DECLARATION

I hereby declare that this thesis entitled **Agronomic evaluation of chemical and bio-agents on Phosphorus dynamics in red loam soils of Southern Kerala** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship, fellowship or other similar title of any other University or Society

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(90 21 02)

CERTIFICATE

Certified that this thesis entitled '**Agronomic evaluation of chemical and bio-agents on phosphorus dynamics in red loam soils of Southern Kerala** is a record of research work done indepen dently by **Sri. K Viswambharan (90-21-02)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship to him

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CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATION

Introduction

1. INTRODUCTION

Phosphorus is classed along with nitrogen and potassium as a major plant nutrient element It is associated with several vital functions and is responsible for several characterstics of plant growth such as utilization of sugars and starch photosynthesis nucleus formation and cell division cell organisation and the transfer of heredity

Phosphorus is a constituent of nucleic acids fats and phospholipids Phosphorus has been reported to stimulate root growth An adequate supply of phosphorus in the early stages of plant growth is important for laying down the primordia for the reproductive parts of plants It helps in early maturity of crops particularly cereals and poor availability of this nutrient retards their growth Phosphorus is essential for seed formation and occurs in large quantities in plant seed and fruit The role of high energy phosphate bond (ATP ADP AMP) in respiratory and photosynthetic processes is well established Two symptoms of phosphorus deficiency are reduced plant size and unusual deep green colour Generally plants take up their phosphorus as the primary orthophosphate ion The secondary orthophosphate ion is also believed to be absorbed by plant roots in small quantities

The rock phosphate deposits concentrated in certain pockets in the world are the ultimate source of fertilizer phsophorus for the plants At present we used to apply phosphorus to all the crops in the name of balanced fertilization irrespective of whether the crops respond to it or not It may also be noted that response to phosphorus is rarely obtained in Kerala may be because of its fixation and other changes in the soil On account of the indiscriminate use of phsophate fertilzers the world deposits of the once concentrated form of rock phosphate is converted into soluble forms and distributed over large areas from where it becomes irrecoverable for further use and response to phosphorus is rarely noticed in terms of crop yield

These facts clearly illustrate the need for streamlining the various approaches to utilize the added and native sources of phsphorus to the extent possible so that the life of the rock phsophate deposits can be extended and crop response can be enhanced If any of the chemical and biological agents are found to be feasible and economical the same can be recommended to farmers for large scale adoption With these large objective in view the present experiments were conducted to find out the various chemical and bio agents on the uptake of native and added phosphorus in the redloam soils of Kerala It also aims at finding out the effect of these agents on the physico chemical properties of the soil monitoring the available phosphorus status of the soil during the post treatment period and its effects on the growth and yield of the test crop grown

Review of Literature

2. REVIEW OF LITERATURE

The review is classified under the following five headings viz

1 Importance of phosphorus as an essential plant nutrient element
2 Effect of phosphorus desorbing anions on the phosphorus availability in soils
3 Effect of chelating agents on the phosphorus availability in soils
4 Effect of microbial agents on the phosphorus availability in soils
5 Crop response to phosphorus application with special reference to legumes

2 1 Importance of phosphorus as an essential plant nutrient element

Phosphorus like nitrogen potassium, calcium magnesium and sulphur is classed as a macronutrient It occurs in most plants in concentrations ranging between 0 1 and 0 4% a range considerably lower than that typically found for nitrogen and potassium Plants can absorb P as either primary H_2PO_4 ion or smaller amounts of the secondary HPO_4 orthophosphate ion Since the former is the most abundant over the range in soil pH prevailing for most crops It is usually the principal form absorbed Studies with some plants have shown that there are about 10 times as many absorption sites on plant roots for H_2PO_4 as there are HPO_4 Absorption of the H_2PO_4 species is the greatest at low pH values where as uptake of the HPO_4 ion is greatest at higher values of soil pH (Tisdale et al 1985)

Other forms of P including the pyrophosphates and metaphosphates which are componenets of certain commercial fertilizers are also suitable for crops Since in aqueous solution both these forms hydrolyse to orthophosphate their absorption probably occurs mainly after conversion to orthophosphate Plants may also absorb certain soluble organic phosphates Nucleic acid and phytin are taken by plants from sterile sand or solution cultures Both compounds may occur as degradation products of the decomposition of soil organic matter and as such could be utilized directly by growing plants The nucleic acid DNA and monopotassium phosphate were found to be equally effective phosphate sources for barley grown on a P deficient soil Of the many essential functions that P has in plant life its role in energy storage and transfer is singly the most important Phosphate compounds act as energy currency within plants Energy obtained from photosynthesis and metabolism of carbohydrates is stored in phosphate compounds for subsequent use in growth and reproductive processes The most common energy currency is that found in ADP and ATP It occurs in the form of high energy pyrophosphate bonds between phosphate molecules located at a terminal position on ADP and ATP structures ATP has two pyrophosphate bonds between its three phosphate molecules and hence contain the most energy When the terminal phosphate molecule from either ATP or ADP is split a relative large amount of energy is liberated ATP is the source of energy that powers practically every energy requiring biological process in plants Almost every motabolic reactions of any significance proceeds via phosphate derivatives (Tisdale et al 1985)

Donation or transfer of the energy rich phosphate molecules from ATP to energy requring substances in the plant is known as phosphorylation In this reaction ATP is converted back to ADP The compounds ADP and ATP are formed and regenerated in the presence of sufficient phosphorus at sites of energy production such as oxidation reactions of respiration (Tisdale et al 1985)

In addition to this vital metabolic role P is an important structural component of a wide variety of bio chemicals including nucleic acids co enzymes nucleotides phosphoproteins phospholipids and sugar phosphates An adequate supply of P early in the life of a plant is important in laying down the primordia for its reproductive parts Large quantities of P are found in seed and fruit and is considered essential for seed formation Phytin composed of calcium and magnesium salts of phytic acids is the principal storage form of P in seeds A good supply of P has been associated historically with increased root growth Several other gross quantitative effects on plant growth are attributed to phsophate fertilization P has long been associated with early maturity of crops particularly in grain crops An adequate supply of P is associated with greater strength of cereal straw The quality of certain fruit forage vegetables and grain crops is said to be improved and disease resistance increased when these crops have satisfactory P nutrition P is readily mobilized in plants and when a deficiency occurs the element contained in the older tissues is transfered to the active meristematic regions (Tisdale et al 1985)

2 2 Effect of phosphorus desorbing anions on the phosphorus availability in soils

The literature on the anion contribution to desorbing P in soil are very limited The anions tested in this experiment include hydroxide carbonate and silicate

Noda and Saio (1952) reported that SiO_2 had greater effect on fixation of P than h d SiO_3 Bastisse (1967) reported that silicate anions tended to send P into solution Obihara and Russell (1972) reported that silicate adsorption was maximum at about a pH of 9 2 Binh et al (1974) reported that application of silicates raised the pH and had markedly increased P availability Smyth and Sanchez (1980) reported that silicates and previous P applications decreased P fixation and improved cation retention properties Domning and Amberger (1988) reported that availability of water soluble soil phosphate was increased by silicate application

Sinha and Mandel (1955) reported that fluoride and hydroxide were more effective in releasing exchangeable P in the soil Baker (1960) reported that the mechanism of P retention appeared to involve an exchange reaction between hydroxide and phosphate anion Anions such as chloride nitrate acetate and sulphate have very little power to displace phosphates The high displacing power is possessed by anions such as hydroxide fluorides oxalate arsenate citrate and tartrate which form stable complexes with iron and aluminum and also reduce secondary sorption of P during extractions with dilute acids (Mathan and Durairaj 1967 Ramamoorthy and Velayudham 1976)

Specific adsorption of silicate and phosphates and its influence in exchange properties and cation protection have been studied in detail by Hingsten and Raupach (1967) Hingsten et al (1968) Obihara and Russell (1972) and Gillman and Fox (1980) Baez Baez et al (1988) reported some favourable influence of carbonates and silicates on P desorption in soil with marked reduction in P adsorption capacity thus favouring P availability Ramos Hernandez and Aguilera He e a (1988) reported that with lime and phosphate, pH could be increased and also both the organic acids and the inorganic P fractions could be mobilized It is evident from these that there is some marked effect of anions for P desorption and thus availability and uptake of P by crops (Han et al (1989) and Wang and Yuan (1989) reported that available P content was increased by addition of lime) Hartikainen and Mohemmedi (1991) reported that the isotopically exchangeable P was affected by $CaCO_3$ only slightly) Vig et al (1994) also reported the effect of various anions on P desorption in soil including silicates

2.3 Effect of chelating agents on the phosphorus availability in soils

Mack Drake (1965) pointed out that by the process of chelation many organic anion from highly stable werner type complex ion with such cation as Ca^{2+} Zn^{2+} Mn^{2+} Al^{3+} and Fe^{3+} The solution thus behaves as if these cations were not present For example addition of EDTA to a solution of $CaCl_2$ prevents the precipitation of calcium on the addition of oxalate anion And in contrast this chelating agent EDTA when added to calcium oxalate will dissolve this precipitate with the formation of oxalic acid and calcium EDTA. By this reaction Fe^{3+} and Al^{3+} ions are inactivated and thereby prevent phosphate fixation Role of chelates in solution of phosphate results in solubilization of iron and aluminium phosphate protection of applied soluble phosphate solubilization of rock phosphate by calcium chelations and chelation of iron and other metals Wheeler (1966) reported that chelation of iron and aluminium found in the vicinity of fertilizer granules was effective in reducing P fixation Hashimoto (1967) reported that EDTA suppressed P fixation in reddish soil and a volcanic ash soil but increased it in a white soil Reuda et al (1981) reported that EDTA and DTPA inhibited almost completely the adsoprtion of zinc on to haematite over a pH range from 4 to 10 Borggar (1983) reported that EDTA and Dithionite EDTA treated to soil remove iron oxides Jayachandran et al (1989) reported a favourable effect on the application of EDDHA in P solubilization

Thus it is revealed that chelates increased the phosphate availability to plants by reacting with P fixing metals like iron aluminium zinc etc which are present in the P deficient as well as P sufficient soils

2 4 Lffect of microbial agents on the phosphorus availability in soils

2 4 1 Effect of phosphabacteria

The effect of phosphabacteria (Bacillus megatherium var phosphaticum) on P solubilization was reported by several authors including Sundara Rao (1968) Kumaraswamy and Rajasekharan (1990) obtained positive results with phosphobacterin treatment for sugarcane and concluded that phosphobacterin has a remarkable role in increasing P fertilization for sugarcane

Dubey and Billore (1992) reported that, in India significant increases in the yield of berseem have been reported due to inoculation with phosphobacterin Similalry the increased in the yield and phosphate uptake in tomato and wheat by bacterisation with phosphobacterin of the Indian strain Bacillus megatherium was subsequently reported Addition of rock phsophate to soil in conjunction with phosphate solubilizing micro organisms was found to make P available to plants in neutral to alkaline soils They also reported that significant yield increases by addition of rock phosphate and many phosphate solubilizing micro organisms have been reported in wheat paddy and soybean In field trials berseem maize wheat and paddy responded to inoculation with phosphobacterin and showed significant increases in yield

Dubey and Billore (1992) reported that microbial inoculation and fertilizer P and their interaction significantly influenced grain and straw yield of chick pea An appreciable increase in grain yield over control was reported with microbial inoculants Among the single inoculant the highest grain yield was obtained with Aspergillus awamori followed by Pseudomonas striata Combined inoculation with Glomus fasciculatum and phosphate solubilizing bacteria augmented straw and grain yields but not significantly over their respective control

2 4 2 Lffect of vesicular arbuscular Mycorrhizae (VAM)

Vesicular Arbuscular Mycorrhizae briefly called the VAM are obligate symbiotic fungi which are endogenous to the roots by the hyphae and are externally spread in to the soil The plant roots supply the required food materials to the fungi and in return the plants get nutrient and water from the soil under deficient situations There are a number of species of VAM but the important one is Glomus fasciculatum

A number of studies with VAM led to the conclusion that plants use the same available phosphate pool whether or not they are mycorrhizal Such a conclusion was reached in experiments using isotope dilution technique or fertilizer labelling techniques (Hayman and Mossae 1972)

In spite of the fact that no general correlation has been found between VAM and soil pH particular soil pH favour particular VAM species This is important because it significantly affects the effectiveness of mycorrhizal fungi (Mossae et al 1981 Hayman 1982 Arines 1990) These papers also revealed that soil pH by charging the solubility status of plant nutrients can indirectly influence VAM formation and/or activity

Krishna and Dart (1984) reported that there was no effect for mycorrhizal inoculation on P fertilization in unsterile soil Negave and Roneadori (1985) reported that in all studies with citrus the mycorrhizal growth response was greatest at low fertility Singh and Singh (1986) reported that lentil responded well to Glomus fasciculatum in the P deficient as well as in the soil ammended with 40 mg P kg^{-1} soil Schubert and Hayman (1986) reported that mycorrhizal infection was usually decreased by increasing additions of P but the rate of root colonisation and infection plateau varied with different endophytes Singh and Singh (1986) reported that mycorrhizae proved effective in enhancing the activity of Rhizobium and in improving growth nodulation N fixation P uptake and yield of lentil It was concluded that P application upto 80 mg P kg ^{1} soil did not inhibit VAM infection and that Glomus fasciculatum inoculation may increase P utilization of lentil cultivars grown on a P deficient soil Rao et al (1986) reported that growth and P uptake of sorghum on a nonsterile P deficient soil were improved by soil inoculation with VAM fungi Lin and Fox (1986) reported that mycorrhizal banana roots were ineffective extractants of P from oxisol A maximum beneficial effect of mycorrhiza were obtained when Idaho rock was the P source Based on the P uptake by mycorrhizal banana the effectiveness of various P sources were in the order of oxisol Idaho rock phosphate Florida rock phosphate North carolina rock phsophate and super phosphate

A great deal of work recently reviewed (Harley and Smith 1983 Smith and Gianinazzi Pearson 1988) show that VAM enhance plant growth as a result of improved mineral nutrition of the host plant and this has been confirmed with the use of isotopic tracers Mycorrhizal plants are not only large but also usually have an increased concentration and/or content of P compared to non mycorrhizal controls The VAM actually increased the rates of growth of plants and increase the partitioning of phytomass between shoot and root This is related to the enhanced nutrient uptake by fungal activity This is followed by the nutrient translocation to the shoot which increases the utilization of photosynthates in the areal part of the plant Therefore relatively less of the products of photosynthesis are allocated to the root (Barea 1991)

The effect of VAM fungi in increasing the nutrient availability in soils was reported by Subba Rao (1982) Similar results were also obtained by Morita and Kon sln (1989) in the tea plantations and Miranda et al (1989) in sorghum plants

Hung et al (1990) reported that inoculation of VAM increased the availability of P for sweet potato and Napier grass

Syvertsen and Graham (1990) reported that well established VAM colonisation does not affect net gas exchange of citrus plants that are comparable in size growth rate and nutritional status with non mycorrhizal plants Barea (1991) reported that the development of an extensive net work of extra metricial hyphae by the Vesicular Arbuscular Mycorrhizae (VAM) in soil surrounding the root together with the capacity of these hyphae for nutrient absorption and transport to the cortical root cells which indicated that VAM modified the nutrient uptake properties of the root system Actually it is widely accepted that VAM plays a recognised role in nutrient cycling in the ecosystem Vivekanandan and Fixen (1991) reported that P uptake in the check plots was highest in the ridge plant corn-soybean system and lowest in the mould board plough corn fallow system Generally VAM colonisation rates were significantly higher in the ridge plant system than in the mould board plough system

2 5 Crop response to phosphorus application with special reference to legumes

2 5 1 General crop responses to available soil phosphorus

Chahil and Virmani (1973) reported that groundnuts are shown to absorb 72% of their P through roots and 28% through fruitining organs Greatest contribution to rice production is made by the P which has been absorbed upto flowering (Mahapatra and Yaduraja, 1981) In maize P accumulation can be particularly high during silking and in sorghum after a slow start P uptake rates can be high right upto maturity (Tandon 1987)

During early stages of growth P accumulation can proceed faster than dry matter production indicating the need for higher P concentration for active vegetative growth and root proliferation which is to follow P uptake increases as the crop grows and in several cases has been found to be quite in the period preceeding maturity (Govil and Prasad 1974 Roy and Wright 1974 Jain 1981 Nagaraj and Kumar 1983)

