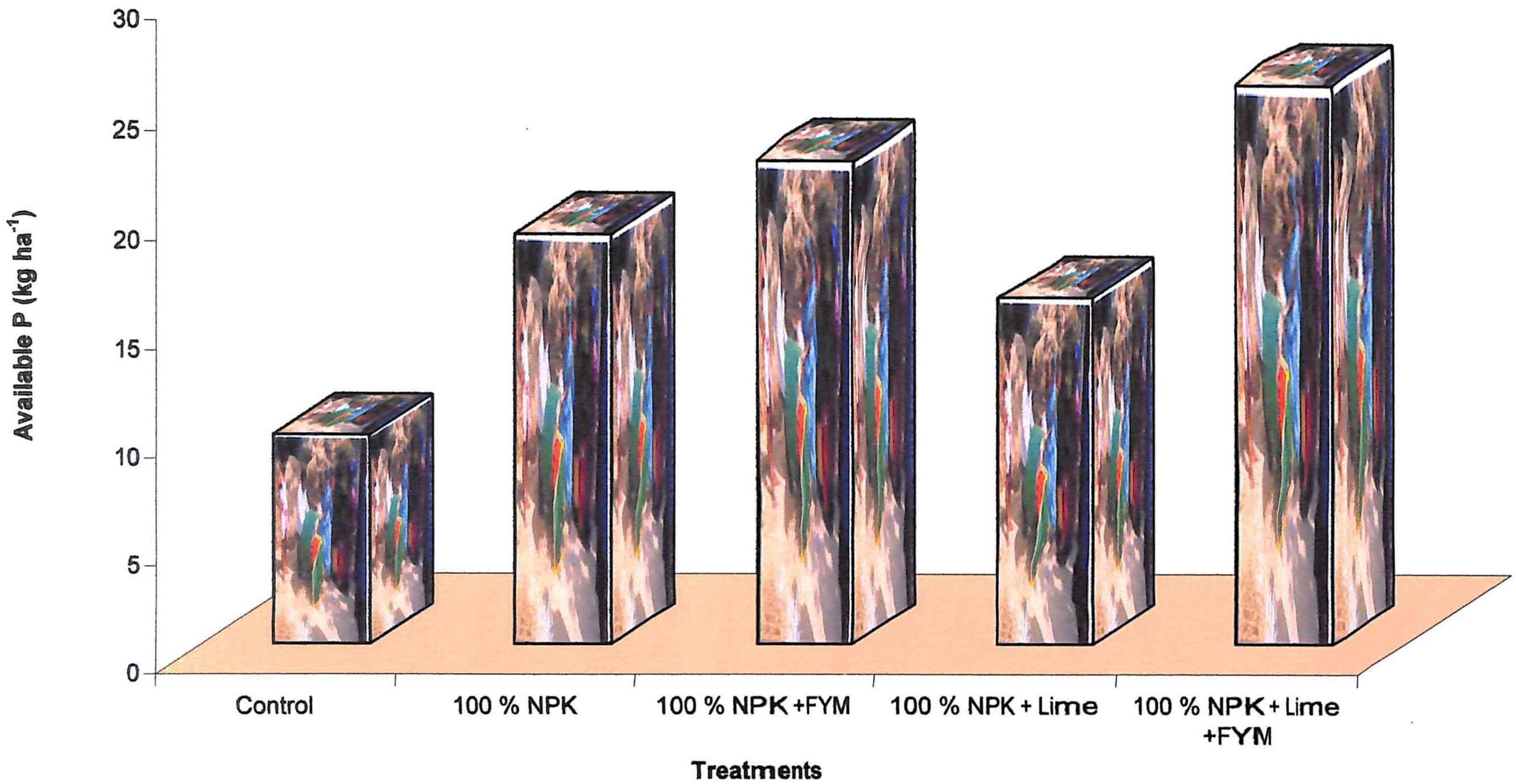

Fig. 4. Effect of selected treatments on available P (kg ha^{-1}) of soil

Zinc : Available zinc status of soil varied from 0.48 to 2.72 ppm as against 0.90 and 1.80 ppm in control and initial soil, respectively. Almost all the treatments recorded higher values than the initial status. The application of zinc, FYM and lime had positive effect on available zinc status of soil. Almost all the treatments were having more than the critical limit of 0.6 ppm.

Similar findings were also observed by Choudhary *et al.* (1981) reported that available phosphorus of the soil increase significantly with P and FYM application. Pattanayk *et al.* (1989) indicated that depletion of phosphorus were more pronounced with 100 % nitrogen dose than that in unfertilized control, Possibly because of enhanced crop growth and phosphorus removal by the crops .Subramanian and Kumarswamy (1989) found that the decomposition of organic matter produced CO_2 and carbonic acid (H_2CO_3) which dissolves the primary phosphate minerals. Sova (1996) observed that the neutralization of acid soil by appropriate amounts of lime significantly increase the portion of loosely bound phosphate on runoff sediment and this phenomenon influenced bio availability of phosphorus. Debnath *et al.* (2000) reported that liming increased the saloid bound phosphorus, Al-P, Ca-P but decrease the iron free fractions. Van and Uexkull (1985) presented a comperative picture of the effect of traditional rice culture and high yielding double cropping rice culture on nutrient balance for a period of 5 years and found that the later has almost 4 times larger demand on soil as compared to former under unfertilized condition .The demand for phosphorus and potassium increased with application of nitrogen. Subarao and Ghosh (1981) concluded that continuous cropping with application of chemical fertilizers and organic manure had shown variable influence on the status of available and total phosphorus in soil. Mandal *et al.* (1985) reported that continuous application of nitrogenous fertilizer alone decrease the available phosphorus content. Subramanian and Kumarswami (1989) reported that phosphorus fixation was greater in soils that had not received phosphorus fertilizer for a long time.