Typically a soil analysing available P less than 23 kg P_2O_5 ha $^{-1}$ is categorised as low in available P (deficient) between 23 and 50 55 as medium and over 50 55 as high in P for field crops (Tandon 1987)

In India the method suggested by Bray and Kurtz (1945) has been suitable for estimating available P status of acidic soils P application rates based on soil testing for targeted crop yields proved distinctly superior to general recommendations as they resulted in a saving of not less than 20% The residual effect of P the differential availability of P during cold and warm seasons the ability of different crops to use soil and fertilizer P and the different P fractions are some of the important criteria in the selection of suitable crops and P management in crop rotations A basis for calculating P fertilizer schedules for which cropping sequences have been adopted by predicting post harvest soil test values (ICRISAT 1988)

Soil testing is an essential prerequisite for taking measures for increasing fertilizer use efficiency Soil testing service in India started in 1956 57 The fertilizer application for targeted yields approach ensures balanced nutrition Crops differ in the requirement of P to produce a unit quantity of grain Oilseeds need more pulses less and cereals still less The average requirements are calcualted as 0 98 kg P 100 kg $^{-1}$ seed for oil seed crops 0 70 kg P 100 kg $^{-1}$ for pulses and 0 44 kg P 100 kg $^{-1}$ grain for cereals The nutrient requirement is a crop characteristic and as such does not depent on the soil type Crop species and varieties also differ significantly in th ir ability to use both available and applied P Except for long duration crops the percentage contribution of P from the soil was around 50% the average value being 48 2% for cereals 50 9% for pulses and 50 0% for oil seeds For long duration crops it was 193 5 % for sugarcane 181 0 % for banana and 90 0% for cotton The P contribution from fertilizer was around 25% for cereals pulses and oilseed crops Fixation of added P in soil which may reach a level as high as 81 0% is one of the mam criteria limiting more efficient use of fertilizer P (ICRISAT 1988)

Al Mustafa (1988) reported that calcium bound P (Ca P) appeared to be of little importance as a short term source of P for corn plants although it constituted upto 86% of the total P in the soil Saad et al (1988) reported that wheat yield response was highest when soil content reaches an average value of 13 ppm Russell et al (1989) reported that in bird food trefoil tissue concentration of P and K were best related to soil solution concentration. Smyth and Cravo (1990) reported that fertilizer P required to raise the initial mehlich soil P to critical levels were 41 to 60 kg P ha^{1} for corn and cowpea respectively Ivarson (1990) reported that during a pot trial with the grass there was a large decrease in the resin P fractions for a long term P fertility trial

2 5.2 Response of legumes to phosphorus application

2 5 2 1 Cowpea

Ezedinma (1965) found that application of P_2O_5 at 40 ka ha^{1} along with 20kg N ha^{1} significantly increased plant height number of leaves per plant and shoot dry matter of cowpea Nair (1966) found that phosphorus applied at 0 to 90 kg P_2O_5 ha^{1} did not influence the height of cowpea Singh et al (1968) observed that application of phsophorus as super phosphate increased the yield of tops and roots in cowpea Garg et al (1970) found that plant height number of branches per plant number of leaves per plant and dry weight per plant increased with increasing levels of phosphorus upto 111 kg P_2O_5 ha^{1} resulting in a higher fodder yield of cowpea Fageria and Bajpai (1971) found that higher and lower levels of phosphorus application retarded plant height of cowepa significantly Rao and Patel (1975) found that application of 44 8 kg P_2O_5 ha^{1} to cowpea increased the dry matter production significantly over no P control Tripathi et al (1977) found that application of 60 Kg P_2O_5 ha^{1} resulted in significantly higher yield of dry matter in cowpea

Yield response of cowpea to P application has been reported by many workers Salam et al (1968) observed that yields of cowpea were significantly increased by P application Mata and Sanchez (1970) found that cowpea grain yield increased with incremental rates of P upto 120 Kg P_2O_5 ha^{1} Pande (1972) found in studies with green gram that grain yield was increased significantly by the application of 90 Kg P_2O_5 ha^{1} applied but not statistically significant Kurdikeri et al (1973) found that in rainfed areas application of 44 Kg P_2O_5 ha^{1} along with 11 Kg N ha^{1} resulted in optimum grain yield of cowpea Malik (1974) observed that P application did not have any significant effect on the grain yield of cowpea Rao and Patel (1975) observed in cowpea experiment in a loamy sand that application of 44 8 Kg P_2O_5 ha^{1} significantly increased the seed yield over no P control Nangju (1976) reported that seed yield of cowpea increased singificantly by the application of P Tripathi et al (1977) observed that optimum economic rate of P application ranged between 33 4 to 46 4 Kg P_2O_5 ha^{1} for different cultivars of cowpea Viswanathan et al (1978) reported that the optimum P requirement for cowpea was 37 37 Kg P_2O_5 ha^{1} while the optimum economic dose was 23 55 Kg ha^{1} (Jayaram and Ramiah (1980) observed response to P only upto 27 Kg P_2O_5 ha^{1})

2 5 2 2 **Chickpea**

In chickpea in general 20 to 30% increase in grain yield has been observed with the application of P ranging from 20 to 45 Kg P_2O_5 ha^{-1} depending upon the soil test values (Prasad et al, 1968 Chaudhury et al 1971 Sinha 1972 Sawhney et al 1975) Chaudhury et al (1975) reported that in chickpea applied P was found to have a significant effect on nodulation and it was reflected with increase n dry weight of plants On the basis of a number of field experiments on cultivators field in Punjab Rana and Singh (1979) recommended 20 Kg P_2O_5 ha^{-1} for optimum yield Suryawanshi and Chaudhary (1979) and Devarajan et al (1980) reported optimum response to P application upto 22 to 25 Kg P_2O_5 ha^{-1} only In several studies with chickpea (Kalsi et al 1982 Kapur et al 1982) depending upon soil significant responses to P with doses varying from 22 to 66 Kg P_2O_5 ha^{-1} have been reported

2 5 2 3 **Lentil**

In lentil with the application of 25,50 and 75 Kg P_2O_5 ha^{-1} along with basal 25 Kg N ha^{-1} Sharma and Chaudhury (1971) obtained a grain yield of 34 37 and 40 q ha^{-1} Panwar et al (1977) reported an optimum dose of 50 Kg P_2O_5 ha^{-1} above which they observed a reduction in grain yield Upadhyaya and Sharma (1977) reported no response to application of of lentil on a soil testing 17 Kg P ha^{-1} which can be considered as an adequate level of soil P

2 5 2 4 **Green gram**

In a number of studies it has been reported that application of P varying from 40 to 80 Kg P_2O_5 ha^{-1} is required to increase significantly the grain yield of gr en gram (Deshpande and Bathkal 1965 Panwar and Singh 1975 Ravankar and Bhade 1975 Singh et al 1975) Rao and Bhardwaj (1980) reported that greengram greatly benefited from P application to the preceeding cereal crop and as such there may not be any need for fresh application of P

2 5 2 5 **Pigeon pea**

Chaudhury and Bhatia (1971) consistently obtained higher yield of pigeon pea with graded levels of applied P and were able to produce three fold yield with 100 Kg P_2O_5 ha [1] Rathi et al (1974) found that application of 80 Kg P_2O_5 ha [1] was significantly superior to 40 Kg P_2O_5 ha [1] which in turn proved superior to unfertilized control A good crop of pigeon pea can remove as much as 30 Kg P_2O_5 ha [1] (Saxena and Yadav 1975) In a field experiment with pigeon pea in rainfed areas first increment of 33 Kg P_2O_5 ha [1] increased yield by 50% and second increment further resulted in a similar increase However studies from Punjab (Kaul and Sekhon 1975) and Uttar Pradesh (Rathi and Tripathi 1978) have shown that pigeon pea responds upto 40 Kg P_2O_5 ha [1] Singh and Prasad (1975) reported highest grain yield with the application of 100 Kg P_2O_5 ha [1] on a sandy loam soil low in Olsen s extractable P Rao and Bhardwaj (1981) studied the direct and residual effects of P application in Pigeon pea wheat rotation They observed that pigeon pea effectively utilized P that was residual inthe soil from the previous crop when supplemented by a direct application of 18 Kg P_2O_5 ha [1] However in studies on direct residual and cumulative P application to pigeon pea in pigeon pea wheat rotation they observed that pigeon pea effectively utilized P that was residual in the soil from the previous crop when supplemented bv a direct application of 18 Kg P_2O_5 ha [1] However in studies on direct residual and cumulative P application to pigeon pea in pigeon pea wheat rotation Pasricha et al (1987) have observed that there is no need of P application when preceeding wheat was given recommended dose of 60 Kg P_2O_5 ha [1]

2 5 2 6 Soybean

In a field trial with soybean Kesavan and Morachan (1973) found that optimum dose of P could vary from 50 to 100 Kg P_2O_5 ha^{1} depending upon the crop variety Singh and Saxena (1973) proposed optimum dose of 52 2 kg P ha^{1} for cv B agg Aggarwal and Narang (1975) found that soybean cv Bragg responded to P application upto 80 Kg P_2O_5 ha^{1} and 20 kg N ha^{1} Roy and Mishra (1975) found that in North Bihar dressing of P required for obtaining maximum yield of 16 to 17 q ha^{1} ranged from 30 to 38 Kg P_2O_5 ha^{1} and the calculated most profitable dose was 32 Kg P_2O_5 ha^{1} Rana and Chand (1977) obtained maximum yield with 80 Kg P_2O_5 ha^{1} Hampiah and Sinha (1979) reported responses of soybean to P application upto 60 Kg P_2O_5 ha^{1} In Punjab soybean responded significantly to P upto 80 Kg P_2O_5 ha^{1} (Aulakh et al, 1990)

2 5 2 7 Black gram

In black gram adequate application or P (40 Kg P_2O_5 ha^{1}) not only increased yield but also helped in increasing root nodulation and consequently nitrogen content of grains (Sahu 1973 Kadwe and Bhade 1973) Rajendran et al (1974a) observed a yield increase with P application of 90 Kg P_2O_5 ha^{1} Subsequently Rajendran et al (1974b) observed that with increased application of P the extractable P in the soil increased upto flowering stage after which it started declining perhaps due to rapid removal by plant and its fixation in the soil Namdeo and Ghatge (1976) reported that adequate application of P (40 Kg P_2O_5 ha^{1}) not only increased yield but also helped in increasing root nodulation and consequently nitrogen content of grains in black gram Panwar et al (1977) reported a linear increase in the yield upto a level of 60 Kg P_2O_5 ha^{1} above which (90 Kg P_2O_5 ha^{1}) there was a decline in the response Bahl et al (1988) reported that as P is essential in the mechanism of N fixation and for growth of nodule bacteria its application to black gram with or without inoculation has also been reported to increase N status of soils

2 5.2 8 Fieldpea

In field pea for some submotaneous soils of Uttar Pradesh 75 Kg P_2O_5 ha^{-1} has been found to be an optimum dose (Singh and Tiwari 1985) Pasricha et al (1987) reported that field pea responded upto 60 Kg P_2O_5 ha^{-1} They also reported that in irrigated areas the yields ranged from 20 to 39 q ha^{-1} with a response of 4 4 and 3 7 q ha^{-1} at 30 and 60 Kg P_2O_5 ha^{-1}

2 5.2 9 Groundnut

Shelke and Khuspe (1980) observed that dry matter production and P uptake by groundnut was higher with 17 5 Kg P_2O_5 ha^{-1} Basha and Rao (1980) reported that in 30 days old groundnut plants P deficiency decreased with root length and number of leaves Patel et al (1981) found that higher levels of P significantly increased the top and root length of groundnut Singh and Ahuja (1985) reported that increasing the rate of P from 30 to 90 Kg P_2O_5 ha^{-1} significantly increased the growth of groundnut Sabale and Khuspe (1986) observed that in groundnut plant height number of leaves and branches and dry weight per plant were increased with increased rate of P from 0 to 60 Kg P_2O_5 ha^{-1} Juan et al (1986) reported that P application increased the plant height and dry matter yield of groundnut

2 5.2 10 Clover

Gourley et al (1993) reported that there were significant differences in shoot and drymass and P accumulation response curves among cultivars of white clover Differences in herbage yield and phosphorus accumulation were associated with larger root system but there were no evidence of greater efficiency of P uptake in plants

The presently available literature on phosphorus is mainly centred around ~~for~~ finding out an economic dose of fertilizer for various crops and soils However few attempts ave also been made for making available the soil phosphorus pool for the crops bei ig cultivated These literatures are not adequate for drawing out suitable recommendations under the existing conditions of crops and environments More attention is required for finding out practices that are capable of utilizing the native and fer lizer phosphorus more effectively under the existing agroclimatic conditions

Materials and Methods

3. MATERIALS AND METHODS

W th a vıew to evaluate the effect of chemıcal and bıo agents on phosphorus dynamıcs ın the red loam soıls of Southern Kerala three sets of field experıments were carrıed out sımultaneously for two seasons fırst experıment for evaluatıng the chemıcal desorbıng anıons second experıment for evaluatıng the effect of synthetıc chelates and the thırd experıment for evaluatıng the effect of mıcrobıal agents for testıng the avaılabılıty of natıve and added phosphorus ın the soıl

The tıtles of the experıments are (1) Effect of phosphorus desorbıng anıons (2) Effect of synthetıc chelates as soıl amendements and (3) Effect of mıcrobıal agents

The detaıls of the experımental sıte season weather condıtıons materıals and methods adopted are presented ın thıs chapter

3 1 Lxperımental sıte

The experıments were carrıed out at the ınstructıonal farm attached to the College of Agrıculture Vellayanı The farm ıs located at 8^0N latıtude and enjoys a humıd tropıcal clımate The altıtude of the sıte ıs 29 metres above mean sea level

3 2 Soıl

The soıl of the experımental field was sandy clay loam (Red loam) ın texture (famıly oxısol) The physıco chemıcal propertıes of the experımental sıtes of the three experıments are gıven ın Tables 1 2 and 3 respectıvely

Table 1 Physico chemical characteristics in the surface soils of the experimental sites for the Experiment No 1

	So l characteristics	Season 1	Season II
1	Bulk density (g cm ^{3})	1 17	1 19
2	Water holding capacity (%)	31 16	30 68
3	Mean weight diameter (mm)	1 06	0 91
4	C E C (me 100 g ^{1})	4 36	4 35
5	pH	5 11	5 09
6	N content (%)	0 122	0 124
7	P content (ppm)	358	379
8	K content (%)	0 103	0 102
9	P f xing capac ty (µg P g ^{1})	28 6	28 5
10	Organic matter content (%)	2 34	2 24
11	Available P content (mg P kg ^{1})	7 21	6 88
12	Available K conte t (ppm)	231	268
13	Point of Zero Charge (PZC)	5 10	5 10

Table 2 Physico chemical characteristics in the surface soils of the experimental sites for the Experiment No 2

	Soil characteristics	Season I	Seson II
1	Bulk density (g cm ^{3})	1 21	1 23
2	Water holding capacity (%)	28 18	31 14
3	Mean weight diameter (mm)	0 90	0 79
4	C E C (me 100 g ^{1})	4 39	4 38
5	pH	5 12	5 10
6	N content (%)	0 122	0 123
7	P content (ppm)	371	376
8	K content (%)	0 109	0 105
9	P fixing capacity (µg Pg ^{1})	28 7	28 4
10	Organic matter content (%)	2 19	2 22
11	Available P conte t (mg P kg ^{1})	7 29	7 16
12	Available K content (ppm)	238	233
13	Point of Zero Charge (PZC)	5 10	5 10

Table 3 Physico chemical characteristics in the surface soils of the experimental sites for the Experiment No.3

	Soil character stics	Season I	Seson II
1	Bulk density (g cm ^{3})	1 22	1 24
2	Water hold ng capacity (%)	31 08	28 14
3	Mean weight diameter (mm)	0 88	0 77
4	C E C (me 100 g ^{1})	4 41	4 40
5	pH	5 12	5 11
6	N content (%)	0 120	0 121
7	P content (ppm)	352	369
8	K content (%)	0 089	0 088
9	P fixing capac ty (µg Pg ^{1})	28 6	28 7
10	Organic matter content (%)	2 18	2 16
11	Available P content (mg P kg ^{1})	8 16	7 98
12	Available K content (ppm)	229	237
13	Point of zero charge (PZC)	5 11	5 11
14	Native mycorrhiza spore population (number per 100 g soil)	12	19

3.3 Nature and cropping history of the fields

The experimental fields were cultivated with bulk cowpea immediately prior to the start of each experiment

3 4 Season

The first season trial of all the three experiments were conducted during the period from 1 6 1992 to 31 8 1992 and the second season trials from 3 10 1992 to 23 12 1992

3 5 Weather conditions

The weather conditions during the period were normal with adequate rainfall temperature and sunshine The weather conditions which prevailed during the cropping period are given in Fig 1 and Appendix I & II

3 6 Materials

3 6 1 Planting material and variety

The test crop was cowpea var C 152 for all the three experiments It is one of th most popular varieties cultivated throughout the country It is not season bound and can be cultivated during any part of the year provided there is adequate rainfall

3 6 2 Fertilizers

The fertilizers used for the crop are

Urea	(46%N)
Mussoriephos	(20% Total P_2O_5 and 7% available P_2O_5)
Muriate of Potash	(60% K_2O)

The recommended fertilizer dose for the crop was 20 30 10 kg ha of N P_2O_5

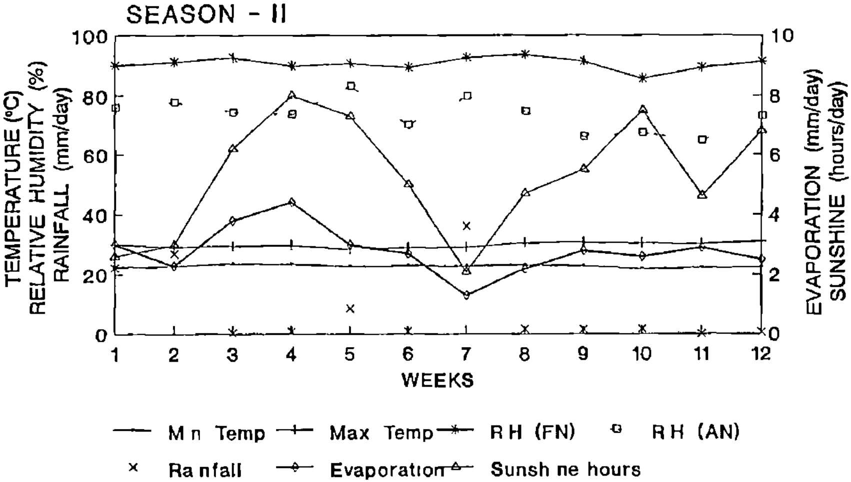
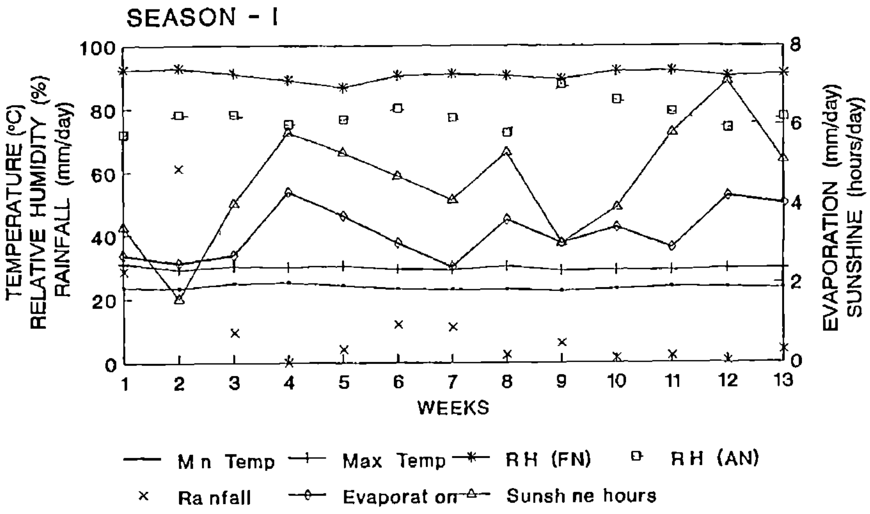


Fig 1 Meterological data for the experimental periods (two seasons)


SEASON - I
TEMPERATURE (°C)
RELATIVE HUMIDITY (%)
RAINFALL (mm/day)
EVAPORATION (mm/day)
SUNSHINE (hours/day)
100
80
60
40
20
0
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
WEEKS
M n Temp
Max Temp
R H (FN)
R H (AN)
Ra nfall
Evaporat on
Sunsh ne hours

and K_2O respectively (Kerala Agricultural University 1989) There were varying rates of phosphorus in all the three trials as per treatments Half the quantity of nitrogen whole of P_2O_5 and K_2O were applied at the time of final land preparation The remaining nitrogen was applied 20 days after sowing

3 7 1 Methods

3 7 1 Design and layout of the experiments

3 7 1 1 Experiment No 1 Effect of phosphorus desorbing anions

The experiment was laid out in factorial Randomized Block Design with three replications

Treatments

T_1 No phosphorus + no anions

T_2 No phosphorus + $Ca(OH)_2$ @ 400 kg ha^{-1}

T_3 No phosphorus + $CaCO_3$ @ 400 kg ha^{-1}

T_4 No phosphorus + $CaSiO_3$ @ 400 kg ha^{-1}

T_5 50% recommended P + no anions

T_6 50% recommended P + $Ca(OH)_2$ @ 400 kg ha^{-1}

T_7 50% recommended P + $CaCO_3$ @ 400 kg ha^{-1}

T_8 50% recommended P + $CaSiO_3$ @ 400 kg ha^{-1}

T_9 100% recommended P + no anions

T_{10} 100% recommended P + $Ca(OH)_2$ @ 400 kg ha^{-1}

T_{11} 100% recommended P + $CaCO_3$ @ 400 kg ha^{-1}

T_{12} 100% recommended P + $CaSiO_3$ @ 400 kg ha^{-1}

Design RBD

Replication 3

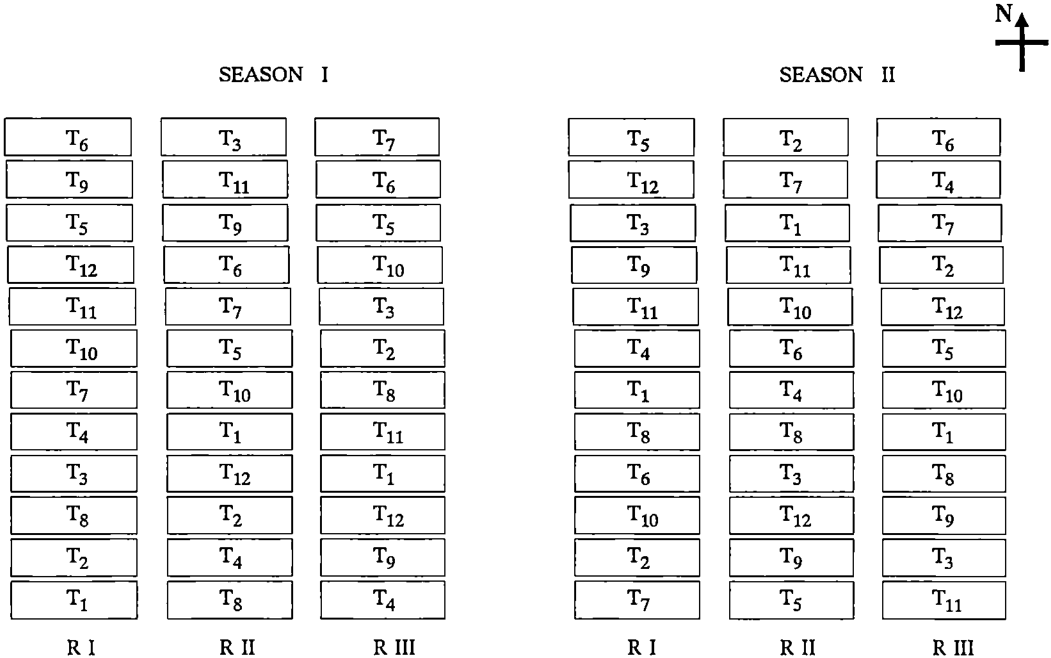


Fig 2 Layout plan of the Experiment No 1 (two seasons)

Plot Size

Gross 5m x 4 05m

Net 4 m x 3 15m

Spacing 25 cm x 15 cm

Seasons two

3 7 1.2 Experiment No 2 Effect of synthetic chelates as soil amendments

The experiment was laid out in factorial Random zed Block Design with three replications

Treatments

T_1 No phosphorus + no chelating agent

T_2 No phosphorus + Ethylene Diamine Tetra Acetic acid (EDTA) at conc of 0 0001 M

T_3 No phosphorus + Diethylene Triamine Penta Acetic acid (DTPA) at conc of 0 0001M

T_4 50% recommended P + no chelating agent

T_5 50% recommended P + Ethylene Diamine Tetra Acetic acid (EDTA) at conc of 0 0001 M

T_6 50% recommended P + Diethylene Triamine Penta Acetic acid (DTPA) at conc of 0 0001 M

T_7 100% recommended P + no chelating agent

T_8 100% recommended P + Ethylene Diamine Tetra Acetic acid (EDTA) at conc of 0 0001 M

T_9 100% recommended P + Diethylene Triamine Penta Acetic acid (DTPA) at conc of 0 0001 M

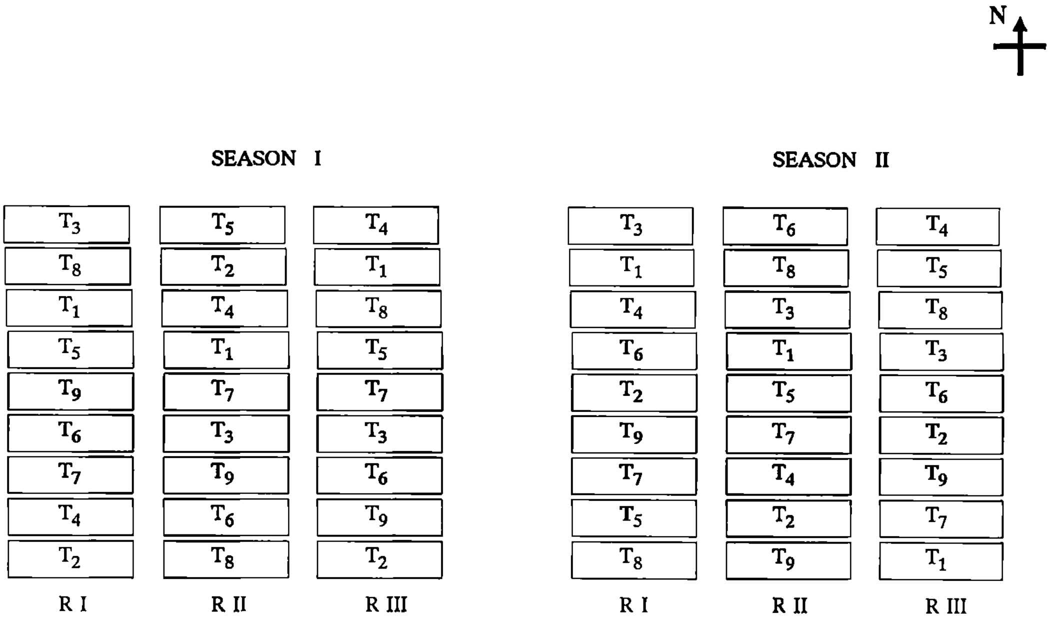


Fig 3 Layout plan of the Experiment No 2 (two seasons)

Design RBD

Replication 3

Plot size

Gross 5m x 4 05m

Net 4m x 3 15m

Spacing 25 cm x 15 cm

Seasons Two

3 7 1.3 Experiment No.3 Effect of microbiological agents

Treatments

T_1 No phosphorus + no microbes

T_2 No phosphorus + Vesicular Arbuscular Mycorrhiza (VAM) inoculation

T_3 No phosphorus + Phosphobacterin (PB) inoculation

T_4 No phosphorus + Vesicular Arbuscular Mycorrhiza (VAM) + Phosphobacterm (PB) inoculations

T_5 50% recommended P + no microbes

T_6 50% recommended P + Vesicular Arbuscular Mycorrhiza (VAM) inoculation)

T_7 50% recommended P + Phosphobacterin (PB) inoculation

T_8 50% recommended P + Vesicular Arbuscular Mycorrhiza (VAM) + Phosphobacterin (PB) inoculations

T_9 100% recommended P + no microbes

T_{10} 100% recommended P + Vesicular Arbuscular Mycorrhiza (VAM) inoculation

T_{11} 100% recommended P + Phosphobacterin (PB) inoculation

T_{12} 100% recommended P + Vesicular Arbuscular Mycorrhiza (VAM) + Phosphobacterin (PB) inoculations

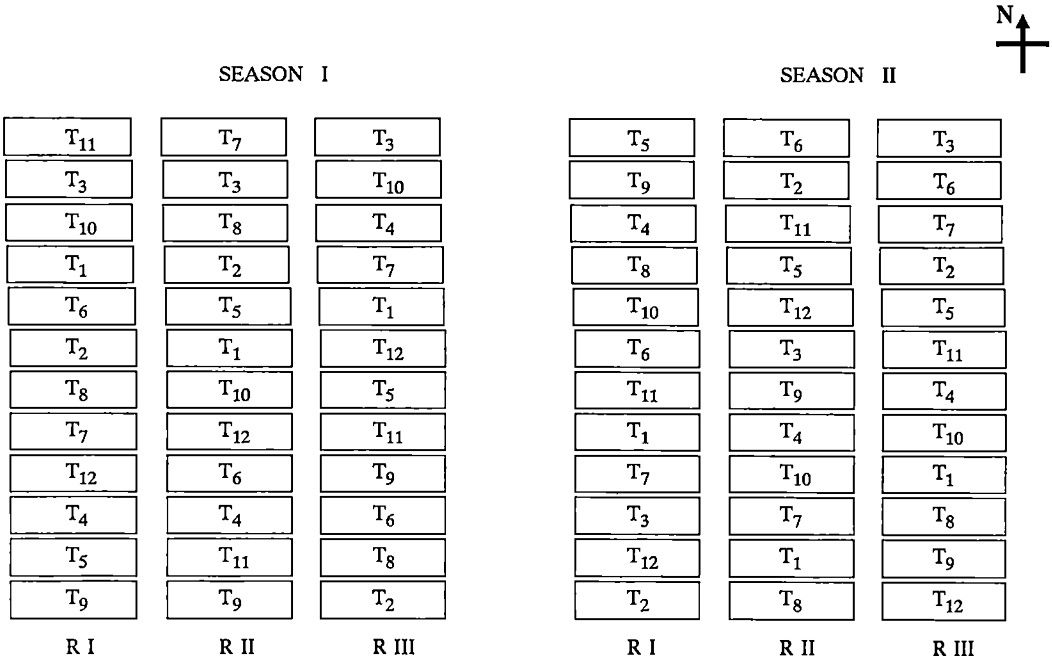


Fig 4 Layout plan of the Experiment No 3 (two seasons)

Design	R B D
Replication	3
Plot size	
Gross	5 m x 4 05m
Net	4 m x 3 15 m
Spacing	25 cm x 15 cm
Seasons	Two

3 7 2 Treatment applications

3 7 2 1 Phosphorus application

Phosphorus was applied basally as Mussorie rock phosphate (20% P_5O_5) at the time of final land preparation as per the treatment requirements for all three experiments

3 7 2 2 Experiment No 1

Application of anions

The hydroxide anion was applied basally at the time of final land preparation as Calcium Hydroxide @ 400 Kg ha ^{1} The carbonate anion was applied basally at the time of final land preparation as Calcium Carbonate @ 400 kg ha ^{1} The silicate anion was applied basally at the time of final preparation of land as Calcium silicate @ 400 kg ha ^{1}

3 7 2 3 Experiment No 2

Chelate application

The experimental chelates (Ethylene Diamine Tetra Acetic acid and Diethylene Triamine Penta Acetic acid) solutions at concentration of 0 0001 M were applied to soil @ 50 ml per plant 10 days after germination and repeated at 10 days interval for a total of five applications as per the method followed by Jayachandran et al (1989)

3 7 2 4 **Experiment No.3**

Application of microbiological agents

Vesicular Arbusular Mycorrhiza (VAM) species Glomus fasciculatum field culture prepared with guinea grass were applied insitu to the seed hole at the planting time @ 10 15 g per hole Phosphobacterin culture was treated with seeds @ 500 g ha^{-1} of seeds used and planted