4.6 EFFECT OF FYM AND LIME ON PHOSPHORUS ADSORPTION

Phosphate adsorption is an important property of soil that retains phosphate against leaching and controls its availability to plant .The study was conducted in the soil samples collected from different treatments (Table 8) after growing rice. The concentration of P added were 0.5,1,2,4,6,8,10,12 in 1:10 soil solution ratio which corresponds to 5,10,20,40,60,80,100,120, μg P added per gram of soil .The equilibrium concentration of P increased and the amount of P adsorbed increased with increase in concentration of P added (Table 9 , Fig 5) .Percent adsorption decreased with increase in concentration of P added. This might be due to increase in population of P with increasing concentration of P added and to occupy the same number of adsorption sites. P adsorption at different concentration of P added was maximum in the control and decreased in the order of control > 100 % NPK >100 % NPK+ FYM > 100 % NPK +LIME > 100 % NPK + FYM + LIME.

In control P adsorption was maximum because no phosphorus was added and there was exhaustion of native phosphorus from soil causing an increase in the number of unoccupied adsorption sites. Adsorption decreased after application of NPK. Due to addition of phosphorus some of adsorption sites might have been occupied by P causing decrease in number of available adsorption sites.

Application of FYM along with NPK decreased the phosphate adsorption at different concentration of P added, as compared to 100%NPK. Application of FYM reduced P adsorption which might be due to coating of the soil particles by organic matter and blocking the adsorption sites. The organic anions also compete with phosphate to occupy the adsorption sites causing the reduction in P adsorption. Similar results have also been reported by Reddy *et al.* (1999).

Table 8. Effect of FYM and Lime on phosphate adsorption

SL. NO	Treatments	P adsorbed (µg g^{-1} soil)							
		Conc. Of P added(µg ml^{-1})							
		0.5	1.0	2.0	4.0	6.0	8.0	10.0	12.0
1	Control	4.00 (80)	7.60 (76)	15.34 (78)	27.82 (70)	37.23 (62)	45.62 (57)	52.12 (52)	55.81 (46)
2	100%NPK	3.75 (75)	7.23 (72)	13.25 (66)	24.05 (60)	33.13 (55)	40.35 (50)	45.29 (45)	48.08 (40)
3	100%NPK+FYM	3.35 (67)	6.30 (63)	11.6 (58)	21.2 (53)	28.2 (47)	34.4 (43)	38.01 (38)	39.6 (33)
4	100%NPK+LIME	3.11 (62)	5.8 (58)	10.6 (53)	18.2 (46)	24.01 (40)	28.8 (36)	32.05 (32)	31.56 (26)
5	100% NPK+FYM+LIME	2.75 (55)	5.01 (50)	9.13 (46)	16.21 (40)	21.09 (35)	24.32 (30)	25.43 (25)	24.06 (20)

* Figures in parentheses represent the percent P adsorbed.

Table 9. Equilibrium conc. of P at different conc. of P added

SL. NO	Treatments	Equilibrium conc. Of P (µg ml^{-1})							
		Conc. of added P added (mg ml^{-1})							
		0.5	1.0	2.0	4.0	6.0	8.0	10.0	12.0
1	Control	0.1	0.24	0.46	1.21	2.27	3.43	4.78	6.42
2	100%NPK	0.12	0.27	0.69	1.59	2.68	3.96	5.47	7.19
3	100%NPK+FYM	0.16	0.37	0.84	1.88	3.18	4.56	6.19	8.04
4	100%NPK+LIME	0.18	0.42	0.94	2.08	3.59	5.12	6.79	8.99
5	100%NPK+FYM+LIME	0.22	0.49	1.08	2.37	3.89	5.56	7.45	9.59

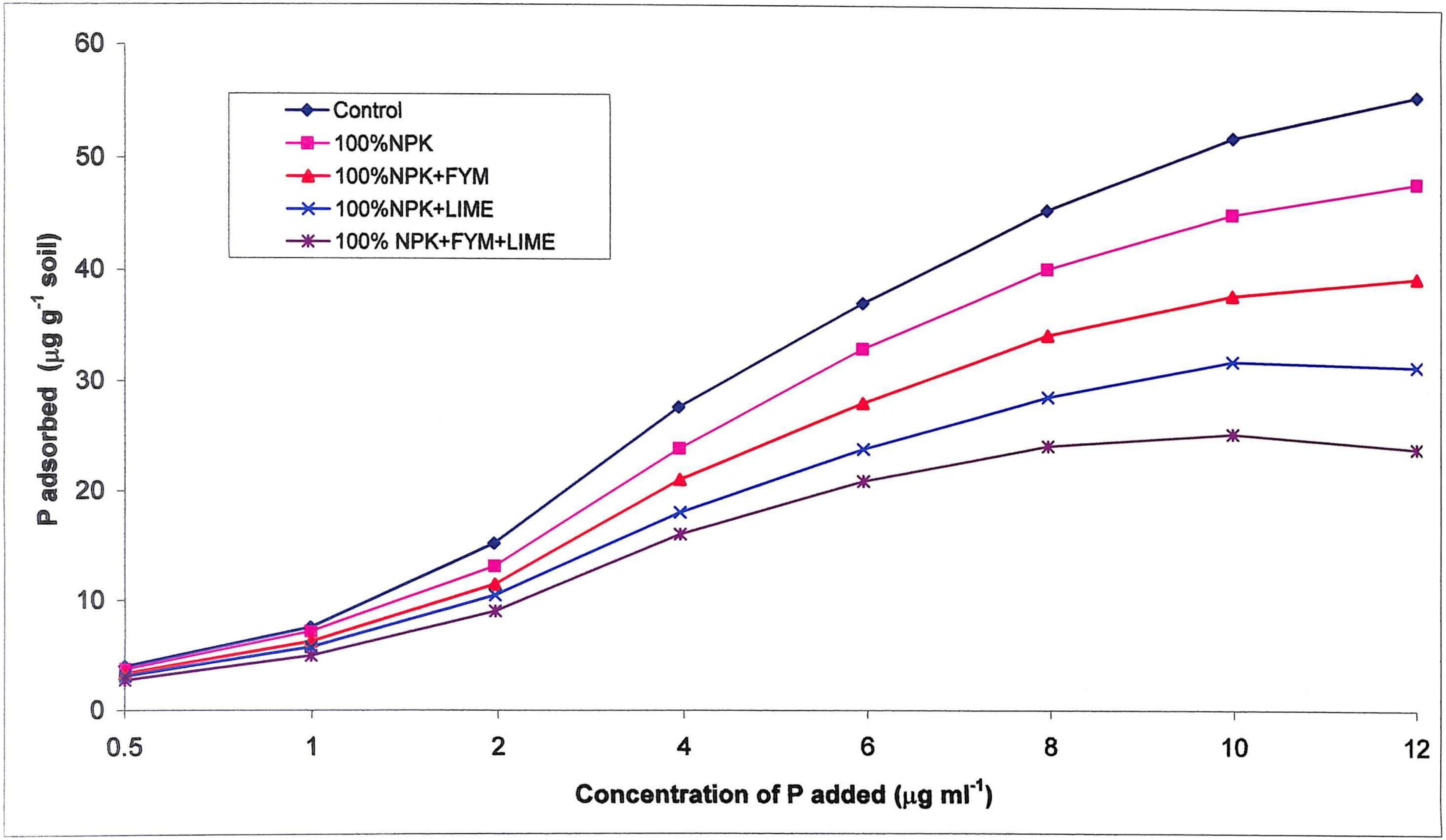

Fig. 5. Effect of selected treatments on adsorption of phosphorus in soil

Liming increases the soil pH, in other wards it increases the hydroxyl ion concentration in soil solution in which might be competing with phosphate to occupy the adsorption sites causing a reduction in P adsorption . Similar observation was also been reported by Prasad and Mathur (1997). P adsorption was minimum in the treatment receiving FYM and Lime which might be explained on the basis of above reasons.

Similar results were also presented by Senapati and Panda (1976) where they have found that with increase in concentrations probably the less reactive sizes adsorb phosphate with the same mechanism. The adsorption isotherm showed that in order to satisfy the phosphate fixing capacity of the soil and in a soil with high phosphorus fixing capacity it will not be economical to use a water soluble phosphatic fertilizer alone.

In control, the amount of P adsorbed at the concentration of 0.5 $\mu g\ ml^{-1}$ of P added was 4 $\mu g\ g^{-1}$ which increased to 55.81$\mu g\ g^{-1}$ at the concentration of 12$\mu g\ ml^{-1}$ of P added. Amount of P adsorbed in 100 % NPK treatment at the concentration of 0.5$\mu g\ ml^{-1}$ of P added was 3.75$\mu g\ g^{-1}$ which increased to 48.08 $\mu g\ g^{-1}$ at the concentration of 12$\mu g\ ml^{-1}$ of P added. Amount of P adsorbed at 100 % NPK + FYM at the concentration of 0.5$\mu g\ ml^{-1}$ of P added was 3.35$\mu g\ g^{-1}$ which increased to 39.6 $\mu g\ g^{-1}$ at the concentration of 12 $\mu g\ ml^{-1}$ of P added. In 100 % NPK+ LIME the amount of P adsorbed at the concentration of 0.5 $\mu g\ ml^{-1}$ of P added was 3.11$\mu g\ g^{-1}$ and it increased to 31.56$\mu g\ g^{-1}$ at the concentration of 12$\mu g\ ml^{-1}$ of P added. In 100 % NPK + FYM + LIME amount of P adsorbed at the concentration of 0.5$\mu g\ ml^{-1}$ of P added was 2.75$\mu g\ g^{-1}$ which increased to 24.06$\mu g\ g^{-1}$ at the concentration of 12$\mu g\ ml^{-1}$ of P added.