3 8 Plant Protection

Plant protection measures were taken as per the package of practices recommendations of Kerala Agricultural University as and when required

3 9 Observations

3 9 1 Leaf Weight Ratio (LWR)

Leaf Weight Ratio was determined as per the method followed by Kevt et al (1971) and Evans (1972)

3 9 2 Leaf Area Ratio (LAR)

Leaf Area Ratio was determined as per the method followed by Radford (1967) and Evans (1972)

3 9 3 Leaf Area Index (LAI)

Leaf Area Index (LAI) was determined by the formula

3 9 9 Grain yield

Grain yield obtained from the net plots were sundried and weighed converted to hectare basis and expressed as kg ha ^{1}

3 9 10 Haulms yield

The bhusa yield obtained from the net plots were sundried and weighed and converted to hectare basis and expressed as kg ha ^{1}

3 9 11 Nitrogen uptake

Nitrogen content of plant samples seed sample and haulms were determined by microkjeldahl s method as reported by Jackson (1958) and modified by Tandon (1993)

3 9 12 Phosphorus uptake

The phosphorus content of plant samples seed samples and haulms were determined by vanadomolydbate yellow colour method as reported by Jackson (1958) and modified by Tandon (1993)

3 9 13 Harvest Index

Harvest Index was found out as the ratio of the seed yield to the total dry matter xpressed as percentage

3 9 14 Protein content of grains

Nitrogen content of grains as previously determined was multiplied by 6 25 to get the protein percentage of grains

3 9 15 <u>Physical properties of the soil</u>

3 9 15 1 Bulk density

Soil samples were collected by core samples dried in an oven at 106°C and weighed and the bulk density is calculated

3 9 15 2 Water holding capacity

Water holding capacity of soil was determined by Keen Razchkovski box method

3 9 15.3 Aggregation of soil samples

Aggregation of soil sample was determined by wet sieve analysis as reported by Gupta and Dakshinamurti (1980) and expressed as mean weight diameter

3 9 16 <u>Chemical properties of the soil</u>

3 9 16 1 Cation Exchange Capacity (C E C)

Cation Exchange Capacity of the soil was determined as per the method suggested by Hesse (1971)

3 9 16 2 Soil reaction (pH)

The pH of the soil was determined as per method followed by Hesse (1971)

3 9 16 3 Total nitrogen

Total Nitrogen of the soil was determined by macrokjeldal s method as reported by Jackson (1958)

3 9 16 4 Total phosphorus

Total phosphorus content of the soil was determined by Vanadomolybdate yellow colour method in nitric acid system (Jackson 1958)

3 9 16 5 Phosphorus fixing capacity

Phosphorus fixing capacity of the soil was determined as per method followed by Hesse (1971)

3 9 16 6 Organic matter content of the soil

Organic matter content of the soil was determined by the method reported by Tandon (1993)

3 9 16 7 Available phosphorus content of the soil

Available phosphorous content of the soil was determined by the procedure suggested by Jackson (1958)

3 9 16 8 Fractionation of soil phosphorus

P fractions of the soil were determined by the method of Petersen and Corey (1966) The organic P was calculated from the difference between total P and total mineral P as suggested by Mehta et al (1954)

Results

4. RESULTS

The results obtained from the three field experiments were statistically analysed and presented in this chapter

4 1 Experiment No 1 (Effect of phosphorus desorbing anions)

4 1 1 Physical properties of the soil

The physical properties of the soil are given in Table 4

4 1 1 1 Bulk density of the soil

During season 1 the bulk density of the soil was 1 17 g cm ^{3} before sowing and the treatment differences were not significant after harvest Therefore there was no response for either phosphate or anions

In the season II the bulk density of the soil was 1 19 before sowing and that there was no response between treatments after harvest

4 1 1 2 Water holding capaicty

During the season I the water holding capacity before sowing was 31 16% and at harvest there was no responses between treatments or factors

During season II the water holding capacity before sowing was 26 16% and after harvest there was statistical differences between treatments The lowest value of 28 54% was recorded by T_8 whereas the highest value of 31 51% was recorded by T_{11} On factorial analysis when 50% phosphorus recorded the lowest value of 29 42% the highest value of 30 57% was recorded by 100% recommended phsophorus which was statistically significant But there was no response between the anions

Table 4 Physical properties of the soil in experiment No 1

Physical properties	Bulk density (g cm $^{-3}$)		Water holding capacity (%)		Mean weight diameter of aggregates from wet sieving analysis (mm)	
Experiment season	Season I	Season II	Season I	Season II	Season I	Season II
a Before sowing	1 17	1 19	31 16	26 16	1 06	0 91
b After harvest						
Treatment No						
T_1	1 32	1 29	32 93	29 77	1 08	0 99
T_2	1 32	1 32	33 58	29 86	1 13	0 98
T_3	1 30	1 29	33 06	29 39	1 01	0 99
T_4	1 30	1 33	32 19	29 33	1 00	1 12
T_5	1 33	1 33	32 23	30 67	1 00	1 06
T_6	1 33	1 30	32 19	28 72	0 96	1 08
T_7	1 33	1 31	33 16	29 75	0 94	1 11
T_8	1 31	1 32	34 09	28 54	0 93	1 13
T_9	1 31	1 30	32 75	28 82	0 92	0 98
T_{10}	1 34	1 32	32 28	30 74	0 99	1 06
T_{11}	1 33	1 31	32 61	31 51	1 04	1 08
T_{12}	1 31	1 31	32 69	31 22	0 99	1 03
SEm $\pm$	0 017	0 018	0 739	0 517	0 036	0 033
C D (0 05)		–		1 515	0 106	0 097
FACTORS						
A Fert P						
1 No.P	1 31	1 31	32 94	29 59	1 06	1 02
2 50%P	1 32	1 31	32 92	29 42	0 96	1 10
3 100%P	1 32	1 31	32 58	30 57	0 99	1 04
C D (0 05)	–		–	0 758	0 053	0 049
B Anions						
1 No anions	1 32	1 31	32 64	29 75	1 00	1 01
2 OH	1 33	1 31	32 68	29 77	1 02	1 04
3 CO_3	1 32	1 30	32 94	30 22	1 00	1 06
4 SiO_3	1 31	1 32	32 99	29 70	0 98	1 09
C D (0 05)		–	–	–	–	0 056

Note In those places where C D is not given the F test is not significant at 5% level

4 1 1.3 Mean wieght diameter of aggregates from wet sieving analysis

The mean weight diameter of aggregates before sowing was 1 06mm and that the treatment differences were significant after harvest The lowest value of 0 92 mm was recorded by T_9 while the highest value of 1 13 mm was recorded in T_2 On factorial analysis when the phosphorus levels were significant there was no response between the anions Among the phosphorus levels 50% phosphorus recorded the lowest value of 0 96 mm and no phosphorus recorded the highest value of 1 06 mm

During Season II mean weight diameter before sowing was 0 91mm and the treatment differences were significant after harvest The lowest value of 0 98 mm was recorded in both T_2 and T_9 the highest value of 1 13 mm was recorded by T_8 On factorial analysis no phosphorus recorded the lowest value of 1 02mm where as 50% phosphorus recorded the highest significant value of 1 10mm No anions recorded the lowest value of 1 01 mm where as silicate anion recorded the highest value of 1 09 mm which was significant

4 1 2 Chemical properties of the soil

The data on chemical properties of the soil are given in Table 5

4 1 2 1 Cation Exchange Capacity (C E C) of the soil

During season I a C E C value of 4 21 me 100 g^{1} was recorded before sowing After harvest the treatment differences were not significant and as such there was no significant response between levels of phosphorus and the various anions

Table 5 **Chemical properties of the soil in experiment No 1**

Chemical Characteristics	CEC (me/100 g)			pH			Total Nitrogen (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
a Before sowing	4 21	4 27	4 24	5 11	5 09	5 10	0 122	0 124	0 123
b After harvest Treatment No									
T_1	4 32	4 32	4 32	5 12	5 11	5 12	0 124	0 126	0 125
T_2	4 45	4 28	4 37	5 17	5 15	5 16	0 129	0 132	0 131
T_3	4 28	4 29	4 28	5 18	5 15	5 17	0 132	0 129	0 131
T_4	4 32	4 50	4 41	5 15	5 16	5 16	0 132	0 136	0 134
T_5	4 37	4 48	4 42	5 14	5 12	5 13	0 126	0 126	0 126
T_6	4 47	4 45	4 46	5 18	5 15	5 17	0 133	0 133	0 133
T_7	4 38	4 44	4 41	5 18	5 15	5 17	0 131	0 134	0 133
T_8	4 36	4 40	4 38	5 18	5 15	5 17	0 132	0 131	0 132
T_9	4 32	4 39	4 35	5 14	5 13	5 13	0 124	0 126	0 125
T_{10}	4 45	4 39	4 42	5 17	5 16	5 16	0 132	0 130	0 131
T_{11}	4 37	4 38	4 38	5 18	5 15	5 17	0 133	0 133	0 133
T_{12}	4 38	4 39	4 39	5 18	5 15	5 17	0 131	0 133	0 132
SEm$\pm$	0 107	0 090	0 070	0 003	0 004	0 003	0 0024	0 0018	0 0015
C D (0 05)				0 010	0 013	0 008	0 0071	0 0052	0 0043
FACTORS									
A. Fert P									
1 No P	4.34	4 35	4 35	5 16	5 14	5 15	0 129	0 131	0 130
2 50%P	4 40	4 44	4 42	5 17	5 14	5 16	0 131	0 131	0 131
3 100%P	4 38	4 39	4 39	5 17	5 15	5 16	0 130	0 131	0 130
C D (0 05)				0 005		0 004			
B Anions									
1 No anions	4 34	4 40	4 37	5 13	5 12	5 13	0 125	0 126	0 125
2 OH	4 46	4 37	4 42	5 17	5 15	5 16	0 131	0 132	0 132
3 CO_3	4 34	4 37	4 36	5 18	5 15	5 17	0 132	0 132	0 132
4 SiO_3	4 35	4 43	4 39	5 17	5 16	5 16	0 132	0 133	0 133
C D (0 05)				0 006	0 006	0 005	0 0041	0 0052	0 0025

(Contd)

Table 5 (Contd)

Chemical Characteristics	Total phosphorus (P) ppm			P Fixing capacity (µg P g[1])			Organic matter content (%)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
a Before sowing	358	379	369	28 6	28.5	28 6	2.34	2 24	2 29
b After harvest Treatment No									
T_1	352	372	362	28 4	28 8	28 6	2 36	2 25	2 31
T_2	348	369	359	28 6	28 6	28 6	2.35	2 24	2.30
T_3	347	365	356	28 9	28 6	28 7	2 34	2 23	2.29
T_4	349	368	358	28 4	28 7	28 6	2.35	2 25	2.30
T_5	351	370	361	28 6	28 6	28 6	2.36	2 26	2.31
T_6	349	369	359	28 7	28 5	28 6	2.35	2 25	2 30
T_7	345	363	354	28 9	28 5	28 7	2 34	2 24	2 29
T_8	346	365	356	28 7	28 6	28 6	2 35	2 25	2 30
T_9	347	368	358	28 5	28 6	28 5	2.36	2 29	2.33
T_{10}	349	369	359	28 8	28 8	28 8	2 36	2 28	2.32
T_{11}	344	366	355	28.5	28 6	28 6	2.34	2 27	2.31
T_{12}	347	366	356	28 7	28 8	28 8	2 35	2 29	2.32
SEm±	5 6	3 8	3 4	0 13	0 14	0 10	0 042	0 040	0 029
C D (0 05)	—	—	—	—	—	—	—	—	—
FACTORS									
A. Fert P									
1 No P	349	368	359	28 6	28 7	28 6	2.35	2 25	2 30
2 50%P	348	367	357	28 7	28 6	28 6	2.35	2 25	2 30
3 100%P	347	367	357	28 6	28 7	28 7	2 35	2 28	2.32
C D (0 05)	—	—	—	—	—	—	—	—	—
B Anions									
1 No anions	350	370	360	28.5	28 7	28 6	2.36	2 27	2.31
2 OH^-	349	369	359	28 7	28 6	28 7	2.35	2 26	2.31
3 CO_3	345	365	355	28 8	28 5	28 7	2 34	2 25	2 30
4 SiO_3	347	366	357	28 6	28 7	28 7	2 35	2 26	2.31
C D (0 05)	—	—	—	—	—	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

During season II C E C of the soil before sowing was 4 27 me 100 g ^{1} and that after harvest there was no significant response between treatments and the levels of various factors

On the pooled analysis of the two season s data C E C of the soil before sowing was 4 24 me 100 g ^{1} The treatment responses were not significant after harvest and hence there was no response between levels of phosphorus and the various anions

4 1 2.2 pH of the soil

During season I pH of the soil before sowing was found to be 5 11 and that after harvest the treatment effects were significant While the lowest value of 5 12 was recorded by T_1 the highest value of 5 18 was recorded by six treatments viz T_3 T_6 T_7 T_8 T_{11} and T_{12} On factorial analysis the lowest value of 5 16 was recorded by no phosphorus treatment while the highest value of 5 17 was recorded both by 50% and 100% phosphorus treatments which was statistically significant also No anions recorded the lowest value of 5 13 while carbonate anion recorded the highest value of 5 18 which was also significant

During season II pH value of the soil before sowing was 5 09 and that after harvest the treatment effects were significant The lowest value of 5 11 was recorded in T_1 whereas the highest value of 5 16 was recorded both in T_4 and T_{10} Factorial analysis revealed that the different levels of phosphorus could not make any significant effect on pH of the soil Among anions no anions recorded the lowest pH of 5 12 whereas silicate anion recorded the significantly highest pH of 5 16

On pooled analysis pH of the soil before sowing was found to be 5 10 The treatment differences were significant after harvest The lowest pH of 5 12 was recorded in T_1 whereas the highest pH of 5 17 was recorded in six treatments viz T_3 T_6 T_7 T_8 T_{11} and T_{12} On factorial analysis it was revealed that the lowest pH of 5 15 was *recorded in* no phosphorus plot where as the significantly highest pH of 5 16 was recorded both in 50% and 100% phosphorus plots No anions plots recorded the lowest pH of 5 13 while carbonate anion recorded the highest pH of 5 17 which was also significant

4 1 2.3 Total Nitrogen content of the soil

The total nitrogen content of the soil before sowing was 0 122% during season I and that after harvest the treatment effects were significant The lowest value of 0 124% was recorded both in T_1 and T_9 whereas the highest value of 0 133% was recorded in both T_6 and T_{11} On factorial analysis it was revealed that different phosphorus levels were not significant on their effects Among anions no anion plots recorded the lowest value of 0 125% where as the highest value of 0 13?% was recorded both in carbonate and silicate treated plots which was significant

During season II the total nitrogen content of the soil before sowing was found to be 0 124% The treatment differences were statistically significant after harvest While the lowest value of 0 126% was recorded in T_1 T_5 and T_9 the highest value of 0 136% was recorded only in T_4 On factorial analysis all the fertilizer phosphorus treatments recorded the same value of 0 131% which was not significant over no phosphorus controls Among the anions no anions recorded the lowest value of 0 126% where as the highest value of 0 133% was recorded by silicate anion and the differences were significant also

On pooled analysis nitrogen content of the soil before sowing was found to be 0 123% The lowest value of 0 125% was recorded in both T_1 and T_9 whereas the highest value of 0 134% was recorded in T_4 after harvest and found significant On factorial analysis the phosphorus levels showed no response while among the anions no anions recorded the lowest value of 0 125% silicate anion recorded the highest value of 0 133% and the difference was significant also

4 1 2 4 Total phosphorus content of the soil

The total phosphorus content of the soil which was 358 ppm before sowing did not differ significantly after harvest during season I between the various treatments

During seaon II the toal phosphurs content of the soil before sowing was found to be 379 ppm and that after harvest the treatment differneces were not significant Both 50% phosphorus and 100% phosphorus recorded the lowest value of 367 ppm whereas no phosphorus plots recorded the highest value of 368 ppm Carbonate anion recorded the lowest value of 365 ppm while the highest value of 370 ppm was recorded by no anions plots

On pooled analysis also the treatment differences were not found to be significant after harvest There was no response between factors