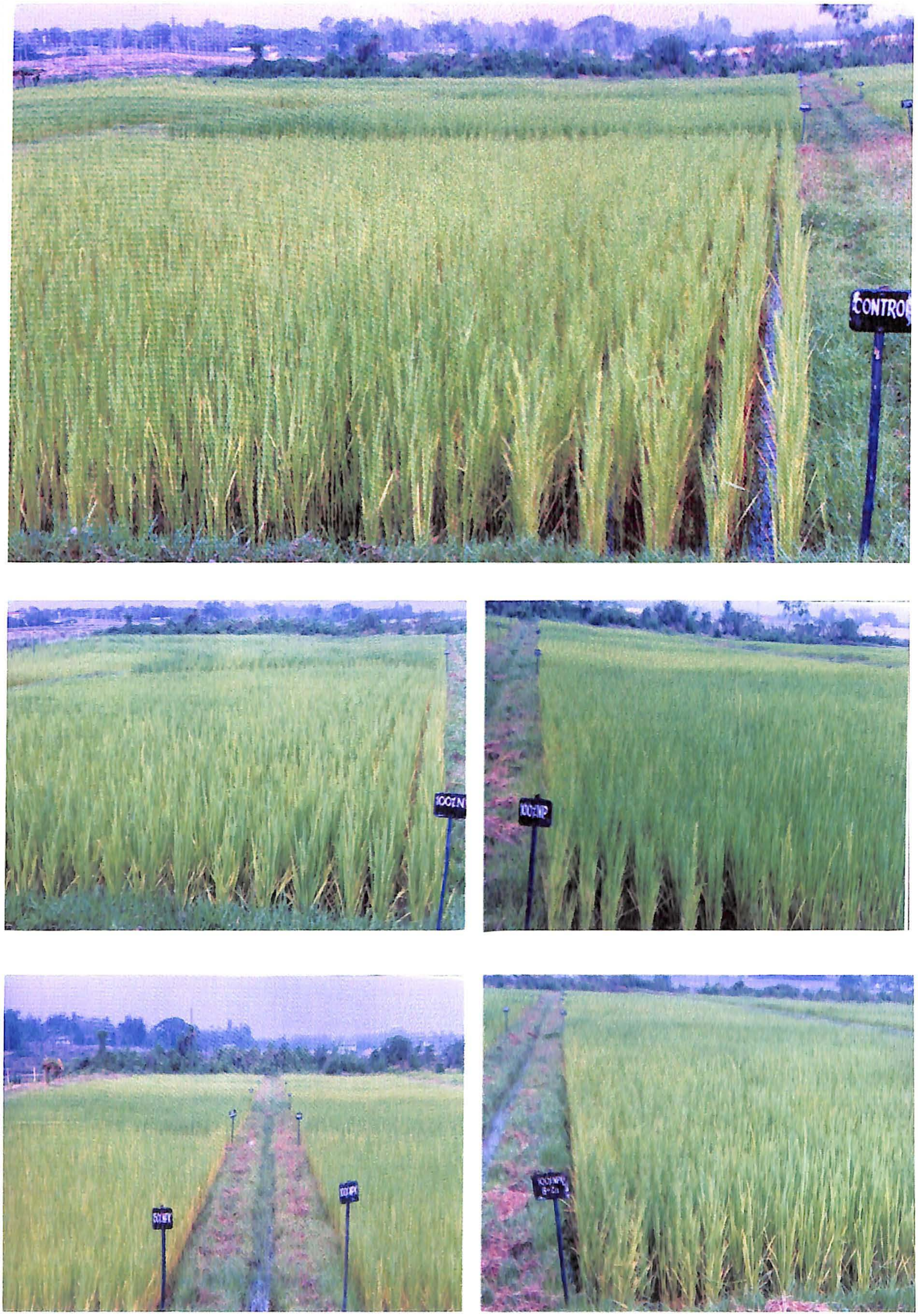

Plate 1. Effect of N, NP, NPK and NPK + B + Zn on rice

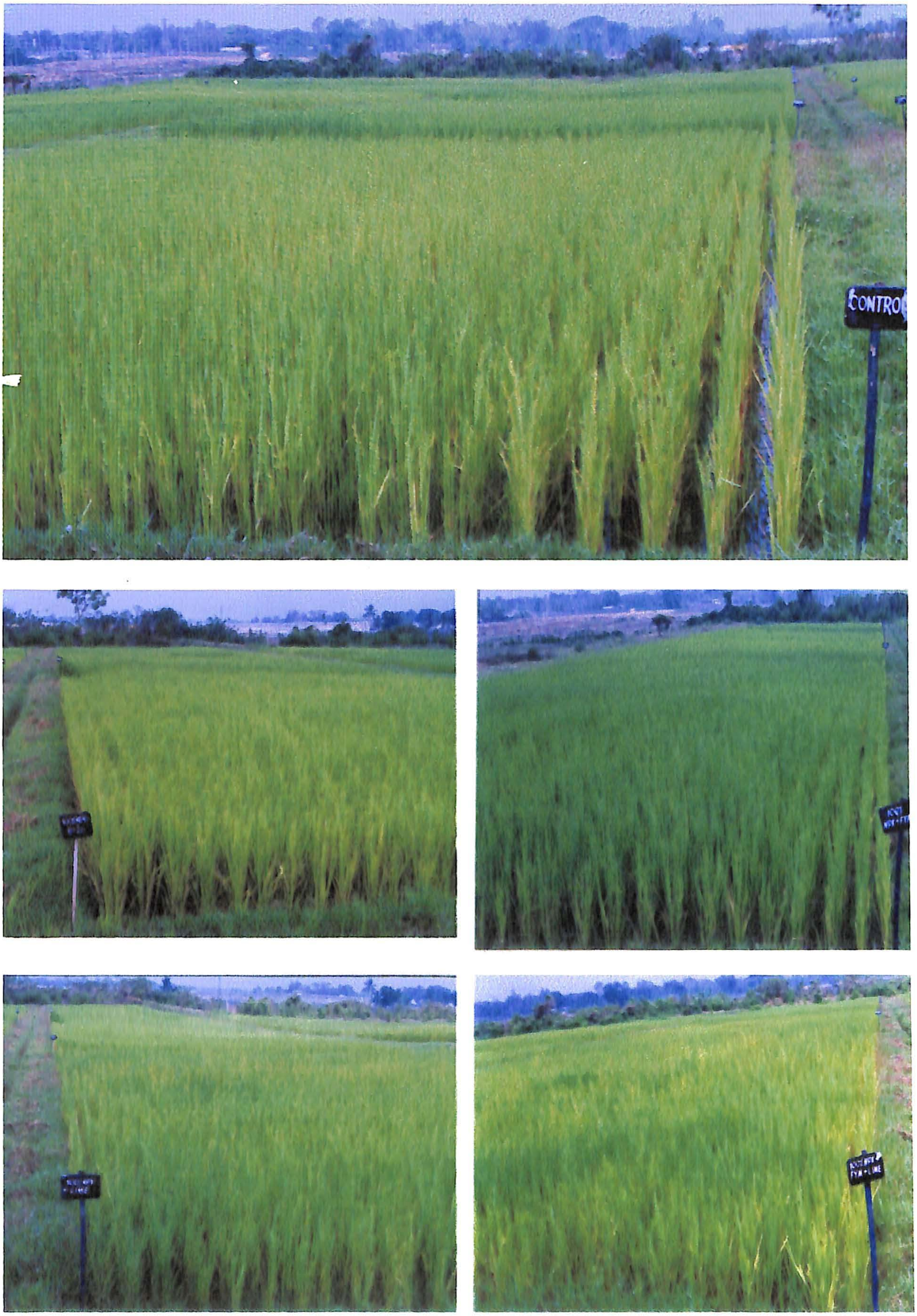

Plate 2. Effect of NPK + S + Zn , NPK + FYM, NPK + Lime and NPK + FYM + Lime on rice

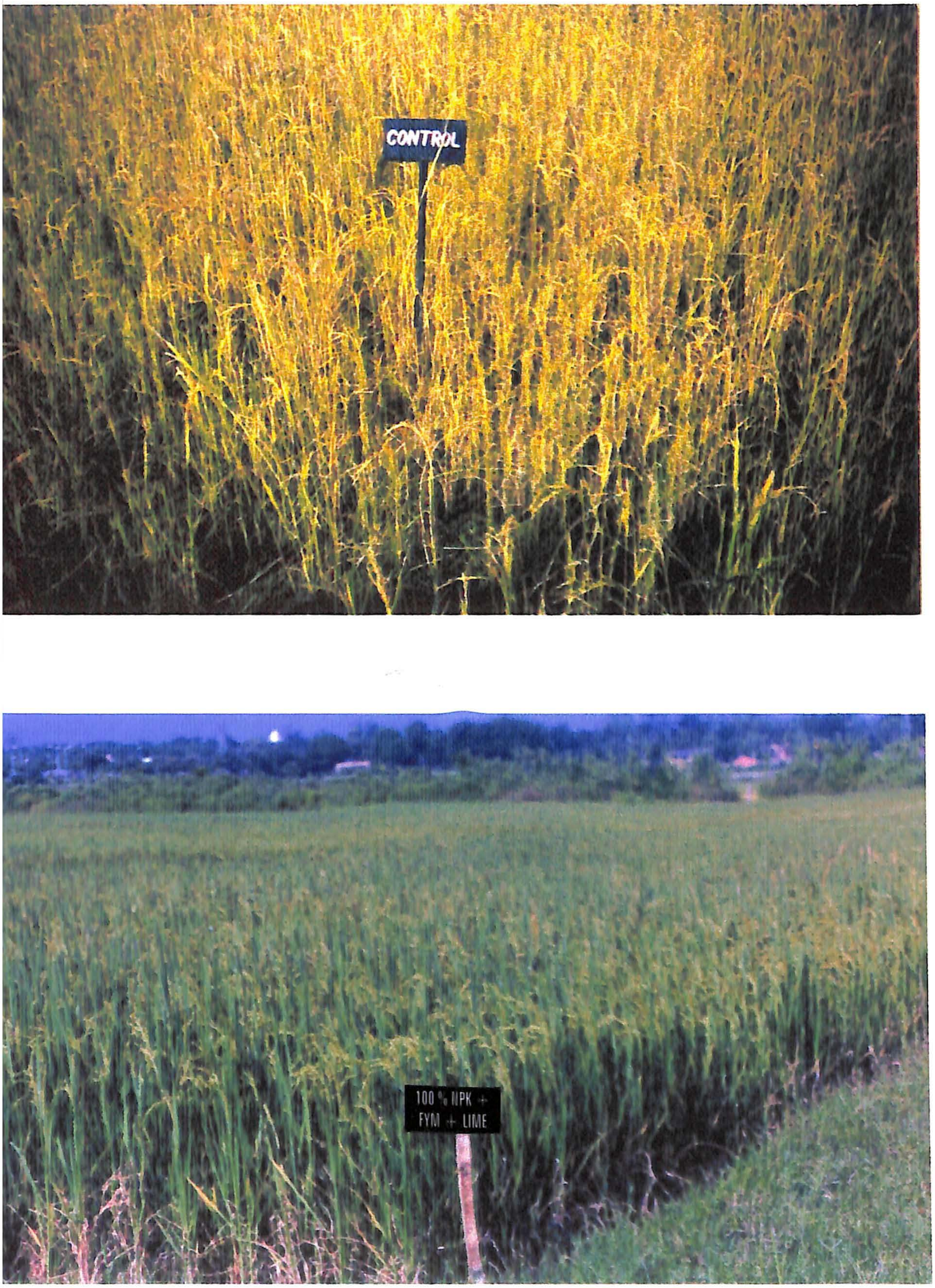

Plate 3. Effect of NPK , Lime and FYM at the time of maturity of rice

CHAPTER-V

Summary and Conclusion

SUMMARY AND CONCLUSION

5.1 The field experiment was conducted in the lateritic inceptisol (*Udic ustochrept*) at Central Research Station of Orissa University of Agriculture and Technology.

5.2 The surface of the soil profile consisted of sandy loam, which extended to sandy clay to clay loam with increase in depth (in subsoil region).

5.3 The experimental site is an eroded poor quality infertile soil zone having low organic carbon content.

5.4 The initial soil had poor fertility status having low (4.3 g kg^{-1}) organic carbon and the available nutrient contents varied from low to medium.

5.5 The soil was acidic in nature having pH 5.8 .

5.6 Due to prevalence of A and Fe, minerals such as strengite and verisite the availability of s water soluble phosphate was a major problem for fixation and adsorption of available form of phosphate.

5.7 The application of FYM and liming responded in such type of soils.

5.8 In rice-rice cropping system with high yielding rice varieties like *Swarna* and *Lalat*. The requirement of phosphorus was failed to be higher.

5.9 Highest , rice, grain yield of 29.7 and 34.0 q ha^{-1} were obtained in treatment having recommended (100% NPK) doses of NPK with FYM and lime.

5.10 The addition of FYM and lime along with the recommended doses of NPK enhanced the harvest index and agronomic efficiency of rice.

5.11 The treatment receiving 100 % NPK with FYM and lime recorded highest P uptake of 9.59 and 2.52 kg ha^{-1} by the grain and straw respectively.

5.12 Addition of different treatments with inorganic, organic and initiation of both types of nutrient sources influenced the soil physico-chemical properties.

5.13 There was marginal function of the soil pH, soil EC secondary and micronutrient (Zn, B).

5.14 The addition of organic carbon and organic carbon plus lime along with recommended doses of NPK increased organic carbon, available nitrogen, phosphorus, potassium and sulphur 6.15 g kg^{-1}, 235.74, 25.86, 69.64, 55.93 kg ha^{-1} respectively as against 4.30 g kg^{-1}, 187, 19.4, 43.4, 22.2 kg ha^{-1}, respectively in inorganic soil

5.15 Phosphorus adsorption at different concentration of P added was maximum in the control and decreased in the order of control > 100 % NPK > 100 % NPK + FYM > 100% NPK + lime > 100 % NPK + FYM + lime.

Bibliography

BIBLIOGRAPHY

Abdou, F.M. and Osman, A. (1967) Relative release and retentiveness of soil phosphates.*Journal of Soil Science* **7**, 61.

Alvaroda, J. and Cajuste, L.J.(1993)Liming and phosphorus retention in volcanic ash soils. *Turrialba* **43**(4), 235-241.

Amrani, M., West fall, D.G. and Moughli, L. (1999) Phosphate sorption in calcareous moroccan soils as affected by soil properties. *Communication of Soil Science Plant Analysis* **30**(9), 1299-1314.

Anjaneyulu, K. and Omanwar, P.K.(1979) Effect of long term manuring in a fixed crop rotation on phosphorus fractions. *Bulletin Indian Society of Soil Science* **12**, 324.

Appelt, H. Colemen, N.T. and Pratt P.F. (1975) Interaction between organic compounds, minerals and ions in volcanic-ash-derived soils. Effects of organic components on adsorption of phosphate. *Soil Science Society of America Proceedings* **39,** 628-631.

Arai, Y., Livi, K.J.T. and Sparks, D.L.(2005) Phosphate reactivity in long-term poultry litter amended southern Delaware Sandy soils. *Soil Science Society of America Proceedings* **69**(3), 616-629.