4 1 2 5 Phosphorus fixing capacity of tne soil

During season I the P fixing capacity before sowing was 28 6 $\mu g\ P\ g^{1}$ and that after harvest the lowest value of 28 4 $\mu g\ P\ g^{1}$ was recorded in both T_1 and T_4 while the highest value of 28 9 $\mu g\ P\ g^{1}$ was recorded in T_3 and T_7 However these differences were not statistically significant with respect to treatments and factors

During season II also phosphorus fixing capacity of the soil after harvest did not exhibit significant response

On pooled analysis of the two season s data also the treatment differences were not found to be statistically significant after harvest and hence there was no response between phosphorus levels and anion factors

4 1.2 6 Organic matter content of the soil

During season I the organic matter content of the soil before sowing was found to be 2 34% It was also revelaed that, the treatment differences showed no response after harvest

During season II also the treatment differences were found to be not significant after harvest with resepct to treatment combination as well as the various factors

On pooled analysis the organic matter content before sowing was found to be 2 29% and that after harvest the treatment differences were not significant with respect to combinations as well as the various factors

4 1 3 Available phosphorus content of the soil

The data on available phosporus conent of the soil at various stages of the experiment are given in Table 6

During season I the available phsophorus content of the soil before sowing was found to be 7 21 mg P kg^{1} and at 30 DAS the treatment differences were significant T_1 recorded the minimum value of 11 62 mg P kg^{1} whereas T_3 recorded the maximum value of 17 93 mg P Kg^{1} On factorial analysis it was recorded that no phosphorus treatment gave the minimum value of 15 48 mg P Kg^{1} whereas 100% phosphorus recorded the maximum value of 16 48 mg P Kg^{1} but was not statistically significant Among the anions no anions recorded the

Table 6 Available P content of the soil (mg $P\ kg^{-1}$) in Experiment No 1

Treatment No	Before sowing			30 DAS			After harvest		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
T_1	7 21	6 88	7 05	11 62	9 98	10 80	8 09	7 53	7 81
T_2	7 21	6 88	7 05	16 19	14 01	15 10	8 40	7 74	8 07
T_3	7 21	6 88	7 05	17 93	14 52	16 22	8 72	7 84	8 28
T_4	7 21	6 88	7 05	16 18	14 50	15 34	8 93	7 79	8 36
T_5	7 21	6 88	7 05	13.57	13 60	13.59	8.52	7 58	8 05
T_6	7 21	6 88	7 05	17 47	15 13	16.30	8 93	7 68	8 31
T_7	7 21	6 88	7 05	17 18	16 55	16 87	9 29	7 82	8 55
T_8	7 21	6 88	7 05	17 09	16 51	16 80	9 47	7 80	8 63
T_9	7 21	6 88	7 05	14 14	12.97	13.55	9 25	7 62	8 43
T_{10}	7 21	6 88	7 05	17 48	15 38	16 43	9 79	7 81	8 80
T_{11}	7 21	6 88	7 05	17 24	16 34	16 79	10 00	7 93	8 96
T_{12}	7 21	6 88	7 05	17 04	16 41	16 73	9 89	7 89	8 89
SEm±	0 00	0 00	0 00	0 993	0.561	0 570	0 318	0.359	0 240
C D (0 05)	—	—	—	2 913	1 644	1 629	0 933	—	0 685
FACTORS									
Fert P									
1 No P	7 21	6 88	7 05	15 48	13 25	14 36	8.53	7 72	8 13
2 50%P	7 21	6 88	7 05	16.33	15 45	15 89	9 05	7 72	8 39
3 100%P	7 21	6 88	7 05	16 48	15 27	15 87	9 73	7 81	8 77
C D (0 05)	—	—	—	—	0 822	0 815	0 467	—	0 342
Anions									
1 No anions	7 21	6 88	7 05	13 11	12 18	12 65	8 62	7 57	8 10
2 OH^-	7 21	6 88	7 05	17 05	14 84	15 94	9 04	7 74	8 39
3 CO_3	7 21	6 88	7 05	17 45	15 80	16 63	9.33	7 86	8 60
4 SiO_3	7 21	6 88	7 05	16 77	15 80	16 29	9 43	7 83	8 63
C D (0 05)	—	—	—	1 682	0 949	0 941	0 539	—	0.395

Note In those places where C D is not given the F test is not significant at 5% level

minimum value of 13 11 mg P Kg ^{1} whereas carbonate anion recorded the maximum value of 17 45 mg P Kg ^{1} and was statistically significant also

After harvest the available phosphorus content of the soil under different treatments were found to be statistically significant the minimum value of 8 09 mg P Kg ^{1} was recorded in T_1 whereas the maximum value of 10 00 mg P Kg ^{1} was recorded in T_{11} On factorial analysis no phosphorus treatment recorded the minimum value of 8 53 mg P Kg ^{1} whereas 100% phosphorus recorded the maximum value of 9 73 mg P Kg ^{1} which was statistically significant Among the anions no anions recorded the lowest value of 8 62 mg P Kg ^{1} whereas silicate anion recorded the highest value of 9 43 mg P Kg ^{1} which was statistically significant also

During season II the available phosphorus content of the soil before sowing was found to be 6 88 mg P Kg ^{1} and at 30 DAS the treatment differences were statistically significant T_1 recorded the minimum value of 9 98 mg P Kg ^{1} while T_7 recorded the maximum of 16 55 mg P Kg ^{1} On factorial analysis no phosphorus treatment recorded the lowest value of 13 25mg P Kg ^{1} whereas 50% phosphorus recorded the highest value of 15 45 mg P Kg ^{1} which was significant also Among the anion treatments no anion recorded the lowest value of 12 18 mg P Kg ^{1} whereas carbonate and silicate anions recorded the highest value of 15 80 mg P Kg which was statistically significant However after harvest the treatment differences were found to be not significant On factorial analysis no phosphorus and 50% phosphorus recorded the lowest value of 7 72 mg P Kg ^{1} while the maximum value of 7 81 mg P kg ^{1} was recorded in 100% phosphorus Among the anions no anions recorded the lowest value of 7 57 mg P Kg ^{1} while carbonate anion recorded the highest value of 7 86 mg P Kg ^{1}

On pooled analysis the available phosphorus content of the soil before sowing was found to be 7 05 mg P Kg^{1} and at 30 DAS the treatment differences were significant as in the case of season I The minimum value of 10 80 mg P Kg^{1} was recorded in T_1 whereas the maximum value of 16 87 mg P Kg^{1} was recored in T_7 On factorial analysis the minimum value of 14 36 mg P Kg^{1} was recorded in no phosphorus treatments while the maximum value of 15 87 mg P Kg^{1} was recorded n 50% phosphorus treatments and this difference was statistically significant Among the anions no anions treatment recorded the lowest value of 12 65 mg P Kg^{1} whereas carbonate anion recorded the highest value of 16 63 mg P Kg^{1} which was again statistically significant After harvest also the treatment differences were significant The lowest value of 7 81 mg P Kg^{1} was recorded in T_1 while the highest value of 8 96 mg P Kg^{1} was recorded in T_{11} On factorial analysis no phosphorus treatment recorded the lowest value of 8 13 mg P Kg^{1} whereas 100% phosphorus recorded the highest value of 8 77 mg P Kg^{1} which was again statistically significant Among the anions no anion treatment recorded the lowest value of 8 10 mg P Kg^{1} whereas silicate anion recorded the highest value of 8 63 mg P Kg^{1} which was also significant

4 1 4 Soil phosphorus fractions

The data on soil phosphorus fractions at different stages of the experiment are given n Tables 7 8 and 9

1 1 4 1 Saloid P (Sal P)

During season I Saloid P before sowing was 15 1 ppm while at flowering the lowest value of 18 0 ppm was recored in T_1 whereas highest value of 31 0 ppm was recorded in T_3 and the treatment difference was significant On factorial analysis it was revealed that the different phosphorus levels could not exert any significant

Table 7 Soil phosphorus (P) fractions (ppm) for Season I in Experiment No 1

Treatment / Period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	15 1	38 3	26 2	19 1	14 0	17 0	229 0	358 7
b At flowering								
Treatment No								
T_1	18 0	38 0	25 7	18 7	14 3	16 7	224 0	355 3
T_2	21 7	36 0	25 0	18 0	13 7	16.3	221 0	351 7
T_3	31 0	31 7	25 0	18.3	13 7	17 3	213 0	350 3
T_4	24 0	34 3	24 7	18 3	13 3	16 7	220 3	351 7
T_5	14 3	38 0	25 0	18 7	14 3	17.3	225 7	353 3
T_6	25 3	36 0	25 0	18 3	14 7	16 3	215 0	350 7
T_7	30 3	33 7	25 0	17.3	14 3	16 0	210 0	346 7
T_8	30 3	33 7	25 0	17 0	13 3	16 7	213 3	349 3
T_9	21 0	35 0	26 0	18 3	14 3	16 0	219 0	349 7
T_{10}	21 7	32 7	25 7	18.3	14 3	16.3	221 7	350 7
T_{11}	28 7	32 0	25 0	17.3	14 0	17 3	214 0	348 3
T_{12}	25 3	34 7	24 7	17 7	13 7	17 0	216 3	349 3
SEm ±	1 36	0 62	0 61	0 40	0.33	0 41	1.58	2 29
C D (0 05)	3 99	1 83	—	—	—	—	4 63	—
FACTORS								
A Fert P								
1 No P	23 7	35 0	25 1	18.3	13 8	16 8	219 7	352 3
2 50%P	25 1	35.3	25 0	17 8	14 2	16 6	216 0	350 0
3 100%P	24 2	33 6	25.3	17 9	14 1	16 7	217 8	349 5
C D (0 05)	—	0 91	—	—	—	—	2 32	—
B Anions								
1 No anions	17 8	37 0	25 6	18 6	14 3	16 7	222 9	352 8
2 OH^-	22 9	34 9	25 2	18 2	14 2	16.3	219 2	351 0
3 CO_3	30 0	32 4	25 0	17 7	14 0	16 9	212 4	348 4
4 SiO_3	26 6	34 2	24 8	17 7	13 4	16 8	216 7	350 1
C D (0 05)	2 30	1 05	—	—	—	—	2 68	—

Contd

Table 7 Contd

Treatment / Penod	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	19 0	37.3	26 0	18 7	14 3	17 0	220 0	352 3
T_2	22 7	35.3	25 0	18 3	14 3	17.3	215 3	348 3
T_3	30 3	33 0	25 0	18 7	14 7	17.3	207 7	346 7
T_4	28 3	34.3	25.3	18.3	14 3	18 3	209 7	348 7
T_5	17 3	35 7	25.3	18.3	14 3	17 3	222 7	351 0
T_6	27 3	35 7	25 0	18 7	14 0	17 3	211 3	349 3
T_7	30 3	33 7	24.3	18.3	13 7	17.3	207 7	345 3
T_8	30 0	34 7	24 7	18 0	14 0	17 0	207 3	345 7
T_9	19 7	34 3	25 0	18.3	14 0	17 0	218 3	346 7
T_{10}	20 0	34 0	25 3	18 7	13 7	17 0	220 7	349 3
T_{11}	23 3	33 3	24 7	17 7	13 7	17 0	214 7	344 3
T_{12}	22 7	34 0	25 0	18.3	13 7	17.3	215 7	346 7
SEm ±	0 76	0 60	0 38	0 33	0.30	0 36	3 39	5.59
C D (0 05)	2 24	1 75	—	—	—	—	9 93	—
ΓACTORS								
A Fert P								
1 No P	25 1	35 0	25 3	18 5	14 4	17 5	213 2	349 0
2 50%P	26 3	34 9	24 8	18 3	14 4	17 3	212 3	347 8
3 100%P	21 4	33 9	25 0	18.3	13 8	17 1	217 3	346 8
C D (0 05)	1 12	0 88	—	—	—	—	—	—
B Anions								
1 No amons	18 7	35 8	25 4	18 4	14 2	17 1	220 3	350 0
2 OH^-	23 3	35 0	25 1	18 6	14 0	17 2	215 8	349 0
3 CO_3	28 0	33 3	24 7	18 2	14 0	17 2	210 0	345 4
4 SiO_3	27 0	34 3	25 0	18 2	14 0	17 6	210 9	347 0
C D (0 05)	1 29	1 01	—	—	—	—	5 73	—

Note In those places where C D is not given the F test is not s gnificant at 5% level

Table 8 Soil phosphorus (P) fractions (ppm) in Experiment No 1 for Season II

Treatment / Period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	16 2	44 1	27 2	20 1	15 3	18 1	239 1	380 1
b At flowering								
Treatment No								
T_1	14 0	46 7	27.3	20 0	14 7	17.3	235 3	375 3
T_2	15 3	46 3	27 0	20.3	15 0	17 0	231 7	372 7
T_3	24 7	38 7	26 0	20 0	14 0	17 7	228 7	369 3
T_4	21 7	40 7	26 3	20.3	14 7	17 7	231 0	372 3
T_5	14 3	47 0	26 0	20 7	14 3	17 3	233 0	372 7
T_6	16 3	46 0	26.3	20 3	14 7	17 7	232 0	373 3
T_7	27 7	36 7	25 7	19 0	13 7	17 7	228 3	368 7
T_8	21 7	41 0	26.3	19.3	14 3	18 0	229 0	369 7
T_9	15 0	46 0	27 0	19 7	15 0	17 3	232 3	372 3
T_{10}	31 0	38 7	26 3	20.3	13 3	18 3	223 3	371 3
T_{11}	30 7	38 0	25 7	19 6	14 7	18 7	223 0	370 3
T_{12}	29 0	40 0	26 3	19 9	14 0	17 7	222 3	369 3
SEm±	1 09	0 52	0 43	0 47	0.36	0 36	1.57	2 55
C D (0 05)	3 18	1 52	—	—	—	—	4 61	—
FACTORS								
A Fert. P								
1 No P	18 9	43 1	26 7	20 2	14 6	17 4	231 7	372 4
2 50%P	20 0	42 7	26 1	19 8	14 3	17 7	230 6	371 1
3 100%P	26 4	40 7	26.3	19 9	14 3	18 0	225 3	370 8
C D (0 05)	1.59	0 76	—	—	—	—	2 30	—
B Anions								
1 No anions	14 4	46 6	26 8	20 1	14 7	17 3	233 6	373 4
2 OH^-	20 9	43 7	26 6	20 3	14 3	17 7	229 0	372 4
3 CO_3	27 7	37 8	25 8	19 6	14 1	18 0	226 7	369 4
4 SiO_3	24 1	40 6	26 3	19 9	14 3	17 8	227 4	370 4
C D (0 05)	1 84	0 87	—	—	—	—	2 66	—

Contd

Table 8 Contd

Treatment / Penod	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	17 7	45 0	26 7	19 7	14 3	17 3	231 0	371 7
T_2	19 0	44.3	26 3	20 0	14 3	18 0	226 7	368 7
T_3	25 0	39 7	26 0	20 0	14 0	17 0	223 7	365 3
T_4	24 0	40 0	26 0	20 0	14 3	18 0	225 3	367 7
T_5	18 0	44.3	26 7	20 0	14 0	17.3	230 0	370 3
T_6	20 3	43 7	26 7	20 0	14 0	17 7	227 0	369 3
T_7	25 0	39 0	26 0	20 3	13 7	17 7	221 3	362 7
T_8	24 3	39 7	26 3	20.3	13 7	17 7	223 3	365 3
T_9	22 0	43 3	26 3	20 0	14 0	17 3	225 3	368 3
T_{10}	30 0	38.3	26 7	20 0	14 0	18 7	221 0	368 7
T_{11}	30 0	37 7	26.3	19 7	14 3	19 0	219 3	366 3
T_{12}	29 0	38.3	26 0	19.3	14 7	18 3	220 0	365 7
SEm ±	0 49	0 44	0 33	0 28	0 23	0 30	2 32	3 79
C D (0 05)	1 43	1 28	—	—	—	—	6 80	—
ΓACTORS								
A Fert P								
1 No P	21 4	42.3	26.3	19 9	14 3	17 6	226 7	368 3
2 50%P	21 9	41 7	26 4	20 2	13 8	17 6	225 4	366 9
3 100%P	27 8	39 4	26 3	19 8	14 3	18 3	221 4	367.3
C D (0 05)	0 72	0 64	—	—	—	—	3 40	—
B Anions								
1 No anions	19 2	44 2	26 6	19 9	14 1	17 3	228 8	370 1
2 OH^-	23 1	42 1	26 6	20 0	14 1	18 1	224 9	368 9
3 CO_3	26 7	38 8	26 1	20 0	14 0	17 9	221 4	364 8
4 SiO_3	25 8	39 3	26 1	19 9	14 2	18 0	222 9	366 2
C D (0 05)	0 83	0 74	—	—	—	—	3 93	—