Biswas, C.R. and Benbi, D.K. (1989) Long term effects of manures and fertilizer on wheat based cropping systems in semi arid alluvial soils. *Fertilizer News* **34**(4), 33-38.

Black, C.A., Evans, D.D., White, J.L., Ensminger, L.E. and Clark, F.E. (1965) Methods of soil analysis (Part-1) Agronomy Monograph No.9, *American Society of Agronomy*, Madison, Wisconsin, USA, pp.371-373.

Boparia, H.K. and Sharma, K.N. (2006) Phosphorus adsorption and desorption characteristics of some soils as affected by clay and available phosphorus content. *Journal of the Indian Society of Soil Science* **54**(1), 111-114.

Chand-Milap, Nirmal S., Randhawa and Vig., A.C. (1995) Phosphate adsorption characteristics of some benchmark soils of N-W India and their relationships with soil properties. *Journal of the Indian Society of Soil Science* **43**(4), 582-586.

Chang, S.C. and Chu, W.K (1961) Fate of soluble phosphate applied to soils. *Journal of Soil Science* **12**, 286-293.

Chaudhary, M.L., Singh, J.P. and Narwal, R.P. (1981) Effect of long term application of P, K and FYM on some soil chemical properties. *Journal of the Indian Society of Soil Science* **29**(1), 81-85.

Chesin, L and Yien, C.H (1951) Turbuidemetric determination of available sulphat. *Soil Science Society of America Proceedings* **14,** 149-51.

Curtin, D. and Syers, J.K. (2001). Lime induced changes in indices of soil phosphate availability. *Soil Science Society of America Proceedings* **65**(1), 147-152.

Dalton, J.D., Russel, G.C. and Seiling, D.H. (1952) Effect of organic matter on phosphate availability. *Soil Science* **73,** 173-177.

Debnath, A., Bhattacharjee, T.K.and Debnath, N.C. (2000) Behaviour of inorganic phosphate fractions in limed acid soils. *Journal of the Indian Society of Soil Science* **48**(4), 829-831.

Devanath, N.C.and Mandal, S.K.(1982) Evaluation of the relationship of inorganic phosphate fraction of soil with available 'P' determined by some chemical and biological method. *Journal of the Indian Society Soil Science* **30,** 489.

Dhillon, N.S., Dhesi, T.S. and Brar, B. S. (2004). Phosphate sorption – desorption characteristics of some ustifluvents of Punjab. *Journal of the Indian Society Soil Science* **52**(1), 17-22.

Dhillon, N.S., Singh, Balwinder and Bishnoi, S.R. (2001) Evaluation of P availability indices for pearl millet.*Journal of the Indian Society Soil Science* **49**(4), 695-698.

Dynia, J.F. and Camargo, O. A. de (1997) The effects of phosphorus and lime application upon phosphorus adsorption in a dark red latosol. *Pesq. Agro. Bras.* **32**(8), 865-868.

Ghosh, G.K. and Sarkar , A.K.(1997) Indices of P availability and fixation of added P in acid alfisols of Chotonagpur plateau of Bihar. *Journal of the Indian Society Soil Science* **45**(3), 455-460.

Gomez, K.A. and Gomez,A.A. (1976) Statistical procedure for Agricultural Research with emphasis on rice. IRRI, Los Banos, Lagume, Philippines.

Grewal, J.S., Sharma, R.C. and Sud, K. C.(1981) Effect of continuous application of P, K fertilizers and FYM on potato yield and some soil properties. *Journal of the Indian Society Soil Science* **29**(1), 129-131.

Hall, J.K. and Baker, D.E. (1971) Phosphorus fixation by montmorillonite and vermiculite clays influenced by pH and soluble Al. *Soil Science Society of America Proceedings* **35**(6), 876-881.

Hue, N.V. (1991) Effects of organic acids/anions on P sorption and phytoavailability in soils with different minerologies. *Soil Science* **152**(6), 463-470.

Hynes, R.J.(1984). Effect of lime and phosphate application on the adsorption of phosphate, sulphate and molybdate by a spodosol. *Soil Science* **135**(4), 483.

Ige, D.V., Akinremi, O.O., Flaten, D.N., Aji boye, B and Kashem, M.A. (2005) Phosphorus sorption capacity of alkaline Manitoba soils and its relationship to soil properties.*Canadian Journal of Soil Science* **85**(3), 417-426.

Iyamuremye, F., Dick, R.P. and Baham, J. (1995a) Organic amendments and and phosphorus dynamics: 1, Phosphorus chemistry and sorption. *Soil Science* **161**, 426-434.

Jackson, M.L. (1973) Soil Chemical analysis, Prentice Hall Inc. Englewood Cliffs, New Jersey, USA.

Jotsmyth, T.and Sanchez, P.A. (1980) Effect of lime silicate and phosphorus application to an oxisol on phosphorus sorption and ion retention. *Soil Science Society of America Proceedings* **44**(4), 500-505.

Kanwar, J.S. and Prihar, S.S. (1962) Effect of continuous application of FYM and inorganic fertilizers on crop yield and properties of soil. *Journal of the Indian Society Soil Science* **10**, 190.

Kanwar, J.S. and Grewal, J.S. (1960) Phosphate fixation in Punjab soil. *Journal of the Indian Society Soil Science* **81**, 211-218.

Khan, D.H.and Roy, A.C. (1964) Study on the phosphate retention and release in some East Pakistan soils. *Plant and soils* **21**, 365-376.

Khurana, H.S., Saroa, G.S. and Vig. A.C. (2003) Reaction products of phosphorus as influenced by texture, moisture, temperature, rate and nature of phosphatic fertilizers. *Journal of the Indian Society Soil Science***51**(2), 199-203.

Kuo, S.and Mikkelsen, D.S. (1979) Distribution of iron and phosphorus in flooded and unflooded soil profiles and their relation to phosphorus adsorption. *Soil Science* **127**(1), 18-25.

Lemare, P.H., Pereira,J. and Goedert, W.J. (1987) Effects of green manuring on isotropically exchangeable phosphate in a dark red latosal in Brazil. *Journal of Soil Science* **38**, 199-209.