Note In those places where C D is not given the F test is not significant at 5% level

Table 9 Soil phosphorus (P) fractions (ppm) in Experiment No 1 (Pooled mean)

Treatment / Period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	15 7	41 2	26 7	19 6	14 7	17 6	234 1	369 4
b At flowering								
Treatment No								
T_1	16 0	42.3	26 5	19.3	14 5	17 0	229 7	365 3
T_2	18 5	41 2	26 0	19 2	14 3	16 7	226 3	362 2
T_3	27 8	35 2	25 5	19 2	13 8	17.5	221 0	359 8
T_4	22 8	37.5	25 5	19.3	14 0	17 2	225 7	362 0
T_5	14 3	42 5	25.5	19 7	14 3	17 3	229 3	363 0
T_6	20 8	41 0	25 7	19.3	14 7	17 0	223 5	362 0
T_7	29 0	35 2	25 3	18 2	14 0	16 8	219 2	357 7
T_8	26 0	37 3	25 7	18 2	13 8	17.3	221 2	359 5
T_9	18 0	40 5	26 5	19 0	14 7	16 7	225 7	361 0
T_{10}	26 3	35 7	26 0	19.3	13 8	17.3	222 5	361 0
T_{11}	29 7	35 0	25.3	18.5	14 3	18 0	218 5	359 3
T_{12}	27 2	37.3	25 5	18 8	13 8	17 3	219 3	359 3
SEm ±	0 87	0 41	0 37	0.31	0 24	0 27	1 11	1 71
C D (0 05)	2 49	1 16	—	0 88	0 70	—	3 18	4 89
FACTORS								
A Fert P								
1 No P	21 3	39 0	25 9	19 3	14 2	17 1	225 7	362.3
2 50%P	22 5	39 0	25 5	18 3	14 2	17 1	223 3	360 5
3 100%P	25 3	37 1	25 8	18 9	14 2	17 3	221 5	360 2
C D (0 05)	1 24	0 58	—	—	—	—	1.59	—
B Anions								
1 No anions	16 1	41 8	26 2	19.3	14 5	17 0	228 2	363 1
2 OH^-	21 9	39.3	25 9	19 3	14 3	17 0	224 1	361 7
3 CO_3	28 8	35 1	25 4	18 6	14 1	17 4	219 6	358 9
4 SiO_3	25 3	37 4	25 6	18 8	13 9	17 3	222 1	360.3
C D (0 05)	1 44	0 67	—	0 51	0 40	—	1 84	2 83

Contd

Table 9 Contd ..

Treatment / Penod	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	18 3	41 2	26.3	19 2	14 3	17 2	225 5	362 0
T_2	20 8	39 8	25 7	19 2	14 3	17 7	221 0	358 5
T_3	27 7	36 3	25.5	19 3	14 3	17 2	215 7	356 0
T_4	26 2	37 2	25 7	19 2	14 3	18 2	217 5	358 2
T_5	17 7	40 0	26 0	19 2	14 2	17 3	226.3	360 7
T_6	23 8	39 7	25 8	19 3	14 0	17 5	219 2	359 3
T_7	27 7	36 3	25 2	19 3	13 7	17 5	214 5	354 0
T_8	27 2	37 2	25 5	19 2	13 8	17 3	215 3	355 5
T_9	20 8	38 8	25 7	19 2	14 0	17 2	221 8	357 5
T_{10}	25 0	36 2	26 0	19.3	13 8	17 8	220 8	359 0
T_{11}	26 7	35 5	25.5	18 7	14 0	18 0	217 0	355 3
T_{12}	25 8	36 2	25.5	18 8	14 2	17 8	217 8	356 2
SEm ±	0 45	0 37	0 25	0 22	0 19	0 23	2 05	3.38
C D (0 05)	1.30	1 06	0 72	—	0 54	0 65	5 86	—
FACTORS								
A Fert P								
1 No P	23 3	38 6	25 8	19 2	14 3	17 5	219 9	358 7
2 50%P	24 1	38 3	25 6	19.3	13 9	17 4	218 8	357 4
3 100%P	24 6	36 7	25 7	19 0	14 0	17 7	219 4	357 0
C D (0 05)	0 65	0 53	—	—	0 27	—	—	—
B Anions								
1 No anions	18 9	40 0	26 0	19 2	14 2	17 2	224 6	360 1
2 OH^-	23 2	38 6	25 8	19 3	14 1	17 7	220 3	358 9
3 CO_3	27 3	36 1	25 4	19 1	14 0	17 6	215 7	355 1
4 SiO_3	26 4	36 8	25 6	19 1	14 1	17 8	216 9	356 6
C D (0 05)	0 75	0 61	0 42	—	—	0 37	3.38	—

Note In those places where C D is not given the F test is not significant at 5% level

influence on the saloid P content of the soil Among the anions no anions recorded the lowest value of 17 8 ppm while carbonate anion recorded the significantly highest value of 30 0 ppm After harvest also the treatment differences were significant and that the lowest value of 17 3 ppm was recorded in T_5 while the highest value of 30 3 ppm was recorded in both T_3 and T_7 On factorial analysis while 100% phosphorus recorded the lowest value of 21 4 ppm 50% phosphorus recorded the highest value of 26 3 ppm which was significant Among the anions no anions recorded the lowest value of 18 7 ppm,while carbonate anion recorded the highest value of 28 0 ppm

During season II saloid P before sowing was found to be 16 2 ppm while at flowering the treatment differences were significant The lowest value of 14 0 ppm was recorded in T_1 whereas the highest value of 31 0 ppm was recorded in T_{10} On factorial analysis no phosphorus treatment recorded the lowest value of 18 9 ppm whereas 100% phosphorus recorded the highest value of 26 4 ppm which was statistically significant Among the anions no anion recorded the lowest value of 14 4 ppm while carbonate anion recorded the highest value of 27 7 ppm which was also significant After harvest also the treatment differences were significant and that the lowest value of 17 7 ppm was recorded in T_1 while the highest value of 30 0 ppm was recorded in both T_{10} and T_{11} On factorial analysis no phosphorus treatment recorded the lowest value of 21 4 ppm whereas 100% phosphorus recorded the highest value of 27 8 ppm which was significant Among the anions no anion treatment recorded the lowest value of 19 2 ppm while carbonate anion recorded the highest value of 26 7 ppm which was also significnat

On pooled analysis also the treatment differences were significant at flowering The lowest value of 14 3 ppm was recorded in T_5 whereas the highest value of 29 7 ppm was recorded in T_{11} On factorial analysis no phosphorus treatment recorded the lowest value of 21 3 ppm while 100% phosphorus treatment record d the highest value of 25 3 ppm which was statistically significant Among the anions when no anion treatment recorded the lowest value of 16 1 ppm carbonate anion recorded the significantly highest value of 28 8 ppm After harvest also the treatment differences were significant with the lowest value of 17 7 ppm being recorded in T_5 and the maximum value of 27 7 ppm being recorded on both T_3 and T_7 On factorial analysis no phosphorus treatment recorded the lowest value of 23 3 ppm where as 100% phosphorus treatment recorded the highest value of 24 6 ppm which was significant Among the anions no anions treatment recorded the lowest value of 18 9 ppm while carbonate anion recorded the highest value of 27 3 ppm which was again statistically significant

4 1 4.2 Aluminium P (Al P)

During season I aluminium **P** before sowing was found to be 38 3 ppm and that at flowering and at harvest, the treatment differences were statistically significant At flowering the lowest value of 31 7 ppm was recorded in T_3 whereas the highest value of 38 0 ppm was recorded in both T_1 and T_5 On factorial analysis 100% phosphorus recorded the lowest value of 33 6 ppm whereas 50% phosphorus recorded the highest value of 35 3 ppm which was statistically significant Among the anions carbonate anion recorded the lowest value of 32 4 ppm while no anions treatment recorded the highest value of 37 0 ppm and this difference was also significant After harvest the lowest value of 33 0 ppm was recorded in T_3 and the highest value of 37 3 ppm was recorded in T_1 On factorial analysis 100% phosphorus recorded the lowest value of 33 9 ppm while no phosphorus treatment recorded the highest value of 35 0 ppm and this difference was significant Among the anions carbonate anion recorded the lowest value of 33 3 ppm whereas no anions recorded the highest value of 35 8 ppm which was significant

During season II Aluminium P before sowing was found to be 44 1 ppm and that at flowering the treatment differences were significant The lowest value of 36 7 ppm was recorded in T_7 while the highest value of 47 0 ppm was recorded in T_5 On factorial analysis 100% phosphorus recorded the lowest value of 40 7 ppm while no phosphorus treatment recroded the highest value of 43 1 ppm which was statistically significant Among the anions carbonate anion recorded the lowest value of 37 8 ppm while no anion recorded the highest value of 46 6 ppm which was also statistically significant After harvest again the treatment differences were significant and that the lowest value of 37 7 ppm was recorded in T_{11} while the highest value of 45 0 ppm was recorded in T_1 On factorial analysis 100% phosphorus recorded the lowest value of 39 4 ppm while no phosphorus recorded the highest value of 42 3 ppm which was also significant Among the anions carbonate anion recorded the lowest value of 38 8 ppm while no anions treatment recorded the highest value of 44 2 ppm which was again statistically significant

On pooled analysis it is seen that Al P before sowing was 41 2 ppm while at flowering the treatment differences were significant The lowest value of 35 0 ppm was recorded in T_{11} while the highest value of 42 5 ppm was recorded in T_5 On factorial analysis 100% phosphorus recorded the lowest value of 37 1 ppm where as no phosphorus and 50% phosphorus recorded the highest value of 39 0 ppm which was significant Among the anions carbonate anion recorded the lowest value of 35 1 ppm while no anions recorded the highest value of 41 8 ppm which was statistically significant After harvest the treatment differences were significant and that the lowest value of 35 5 ppm was recorded in T_{11} while the highest value of 41 2 ppm was recorded in T_1 On factorial analysis 100% phosphorus recorded the lowest value of 36 7 ppm whereas no phosphorus recorded the highest value of 38 6 ppm which was significant Among the anions the lowest value of 36 1 ppm was r corded by the carbonate anion while the higehst value of 40 0 ppm was recorded by no anions treatment which was again significant

4 1 4.3 Iron P (Fe-P)

During season I the Fe P content of the soil which was 26 2 ppm before sowing did not exhibit any significant difference either at flowering or after harvest with respect to treatments and factors After harvest there was no response with respect to Fe P of the soil under various treatments and factors

During season II also the treatment differences were not significant either at flowering or after harvest with respect to treatment combinations or factors

On pooled analysis also it was revealed that the treatment responses were not sign ficant with respect to Fe P of the soil at the treatment combination level or factors at the flowering stage After harvest the treatment differences were significant The lowest value of 25 2 ppm was recorded in T_7 while the highest valı e of 26 3 ppm was recorded in T_1 On factorial analysis 50% phosphorus recorded the lowest value of 25 6 ppm where as no phosphorus recorded the highest value of 25 8 ppm However the difference was not significant Among the anions carbonate anion recorded the lowest value of 25 4 ppm while no anions recorded the highest value of 26 0 ppm which was found to be significant

4 1 4 4 Reductant soluble P (Red-P)

During season I Red P before sowing was 19 1 ppm and at flowering, the treatments showed no significant response at the combination level or factorial levels

After harvest also the treatment differences were not significant at the combination level or factorial level

During season II also the treatment differences were not significant at flowering at the combination level and factorial level during flowering

After harvest also there was no response between treatments with respect to Red P of the soil at the combination level or factorial level

On pooled analysis it was found that Red P before sowing was 19 6 ppm and that at flowering the treatment difference were significant The lowest value of 18 2 ppm was recorded in both T7 and T8 while the highest value of 19 7 ppm was recorded in T5 On factorial analysis 50% phosphorus recorded the lowest value of 18 3 ppm whereas no phosphorus recorded the highest value of 19 3 ppm which was not significant Among the anions while carbonate anion recorded the lowest value of 18 6 ppm while both no anion and hydroxyl anion recorded the highest value of 19 3 ppm and this difference was significant

After harvest of the crop on pooled analysis there was no significant response between treatments with respect to Red P of the soil at the combination level or factorial level

4 1 4 5 Occluded P (Occl P)

During season I occluded P which was 14 0 ppm before sowing did not differ significantly both at flowering and after harvest of the crop both at combination level and factorial level

During season II also there was no response between treatments both at flowering and after harvest with respect to occluded P of the soil

On pooled analysis there was significant difference between treatments There was no response between levels of phosphorus Among anions, silicate anion recorded the lowest value of 13 9 ppm while no anion recorded the significantly highest value of 14 5 ppm

4 1 4 6 Calcium P (Ca-P)

Ca P which was 17 0 ppm before sowing during season I did not differ significantly both at flowering and at harvest of the crop

During season II also the treatment differences were not significant both at flowering and after harvest

During pooled analysis also Ca P which was 17 6 ppm before sowing did not differ significantly at flowering

After harvest the treatment differences were found to be significant and that the lowest value of 17 2 ppm was recorded in T_1 T_3 and T_9 while the highest value of 18 2 ppm was recorded in T_4 On factorial analysis there was no response between the levels of phosphorus with respect to Ca P of the soil Among the anions no anions recorded the lowest value of 17 2 ppm while silicate anion recorded the highest value of 17 8 ppm which was significant

4 1 4 7 Organic P (Org P)

During season I organic P which was 229 ppm before sowing recorded significant responses at flowering as well as after harvest At flowering the lowest value of 210 0 ppm was recorded in T_7 while the highest value of 225 7 ppm was recorded in T_5 On factorial analysis 50% phosphorus recorded the lowest value of ?16 0 ppm whereas no phosphorus recorded the highest value of 219 7 ppm which was significant Among the anions carbonate anion recorded the lowest value of 21? 4 ppm while no anion recorded the highest value of 222 9 ppm which was also significant After harvest the lowest value of 207 3 ppm was recorded in T_8 while the maximum value of 220 0 ppm was recorded in T_1 On factorial analysis 50% phosphorus recorded the lowest value of 212 3 ppm whereas 100% phosphorus recorded the highest value of 217 3 ppm which was however not significant Among the anions carbonate anion recorded the lowest value of 210 0 ppm where as no anion recorded the highest value of 220 3 ppm which was significant

During the season II organic P recorded 239 1 ppm before sowing and that the treatment differences were significant at flowering The lowest value of 222 3 ppm was recorded in T_{12} while the maximum value of 235 3 ppm was recorded in T_1 On factorial analysis 100% phosphorus recorded the lowest value of 225 3 ppm whereas no phosphorus recorded the highest value of 231 7 ppm which was statistically significant Among the anions carbonate anion recorded the lowest value of 226 7 ppm, while no anions recorded the highest value of 233 6 ppm which was also significant After harvest also the treatement differences were significant and that the lowest value of 219 3 ppm was recorded in T_{11} whereas the highest 231 0 ppm was recorded in T_1 On factorial analysis 100% phosphorus recorded the lowest value of 221 4 ppm while the highest value of 226 7 ppm was recorded in no phosphorus treatment which was however statistically significant Among anions carbonate anion recorded the lowest value of 221 4 ppm while no anions recorded the highest value of 228 8 ppm which was also statistically significant

On pooled analysis organic P was 234 1 ppm before sowing and at flowering as well as after harvest the treatment differences were significant At flowering the minimum value of 218 5 ppm was recorded in T_{11} while the maximum value of 229 7 ppm was recorded by T_1 On factorial analysis 100% phosphorus recorded the lowest value of 221 5 ppm and no phosphorus recorded the highest value of 225 7 ppm which was significant Among the anions carbonate anion recorded the lowest value of 219 6 ppm whereas no anions recorded the highest value of 228 2 ppm which was also significant After harvest the lowest value of 214 5 ppm was recorded by T7 while the highest value of ?26 3 ppm was given by T5 On factorial analysis 50% phosphorus recorded the lowest value of 218 8 ppm whereas no phosphorus recorded the highest value of 219 9 ppm but was not statistically significant Among the anions carbonate anion recorded the lowest value of 215 7 ppm while no anions recorded the highest value of 224 6 ppm which was also statistically significant