Majumdar, B., Kailash Kumar, Venkatesh, M.S. and Patiram (2005) Effect of lime on phosphorus adsorption and desorption behaviour of acidic Alfisols and Entisols of Meghalaya. *Journal of the Indian Society Soil Science* **53**(2), 188-193.

Majumdar, B., Venkatesh, M.S., Kailash Kumar and Patiram. (2004) Effect of different farming systems on phosphorus fractions in an acid *alfisol* of Meghalaya. *Journal of the Indian Society Soil Science* **52**(1), 29-34.

Mallikarjuna, G., Sudhir, K., Srikanth, K. and Srinivasamurthy, C.A. (2003). Phosphorus fixation capacity and its relationship with the soil characteristics in laterite soils of Karnataka. *Journal of the Indian Society Soil Science* **51**(1), 23-25.

Mandal, B.C., Saha, M.M. and Ray, A.B.(1985) Effect of long term fertilizer use on the available NPK status in soil under rotational cropping with Jute-rice-wheat sequence over 10 years. *Indian Journal of Agricultural Science* **55**(6), 421-426.

Maurya, P. R. and Ghosh, A.B.(1972). Effect of long term manuring and rotational cropping on fertility status of alluvial calcareous soil. *Journal of the Indian Society Soil Science* **20**(1), 31.

Melo, J.G., Yunda, A.L. de and Rojas, L.A. (2001) Effect of the organic amendments on the phosphorus dynamics in an oxisol. *Soue. Ecuat.* **31**(1), 32-39.

Mishra, B.and Khanna, P.K. (1982) Contribution of different phosphorus fractions to the labile pool of phosphorus as measured by Isotopic dilution technique. *Journal of the Indian Society Soil Science* **30**, 484.

Mondal, A.K., Jalali, V.K., Navneet Pareek and Wali Pardeep (2004). Phosphorus adsorption characteristics of subtropical soils in Jammu region. *Journal of the Indian Society Soil Science* **52**(4), 467-468.

Mukhapadhaya, A.K., Subir, K. and Mandal, L.N.(1979) Influence of moisture regime and application of fertilizer P and FYM prior to flooding on the availability of P in soil. *Bulletin Indian Society of Soil Science* **12,** 300.

Muralidharan, P. and Rattan, R.K.(2001) Effect of lime and phosphorus application on quantity and intensity parameters of phosphorus in acid saline soils under submergence. *Journal of the Indian Society Soil Science* **49**(1), 60-64.

Muralidharan, P. and Rattan, R.K. (2001) Effect of lime and phosphorus application on quantity and Intensity parameters of Aluminium and its uptake by rice in acid saline soils. *Journal of the Indian Society Soil Science* **49**(1), 124-129.

Nwoke, O.C., Vanlauwe, B., Diels, J. , Sanginga, N. and Osonubi, O. (2004) The distribution of phosphorus fractions and desorption characteristics of some soils in the moist Savanna zone of West Africa. *Nutr. Cycl. Agroeco* **69**(2), 127-141.

Page, A. L. , Miller, R.H. and Keeny, D.R. (1982) Methods of soil analysis, part-2, Chemical and microbiological properties. 2nd Edition No.(9) part-z in the series of Agronomy. *American Society of Agronomy, Inc. Soil Science of America*, Madison.

Paliyal, S.S. and Verma, T.S. (2002) Adsorption of added phosphorus as influenced by the application of lime and gypsum in an acid alfisol of Himalayan region. *Journal of the Indian Society Soil Science* **50** (2), 163-167.

Panda, N. and Sahoo, D. (1989) Long term effect of Manures and Fertilizers in Rice based Cropping systems in sub-humid lateritic soils. *Fertilizer News* **34**(4), 39-44.

Patel, S.P., Ghosh, A.B. and Sen, S. (1965) P manuring of Berseem on the fertility status of Delhi soil. *Journal of the Indian Society Soil Science* **11**, 225.

Patnaik, S., Panda, D. and Dash, R.N. (1989) Long term fertilizer experiments with wetland rice. *Fertilizer News* **34**(4), 47-52.

Piper, C.S.(1950) Soil Plant analysis. The University of Adelaide Australia, pp.47-229.

Prakash, R., Verma, L.P. and Singh, P (1993) Availability of phosphorus in soil and its concentration in blackgram (urd) as influenced by superphosphate coated with different materials. *Journal of the Indian Society Soil Science* **45**(4), 763-766.

Prasad, J. and Mathur, B.S. (1997). Influence of long term use of fertilizers, manures and lime on phosphate adsorption parameters in acid alfisols of Ranchi. *Journal of the Indian Society Soil Science* **45**(1), 24-27.

Prasad, B., Singh, R.P., Ray, H.K. and Singh, H. (1983). Effect of fertilizer, Lime , manure on some physical and chemical properties of red loam soil under multiple cropping. *Journal of the Indian Society Soil Science* **31**(4), 601.

Ramamurthy, B. and Bisen, D.C. (1971) Statistical and physico-chemical approach to availability of different forms of soil phosphorus to wheat , rice and to chemical extractions. Proc. Int. Symp. Soil Fert. Evaluation. *Journal of the Indian Society Soil Science* **1**, 63.

Rana, D.S., Singhth, B. Sharma, K.N., Kapoor, M.L. and Sodhi, J.S. (1983) Changes in soil phosphorus and its uptake with maize-wheat rotation under different levels of fertilization. *Indian Journal of Agricultural Science* **53**(8), 690-694.

Rao Seshagiri, Ahmed, T.N. and Rao Gopinath, H.K. (1972) Fractionation of the residual P compounds in black and red soils treated with P fertilizer. *Journal of the Indian Society Soil Science* **20**, 329.

Reddy, D. Damodar, Subba Rao, A. and Takkar, P.N. (1999) Phosphate adsorption behaviour of a typic haplustert in relation to long term use of fertilizer phosphorus and manure under soybean-wheat rotation. *Journal of the Indian Society Soil Science* **47**(3), 425-430.

Reddy, K.R., Overcash, M.R., Khaleel, R. and Westerman, P.W. (1980) phosphorus adsorption-desroption characterstics of two soils utilized for disposal of animal waste. *J. Environ . Qual* . **9** , 86-92.