4 1 4 8 Total phosphorus (Total-P)

During season I the total phosphorus conent of the soil was found to be 358 7 ppm before sowing and that at flowering the treatment responses were not significant

After harvest also the treatment responses were not significant at the combination level and factorial level

During season II also total phosphorus content of soil did not show any significant difference either at flowering or after harvest

On pooled analysis however, the total phosphorus content which was 369 4 ppm before sowing exhibited significant variation at flowering The lowest value of 357 7 ppm was recorded in T7 while the highest value of 365 3 ppm was recorded in T1 On factorial analysis it was revealed that 100% phosphorus recorded the lowest value of 360 2 ppm while the highest value of 362 3 ppm was recorded by no phosphorus treatments although the difference was not significant Among anions carbonate anion recorded the lowest value of 358 9 ppm while the highest value of 363 1 ppm was recorded by no anion treatment which was significant

After harvest again as in the case of season I and season II the treatment differences were not significant

4 1 5 Leaf Area Index (LAI)

The data on leaf area index at different stages of the experiment are given in Table 10

During season I the data on leaf area index at 30 DAS revealed that the treatment responses were not significant

During season II also the data on leaf area index at 30 DAS showed no significant response

LAI at flowering revealed that the treatment differences were significant during season I The lowest value of 2 40 was recorded in T_1 whereas the highest value of 4 53 was recorded by T_7 On factorial analysis no phosphorus recorded the lowest value of 3 47 and 50% phosphorus as well as 100% phosphorus recorded the highest value of 3 86 which was significant Among the anions no anions recorded the lowest value of 2 89 while carbonate anion recorded the higest value of 4 19 which was also significant

During season II also LAI at flowering revealed that the treatment differences were significant and that the lowest value of 2 01 was recorded by T_1 while the highest value of 3 48 was recorded by T_7 On factorial analysis no phosphorus recorded the lowest value of 2 70 and 100% phosphorus recorded the highest value of 3 14 and were significant Among the anions no anions recorded the lowest value of 2 38 while carbonate anion recorded the highest value of 3 29 and were significant

Table 10 Leaf Area Index (LAI) at different stages in Experiment No 1

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flowering
T_1	1 20	2 40	1 09	2 01
T_2	1 19	3 77	1 25	2 97
T_3	1 22	3 98	1 25	2 97
T_4	1 23	3 72	1 18	2 85
T_5	1 10	2 88	1 13	2 38
T_6	1 24	4 20	1 22	3 20
T_7	1 30	4 53	1 15	3 48
T_8	1 24	3 81	1 20	2 92
T_9	1 19	3 40	1 25	2 74
T_{10}	1 26	4 04	1 20	3 08
T_{11}	1 24	4 06	1 18	3 41
T_{12}	1 36	3 95	1 28	3 33
SEm ±	0 053	0 044	0 059	0 038
C D (0 05)	—	0 130	—	0 111
FACTORS				
A Fert P				
1 No P	1 21	3 47	1 19	2 70
2 50% P	1 22	3 86	1 18	2 99
3 100% P	1 26	3 86	1 23	3 14
C D (0 05)	—	0 065	—	0 055
B Anions				
1 No anions	1 16	2 89	1 16	2 38
2 OH^-	1 23	4 00	1 22	3 08
3 CO_3	1 25	4 19	1 19	3 29
4 SiO_3	1 28	3 83	1 22	3 03
C D (0 05)	—	0 075	—	0 064

Note In those places where C D is not given the F test is not significant at 5% level

4 1 6 Leaf Area Ratio of plants (LAR)

The data on leaf area ratio of plants are given in Table 11

During season I LAR at 30 DAS revealed that the treatment differences were significant and the lowest value of 15 56 cm^2 g^{1} was recorded by T_7 while the highest value of 25 56 cm^2 g^{1} was recorded in T_1 Among the factors while 50% phosphorus recorded the lowest value of 17 52 cm^2 g^{1} no phosphorus recorded the highest value of 19 44 cm^2 g^{1} which was significant Among the anions carbonate anion recorded the lowest value of 16 19 cm^2 g^{1} whereas no anion recorded the highest value of 22 22 cm^2 g^{1}

During the season II also LAR at 30 DAS revealed that the treatment differences were significant While the lowest value of 13 16 cm^2 g^{1} was recorded by T_7 the highest value of 21 47 cm^2 g^{1} was recorded by T_1 On factorial analysis 100% phosphorus recorded the lowest value of 15 55 cm^2 g^{1} the highest value of 17 89 cm^2 g^{1} was recorded by no phosphorus treatment which was significant Among the anions carbonate anion recorded the lowest value of 14 54 cm^2 g^{1} while no anions recorded the highest value of 19 40 cm^2 g^{1}

During season I it was revealed that LAR values at flowering were not significant

In the case of season II however LAR at flowering recorded that the treatment differences were significant When the lowest value of 12 04 cm^2 g^{1} was recorded by T_3 the highest value of 14 18 cm^2 g^{1} was recorded in T_{11} On factorial analysis no phosphorus recorded the lowest value of 12 30 cm^2 g^{1} while 100% phosphorus recorded the highest value of 12 78 cm^2 g^{1} Among anions both silicate anion and hydroxyl anion recorded the lowest value of 12 32 cm^2 g^{1} while carbonate anion recorded the highest value of 12 85 cm^2 g^{1} and significant

Table 11 Leaf Area Ratio (LAR) of the plants (cm^2 g^{-1}) in Experiment No 1

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flowering
T_1	26 56	13 78	21 47	12 44
T_2	16 84	13 85	16 95	12 39
T_3	16 57	13 77	16 74	12 04
T_4	17 79	13 81	16 39	12 31
T_5	20 94	13 93	18 70	12 34
T_6	16 08	13 81	14 76	12 30
T_7	15 56	13 80	13 16	12 32
T_8	17 49	13 85	17 78	12 28
T_9	19 16	13 80	18 03	12 30
T_{10}	16 97	13 80	15 25	12 28
T_{11}	16 42	13 82	13 72	14 18
T_{12}	18 51	13 78	15 18	12 35
SEm ±	0 776	0 104	0 903	0 109
C D (0 05)	2 275	—	2 650	0 320
FACTORS				
A Fert P				
1 No P	19 44	13 80	17 89	12 30
2 50%P	17 52	13 85	16 10	12 31
3 100%P	17 77	13 80	15 55	12 78
C D (0 05)	1 138	—	1 325	0 160
B Anions				
1 No anions	22 22	13 84	19 40	12 36
2 OH^-	16 63	13 82	15 65	12 32
3 CO_3	16 19	13 80	14 54	12 85
4 SiO_3	17 93	13 81	16 45	12 32
C D (0 05)	1 314	—	1 530	0 185

Note In those places where C D is not given the F test is not significant at 5% level

4 1 7 Leaf Weight Ratio of plants (LWR)

The data on leaf weight ratio of plants are given in Table 12

During season I leaf weight ratio (LWR) of plants at 30 DAS recorded that there was no response between treatments

At flowering also LWR of plants recorded no response between treatments

In season II also LWR of plants at 30 DAS revealed that there was no response between treatments

At flowering in season II there was significant response between treatments and that the lowest value of 0 429 was recorded in T_7 T_8 T_9 and T_{10} while the highest value of 0 492 was recorded in T_{11} On factorial analysis no phosphorus recorded the lowest value of 0 428 whereas 100% phosphorus recorded the highest value of 0 445 and significant Among the anions no anions hydroxyl anion and silicate anion recorded the lowest value of 0 430 while carbonate anion recorded the highest value of 0 477 and significant

4 1 8 Number of effective nodules per plant

The data on the number of effective nodules per plant are given in Table 13

During season I the number of effective nodule per plant at 30 DAS recorded that there was no response between treatments

During season II the treatments showed significant response at 30 DAS and that the minimum value of 15 66 was recorded by T_4 while the maximum value of 17 77 was recorded by T_{10} Among the factors no phosphorus recorded the lowest

Table 12 Leaf Weight Ratio (LWR) of plants in Experiment No 1

Treatment No	Season I		Season II	
	30 DAS	at flower ng	30 DAS	at flowering
T_1	0 525	0 399	0 385	0 431
T_2	0 546	0 393	0 402	0 431
T_3	0 353	0 390	0 397	0 421
T_4	0 541	0 401	0 391	0 431
T_5	0 569	0 397	0 396	0 432
T_6	0 541	0 400	0 378	0 430
T_7	0 527	0 400	0 388	0 429
T_8	0 538	0 399	0 437	0 429
T_9	0 557	0 400	0 391	0 429
T_{10}	0 533	0 397	0 390	0 429
T_{11}	0 543	0 398	0 390	0 492
T_{12}	0 531	0 401	0 388	0 431
SEm ±	0 0509	0 0031	0 0136	0 0041
C D (0 05)	—	—	—	0 0121
FACTORS				
A Fert P				
1 No P	0 491	0 396	0 394	0 428
2 50%P	0 544	0 399	0 400	0 430
3 100%P	0 541	0 399	0 390	0 445
C D (0 05)	—	—	—	0 0061
B Anions				
1 No anions	0 550	0 399	0 391	0 430
2 OH^-	0 540	0 397	0 390	0 430
3 CO_3	0 475	0 396	0 392	0 447
4 SiO_3	0 537	0 400	0 405	0 430
C D (0 05)	—	—	—	0 0070

Note In those places where C D is not given the F test is not sign ficant at 5% level

Table 13 Number of effective nodules per plant in Experiment No 1

Treatment No	Season I		Season II		Pooled mean	
	30 DAS	at flowering	30 DAS	at flowering	30 DAS	at flowring
T_1	18 84	9.34	16.35	12 60	17 60	10 97
T_2	19 49	9 49	16 53	10 47	18 00	9 98
T_3	20 29	9 74	15 84	10 81	18 07	10 27
T_4	20 91	8 66	15 66	10 24	18 28	9 45
T_5	20 97	10 14	17 48	7 79	19 23	8 97
T_6	20 97	9 23	18 13	10 81	19 55	10 02
T_7	20 62	9 85	16 64	10 46	18 63	10 16
T_8	22 98	10 15	17 58	10 84	20 28	10 49
T_9	22 58	8 90	16 78	12 72	19 68	10 81
T_{10}	21 22	9 46	17 77	10 11	19 50	9 78
T_{11}	20 35	10 54	17 58	9 47	18 97	10 01
T_{12}	23 42	10 16	17 54	11.39	20 48	10 77
SEm±	1 188	0 444	0 626	0 724	0 671	0 425
C D (0 05)	—	—	1 835	2 124	1 918	1 082
FACTORS						
A Fert. P						
1 No P	19 88	9 31	16 09	11 03	17 99	10 17
2 50%P	21 39	9 84	17 46	9 98	19 42	9 91
3 100%P	21 89	9 76	17 42	10 92	19 66	10 34
C D (0 05)	—	—	0 918	1 032	0 959	—
B Anions						
1 No anions	20 80	9 46	16 87	11 04	18 84	10 25
2 OH	20 56	9.39	17 48	10 46	19 02	9 93
3 CO_3	20 42	10 04	16 69	10 25	18 55	10 14
4 SiO_3	22 43	9 65	16 93	10 82	19 68	10 24
C D (0 05)	—	—	—	—	—	—

Note In those places where C D is not given, the F test is not significant at 5% level

whereas hydroxyl anion recorded the highest value of 17 48 which was not significant On pooled analysis the number of effective nodules per plant at 30 DAS recorded that the treatment differences were significant and that the lowest value of 17 60 was recorded in T_1 while the maximum value of 20 48 was recorded by T_{12} On factorial analysis no phosphorus recorded the lowest value of 17 9) while 100% phosphorus recorded the highest value of 19 66 and was significant Among the anions carbonate anion recorded the lowest value of 18 55 while silicate anion recorded the highest value of 19 68 which was not significant

During season I the number of effective nodules at flowering revealed that there was no response between treatments

During season II the number of effective nodules at flowering revealed that the treatment responses were significant and that the lowest value of 7 79 was recorded by T_5 while the highest value of 12 72 was recorded by T_9

On factorial analysis 50% phosphorus recorded the lowest value of 9 98 whereas no phosphorus recorded the highest value of 11 03 and was significant Among the anions carbonate anion recorded the lowest value of 10 25 and no anions recorded the highest value of 11 04 which was not significant

On pooled analysis the number of effective nodules per plant recorded that the treatment had significant responses and that the minimum value of 8 97 was recorded by T_5 whereas highest value of 10 97 was recorded by T_1 On factorial analysis 50% phosphorus recorded the lowest value of 9 91 and 100% phosphorus recorded the highest value of 10 34 per plant but was not significant Among the anions also the differences were not significant However the phosphorus x anion interaction revealed statistical significance

4 1 9 Dry weight of nodules per plant

The data on dry weight of nodules per plant are given in Table 14

During season I the dry weight of nodule per plant at 30 DAS revealed that the treatment responses were significant and that the minimum value of 73 0 mg was recorded by T_{12},while the maximum value of 116 3 mg was recorded by T_7 On factorial analysis the phosphorus levels showed no significant response Among the anions silicate anion recorded the lowest value of 82 1 mg and carbonate anion recorded the highest value of 100 1 mg and was statistically significant

During season II also the dry weight of nodules at 30 DAS recorded that the treatment responses were significant and that the lowest value of 57 3 mg was recorded by T_1 while the highest value of 82 7 mg was recorded by T_{10} On factorial analysis 50% phosphorus recorded the lowest value of 66 3 mg while the highest value of 76 1 mg was recorded by 100% phosphorus and was significant The various anion levels were not significant

On pooled analysis the dry weight of plants at 30 DAS revealed that the treatment responses were not significant

During season I the dry weight of nodules at flowering recorded that the tr atment differences were significant and that the lowest value of 77 9 mg was recorded by T_1 while the highest value of 89 5 mg was recorded by T_{11} On factorial analy is no phosphorus recorded the lowest value of 81 2 mg while the highest value of 88 1 mg was recorded by 100% phosphorus which was significant Among the anions the differences showed no significant response

During the season II the dry weight of nodules at flowering revealed that the treatment differences were significant and that the lowest value of 63 2 mg was

Table 14 Dry weight of nodules per plant (mg) in Experiment No 1

Treatment No	Season I		Season II		Pooled mean	
	30 DAS	at flowering	30 DAS	at flowering	30 DAS	at flowring
T_1	110 0	77 9	57 3	67 0	83 7	72 5
T_2	90 3	82 8	62 7	76 2	76 5	79 5
T_3	90 0	80.5	79 0	72 9	84 5	76 7
T_4	87 7	83 5	69 3	76 7	78 5	80 1
T_5	88 0	87 0	67 7	90 0	77 8	88 5
T_6	99 0	86 4	63 0	71 1	81 0	78 7
T_7	116 3	85 8	67 0	73 2	91 7	79 5
T_8	85 7	80 4	67.3	75 3	76 5	77 9
T_9	86 7	88 1	77 3	71 8	82 0	80 0
T_{10}	100 0	86 8	82 7	63 2	91.3	75 0
T_{11}	94 0	89 5	71 3	69 5	82 7	79 5
T_{12}	73 0	88 1	73 0	69 2	73 0	78 6
SEm+	7 70	2 85	4 39	3 82	4 43	2 39
C D (0 05)	22 58	8 37	12 88	11 21	—	—
FACTORS						
A Fert. P						
1 No P	94 5	81 2	67 1	73 2	80 8	77 2
2 50%P	97 3	84 9	66.3	77 4	81 8	81 1
3 100%P	88 4	88 1	76 1	68 4	82.3	78 3
C D (0 05)	—	4 2	6 44	5 61	—	—
B Anions						
1 No anions	94 9	84 3	67 4	76 3	81 2	80 3
2 OH^-	96 4	85 3	69 4	70 1	82 9	77 7
3 CO_3	100 1	85.3	72 4	71 9	86 3	78 6
4 SiO_3	82 1	84 0	69 9	73 7	76 0	78 9
C D (0 05)	13 03	—	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

recorded by T_{10} while the highest value of 90 0 mg was recorded by T_5 Among the factors 100% phosphorus recorded the lowest value of 68 4 mg and 50% phosphorus recorded the highest value of 77 4 mg and was significant Among the anion again the differences were not significant

On pooled analysis the dry weight of nodules at flowering revealed that the treatment responses were not significant