Sahoo, D. (1934) Effect of long term manuring on P status and availability in an acidic sandy soil under rice-rice cropping system. Term paper, INSFFER Training course, IRRI, Philippines.

Sanchez, P.A. and Uehara, G. (1980) Management considerations for acid soils with high phosphorus fixing capacity In. M. Stelly (Ed.).The role of phosphorus in Agriculture. *American Society of Agronomy*, Madison, Wisconsin, U.S.A. pp.471-514

Sarma, R.N.S. and Singh, M. (1978) Transformation of native and added phosphorus in four soils under submerged condition. *Riso* .**27**(4),317-322.

Senapati, H.K. and Dash, A.K. (2006) The book on nutrient dynamics influencing crop productivity and sustainability under long term fertilizer application p.13.

Senapati, H.K., Dash,A.K. and Jena, Bandita (2003) The book on Integrated Plant Nutrient Management Strategies for different soil moisture regimes, p.71.

Serrao, M. da.G. (1998) Liming and phosphorus availability in acid soils derived from granites. Effect of calcium carbonate on the sorption of phosphate. *Agro. Lusit.* **46**(1), 5-20.

Sibanda, H.M. and Young, S.D. (1986) Competitive adsorption of humus acids and phosphate on geothite gibsite and two tropical soils. *Journal of Soil Science* **37**, 197-204.

Sing, B.B.and Jones, J.P. (1976) Phosphorus sorption and desorption characteristics of soils as affected by organic resources. *Soil Science Society of American Journal* **40**, 389-394.

Singh, B., Kapoor, M.L., Sharma,K.N., Rana, D.S. and Sodhi, J.S. (1983) Available P and K and soil organic matter contents as influenced by long term application of fertilizers and FYM to wheat-maize rotations. *Journal of the Indian Society Soil Science* **31**(4),491.

Singhania, R.A. and Goswami, N.N. (1978) Transformation of applied phosphate under stimulated condition of growing rice-wheat in a sequence. *Journal of the Indian Society Soil Science* **26**, 193.

Singhania, R.A. and Goswami, N.N. (1978b) *Plant and Soil* **50,** 527.

Sova, U. (1996) The influence of lime application to the acid soil on bioavailability of phosphorus in runoff. *Wat. Sci. Tech.* **33**(4), 97-301.

Suba Rao, A. and Ghosh, A.B.(1981) Effect of intensive cropping and fertilizer use on crop removal of sulphur and zinc and their availability in soil. *Fertilizer Research* **2**, 306-308.

Subehia, S. K., Sudhir Varma and Sharma S.P.(2005) Effect of long-term use of chemical fertilizers with and without organics on forms of soil acidity, phosphorus adsorption and crop yields in an acid soil. *Journal of the Indian Society Soil Science* **53**(3), 308-314.

Subramanian, K.S. and Kumarswamy, K. (1989) Effect of continuous cropping and fertilization on the phosphate fixation capacity of soil. *Journal of the Indian Society Soil Science* **37** (4), 682-686.

Swarup, A.and Chillar, R.K. (1986) Buildup and depletion of soil phosphorus and potassium in a long term field experiment. *Plant and Soil* **91,** 161-170.

Tarafdar,J.C., Yadav, R.S., Meenu bareja and Singh G. (2006) Phosphorus fractionation under crops, tree and grasses. *J. Indian Soc. Soil Sci.*, **54**(1), 38-44.

Thakur, R.S., Bisen, D.C. and dubey, S.M.(1977) Evaluation of phosphorus soil test, based on fractionation. *Journal of the Indian Society Soil Science* **25**, 384.

Toor, G.S., Bahl, G.S. and Vig, A.C. (1997) Pattern of P availability in different soils as assessed by different adsorption equations. *Journal of the Indian Society Soil Science* **45**(4), 719-723.

Van uexkull,H.R. (1985). Availability and management of potassium in wetland rice soils. In wetland soils: characterisation, classification and utilization, *IRRI, Philippines*, 293-306.

Veeresh, H., Patil, C.V. Vishwanath, J. and Chaudhuri doyel. (2001) Phosphorus adsorption characteristics in a fly ash amended vertisol. *Journal of the Indian Society of Soil Science* **49**(2): 255-259.

Venkatreddy, N., Saxena, M.C., Srinibasulu, R. (1981) Inorganic phosphorus fraction of foot hill Tarai soils long continued phosphorus fertilization. *Journal of the Indian Society Soil Science* **31**, 125.

Verma, L.P., Yadav, D.S.and Singh, R.(1987) Effect of continuous cropping and fertilizer applicationon fertility of soil. *Journal of the Indian Society Soil Science* **35**(4), 754-756.

Verma, R.N.S.and Singh, M. (1978) Transformation of native and added phosphorus in four soils under submerged condition. *Riso* **27**(4), 317-322.

Vig, A.C., Milap-Chand, S. Nirmal and Randhawa (1995) Standardization of equilibration time for phosphorus adsorption studies in low P fixing alluvial soils. *Journal of the Indian Society Soil Science* **43**(4),676-678.

Vig, A.C., Yash-Pal, Saroa, G.S. and Bahl, G.S. (2000) Forms of P and efficacy of different soil tests for P extractability in calcareous soils. *Journal of the Indian Society of Soil Science* **48**(3),527-532.

Vig. A.C.and Dev, G. (1984) Phosphorus adsorption characteristics of some acid and alkaline soils. *Journal of the Indian Society Soil Science* **32,** 235-39.

Vyas, M.K. and Motiramani, D.P. (1971) Effect of organic matter, silicates and moisture levels on availability of phosphate. *Journal of the Indian Society Soil Science* **19**(1), 39-43.

Westermann, D.T. (1992) Lime effects on phosphorus availability in a calcareous soil. *Soil Science Society of American Journal* **56**(2), 489-494.

Wuz hong NI, Zhang Yang Song, Sun XI (1995) Effects of organic manure on phosphate adsorption-desorption and availability in paddy soils derived from red earth. *Pedosphere* **5**(4), 357-361.

Yaduvanshi, H.S., Tripathi, B.R. and Kanwar, B.S. (1985) Effect of continuous manuring on some soil properties of an Alfisol. *Journal of the Indian Society Soil Science* **33**(3), 700-703.