4 1 10 Yield components of cowpea

The data on yield components of cowpea are given in Table 15 and results are shown under

4 1 10 1 Number of pods per plant

During season I the number of pods per plant recorded that the treatment differences showed significant response and that lowest value of 1 35 was recorded by T_1 while the maximum value of 2 53 was recorded by T_7 On factorial analysis no phosphorus recorded the lowest value of 1 95 while the highest value of 2 16 was recorded by 100% phosphorus which was significant Among the anions no anions recorded the lowest value of 1 62 while carbonate anion recorded the highest value of 2 35 and was again significant

During season II the treatment differences were significant and the lowest value of 1 68 was recorded in T_1 while the highest value of 2 92 was recorded by T_7 On factorial analysis no phosphorus recorded the lowest value of 2 26 while 100% phosphorus recorded the highest value of 2 64 and were significant Among the anions no anions recorded the lowest value of 2 00 while the highest value of 2 76 was recorded by carbonate anion which was again significant

Table 15 Yield components of cowpea in Experiment No 1

Treatment No	No of pods/plant		No of seeds/pod		100 seed weight (g)		Pod length (cm)	
	Season I	Season II	Season I	Season II	Season I	Season II	Season I	Season II
T_1	1.35	1 68	15 4	14 9	9 21	8 69	15 7	14 9
T_2	2 12	2 49	15 5	14 9	9 21	8 70	15 6	14 9
T_3	2 23	2 50	15 4	14 9	9 21	8 69	15 7	14 9
T_4	2 09	2.39	15 4	14 9	9 21	8 67	15 7	14 8
T_5	1 59	2 00	15 4	14 9	9 21	8 68	15 7	14 9
T_6	2 36	2 69	15 4	15 0	9 21	8 69	15 7	14 9
T_7	2 53	2 92	15 5	14 9	9 21	8 71	15 7	14 9
T_8	2 13	2 46	15 4	14 9	9 21	8 71	15 7	14 8
T_9	1 90	2.31	15 4	14 8	9 22	8 70	15 7	14 8
T_{10}	2 25	2 60	15 4	14 9	9 21	8 70	15 7	14 8
T_{11}	2 28	2 86	15 4	14 9	9 21	8 69	15 8	14 8
T_{12}	2 22	2 81	15 4	15 0	9 21	8 69	15 7	14 8
SEm +	0 021	0 026	0 05	0 05	0 005	0 010	0 05	0 05
C D (0 05)	0 061	0 077	—	—	—	—	—	—
FACTORS								
A Fert. P								
1 No P	1 95	2 26	15 4	14 9	9 21	8 69	15 7	14 9
2 50%P	2 15	2 51	15 4	14 9	9 21	8 70	15 7	14 9
3 100%P	2 16	2 64	15 4	14 9	9 21	8 70	15 7	14 8
C D (0 05)	0 031	0 039	—	—	—	—	—	—
B Anions								
1 No anions	1 62	2 00	15 4	14 9	9 21	8 69	15 7	14 9
2 OH^-	2 24	2 51	15 4	14 9	9 21	8 70	15 7	14 9
3 CO_3	2 35	2 76	15 4	14 9	9 21	8 70	15 7	14 9
4 SiO_3	2 15	2 55	15 4	14 9	9 21	8 69	15 7	14 8
C D (0 05)	0 035	0 045	—	—	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

4 1 10 2 Number of seeds per pod

During season I the number of seeds per pod revealed that the treatment showed no significant response

During season II also the number of seeds per pod recorded that the treatment differences were not significant

4 1 10 3 Hundred seed weight

During season I hundred seed weight recorded that the treatment differences were not significant

During season II also hundred seed weight showed no significant response with respect to various treatment combinations and factors

4 1 10 4 Pod length

During season I pod length recorded that the treatment differences were not significant

During season II also pod length recorded that the treatment differences showed no significant response

4 1 11 Grain yield of cowpea

The data on grain yield of cowpea under different treatments are given in Table 16 and Fig 5

During season I the grain yield data recorded that the treatment differences were significant and that the lowest yield of 511 kg ha^{-1} was recorded by T_1 while the highest yield of 958 kg ha^{-1} was recorded by T_7 On factorial analysis no phosphorus recorded the lowest yield of 736 kg ha^{-1} and 100% phosphorus treatment recorded the highest yield of 817 kg ha^{1} and were significant Among the anions no anions treatment recorded the lowest yield of 611 kg ha^{1} while carbonate anion recorded the highest yield of 887 kg ha^{1} and the responses were significant

During season II also the grain yield data recorded that the treatment differences were significant and that the lowest yield of 580 kg ha^{1} was recorded by T_1 while the highest yield of 1008 kg ha^{1} was recorded by T_7 On factorial analysis no phosphorus treatment recorded the lowest yield of 782 kg ha^{1} while 100% phosphorus recorded highest yield of 912 kg ha^{1}and were significant Among the anions no anions treatment recorded the lowest yield of 689 kg ha^{1} while carbonate anion treatment recorded the highest yield of 952 kg ha^{1} and were significant

On pooled analysis also the grain yield data recorded that the treatment differences were significant and that the lowest yield of 545 kg ha^{1} was recorded by T_1 while highest yield of 983 kg ha^{1} was recorded by T_7 On factorial analysis no phosphorus recorded the lowest yield of 759 kg ha^{1} while 100% phosphorus recorded the highest yield of 865 kg ha^{1} and were significant Among the anions no anions recorded the lowest yield of 650 kg ha^{1} whereas carbonate anion recorded the highest yield of 920 kg ha^{1} and were significant

4 1 12 Haulms yield of cowpea

The data on haulms yield of cowpea are given in Table 16

During season I haulms yield data recorded that the treatment differences were significant and that the lowest yield of 2038 kg ha^{1} was recorded by T_1 whereas the highest yield of 3791 kg ha^{1}was recorded by T_7 On factorial analysis no phosphorus treatment recorded the lowest yield of 2955 kg ha^{1} while 100%

phosphorus recorded the highest yield of 3244 kg ha ^{1} and were significant Among the anions no anions recorded the lowest yield of 2470 kg ha ^{1} and carbonate anion recorded the highest yield of 3499 kg ha ^{1} and were significant

During season II haulms yield data revealed that the treatment differences were significant and that the lowest yield of 1850 kg ha ^{1} was recorded by T_1 and the highest yield of 3214 kg ha ^{1} was recorded by T_7 On factorial analysis no phosphorus recorded the lowest yield of 2441 kg ha ^{1} and 100% phosphorus recorded the highest yield of 2980 kg ha ^{1} which was significant Among the anions no anions recorded the lowest yield of 2220 kg ha ^{1} and carbonate anion recorded the highest yield of 3010 kg ha ^{1} and were significant

On pooled analysis haulms yield data recorded that the treatment differences were significant The lowest yield of 1944 kg ha ^{1} was recorded by T_1 while the highest yield of of 3502 kg ha ^{1} was recorded by T_7 On factorial analysis while no phosphorus treatment recorded the lowest yield of 2698 kg ha ^{1} and the highest yield of 3112 kg ha ^{1} was recorded by 100% phosphorus and were significant Among the anions no anions recorded the lowest yield of 2345 kg ha ^{1} while carbonate anion recorded the highest yield of 3255 kg ha ^{1} which was again significant

4 1 13 Harvest index of cowpea

The data on the harvest index of cowpea are given in Table 17

During season I the data on the harvest index of cowpea revealed that the treatment responses were not significant

Unlike season I during season II harvest index recorded that the treatment differences were significant The lowest value of 22 7% was recorded by T_9 while

Table 17 Harvest Index (%) in Experiment No 1

Treatment No	Season I	Season II
T_1	20 1	23 9
T_2	19 9	24 9
T_3	20 3	24 8
T_4	19 6	23 4
T_5	19 9	24 3
T_6	20 8	24 2
T_7	20 2	23 9
T_8	19 9	23 4
T_9	19 6	22 7
T_{10}	20 4	23 6
T_{11}	20 2	23 6
T_{12}	20 3	23 5
SEm±	0 003	0 003
C D (0 05)	—	0 010
FACTORS		
A Fert P		
1 No P	20 0	24 2
2 50%P	20 2	23 9
3 100%P	20 1	23 4
C D (0 05)	—	0 005
B Anions		
1 No anions	19 9	23 6
2 OH^-	20 3	24 2
3 CO_3	20 2	24 1
4 SiO_3	19 9	23 4
C D (0 05)	—	0 006

Note In those places where C D is not given the F test is not significant at 5% level

the highest value of 24 9% was recorded by T7 On factorial analysis 100% phosphorus recorded the lowest value of 23 4% whereas no phosphorus recorded the highest value of 24 2% which was significant Among the anions silicate anion recorded the lowest value of of 23 4% and hydroxyl anion recorded the highest value of 24 2% which was significant

4 1 14 Protein content of grains

The data on protein content of grains are given in Table 18

During season I protein content of grains recorded that the treatment responses were significant and that the lowest value of 21 97% was recorded in T_1 while the highest value of 23 64% was recorded in T_{12} On factorial analysis no phosphorus recorded the lowest value of 22 53% while the highest value of 23 41% was recorded by 100% phosphorus and was significant Among the anions where no anions recorded the lowest value of 22 62% silicate anion recorded the highest value of 23 24% which was significant

During season II also the treatment responses were significant and that the lowest value of 22 02% was recorded by T_1 whereas the highest value of 23 68% was recorded by T_{12} On factorial analysis no phosphorus recorded the lowest value of 22 60% and 100% phosphorus recorded the highest value of 23 51% which was significant Among the anions no anions recorded the lowest value of 22 70% while silicate anion recorded the highest value of 23 33% which was again significant

4 1 15 Nitrogen uptake of cowpea

The data on nitrogen uptake of plants at various stages are given in Table 19 and Fig 6

Table 18 Protein content of grains (%) in Experiment No 1

Treatment No	Season I	Season II
T_1	21 97	22 02
T_2	22 65	22 72
T_3	22 72	22 79
T_4	22 79	22 88
T_5	22 64	22 73
T_6	23 53	23 59
T_7	23 11	23 37
T_8	23 29	23 43
T_9	23 24	23 36
T_{10}	23 18	23 43
T_{11}	23 58	23 58
T_{12}	23 64	23 68
SEm ±	0 068	0 102
C D (0 05)	0 199	0 300
FACTORS		
A Fert P		
1 No P	22 53	22 60
2 50%P	23 14	23 28
3 100%P	23 41	23 51
C D (0 05)	0 099	0 150
B Anions		
1 No anions	22 62	22 70
2 OH^-	23 12	23 25
3 CO_3	23 13	23 24
4 SiO_3	23 24	23 33
C D (0 05)	0 155	0 173

Table 19 N uptake of plants (kg ha ^{1}) in Experiment No 1

Treatment No	Season I			Season II			Pooled mean		
	30 DAS	at flowring	at harvest	30 DAS	at fowering	at harvest	30 DAS	at flowering	at harvest
T_1	10 47	41 59	54 24	12 30	41 09	54 88	11 39	41.34	54 56
T_2	16 67	67 52	87 74	18 29	62 76	79 46	17 48	65 14	83 60
T_3	17 45	71 26	90 37	18 62	64 90	79 26	18 03	68 08	84 81
T_4	16 35	66 00	87 72	17 57	60 89	79 20	16 96	63 45	83 46
T_5	12 30	53 40	65 94	14 78	49 86	64 37	13 54	51 63	65 16
T_6	19 14	81 39	97 42	21 19	72 28	88 25	20 16	76 83	92 83
T_7	20 21	85 73	104 44	22 44	77 48	96 14	21 33	81 60	100 29
T_8	17 05	71 10	88 90	17 19	64 43	82 94	17 12	67 76	85 92
T_9	14 90	63 13	80 24	17 25	60 09	78 51	16 08	61 61	79 38
T_{10}	17 70	73 07	92 27	18 98	66 66	86 91	18 34	69 86	89 59
T_{11}	17 95	74.36	93 78	21 15	63 33	95 01	19 55	68 84	94 39
T_{12}	19 78	74 26	91 12	21 19	72 61	94 69	20 49	73 44	92 91
SEm ±	0.392	0 982	1 366	0 485	0 356	1 561	0 312	0 607	1 037
C D (0 05)	1 151	2 879	4 007	1 423	1 045	4.578	0 891	1 733	2 963
FACTORS									
A Fert. P									
1 No P	15 24	61 60	80 02	16 70	57 41	73 20	15 97	59 50	76 61
2 50% P	17 18	72 90	89 17	18 90	66 01	82 93	18 04	69 46	86 05
3 100% P	17 58	71 20	89.35	19 64	65 67	88 78	18 61	68 44	89 07
C D (0 05)	0 575	1 440	2 003	0 711	1 045	2 289	0 446	0 866	1 481
B Anions									
1 No anions	12 56	52 71	66 81	14 78	50 35	65 92	13 67	51 53	66.37
2 OH	17 84	73 99	92 48	19 49	67 23	84 87	18 66	70 61	88 67
3 CO_3	18 54	77 12	96 19	20 74	68 57	90 14	19 64	72 84	93 17
4 SiO_3	17 73	70 45	89 25	18 65	65 98	85 61	18 19	68 21	87 43
C D (0 05)	0 664	1 662	2 313	0 821	1 207	2 643	0 514	1 000	1 710

During season I and season II N uptake of plants at 30 DAS recorded that the treatment differences were significant During Season I the lowest value of 10 47 kg ha ^{1} was recorded by T_1 while the highest value of of 20 21 kg ha ^{1} was recorded by T_7 On factorial analysis no phosphorus recorded the lowest value of 15 24 kg ha ^{1} whereas 100% phosphorus recorded the highest value of 17 58 kg ha ^{1}which was significant Among the anions no anions recorded the lowest value of 12 56 kg ha ^{1} and carbonate anion recorded the highest value of 18 54 kg ha ^{1} and was statistically significant

During season II the lowest value of 12 30 kg ha ^{1} was recorded in T_1 whereas the highest value of 22 44 kg ha ^{1} was recorded in T_7 On factorial analysis no phosphorus recorded the lowest value of 16 70 kg ha ^{1} while the maximum value of 19 64 kg ha ^{1} was recorded by 100% phosphorus which was statistically significant Among the anions no anion recorded the lowest value of 14 78 kg ha ^{1} while carbonate anion recorded the highest value of 20 74 kg ha ^{1} which was again significant

On pooled analysis nitrogen uptake of plants at 30 DAS showed that the treatment differences were significant and that the lowest value of 11 39 kg ha ^{1} was recorded by T_1 whereas the highest value of 21 33 kg ha ^{1} was recorded by T_7 On factorial analysis no phosphorus recorded the lowest value of 15 97 kg ha ^{1} while the highest value of 18 61 kg ha ^{1} was recorded by 100% phosphorus which was significant Among the anions while no anions recorded the lowest value of 13 67 kg ha ^{1} carbonate anion recorded the highest value of 19 64 kg ha ^{1} which was significant

During season I nitrogen uptake at flowering revealed that treatment differences were significant wherein the lowest value of 41 59 kg ha ^{1} was recorded by T_1 while the highest value of 85 73 kg ha ^{1} was recorded by T_7 which was significant On factorial analysis 50% phosphorus recorded the highest significant value of 72 90 kg ha ^{1} Among the anions no anions recorded the lowest value of 52 71 kg ha ^{1} and carbonate anion recorded the highest value of 77 12 kg ha ^{1} which was also significant During season II also the treatment differences were staitistically significant at flowering and that the lowest value of 41 09 kg ha ^{1} was recorded by T_1 while the highest value of 77 48 kg ha ^{1} was recorded by T_7 On factorial analysis no phosphorus treatment recorded the lowest value of 57 41 kg ha ^{1} and 50% phosphorus recorded the highest value of 66 01 kg ha ^{1} which was significant Among the anions carbonate anion recorded significantly highest value of 68 57 kg ha ^{1}

On pooled analysis also nitrogen uptake of plants at flowering showed that the treatment differences were significant and that the lowest value of 41 34 kg ha ^{1} was recorded by T_1 while the maximum value of 81 60 kg ha ^{1} was recorded by T_7 On factorial analysis no phosphorus recorded the lowest value of 59 50 kg ha ^{1} and the highest value of 69 46 kg ha ^{1} was recorded by 50% phosphorus treatment which was significant Among the anions no anions recorded the lowest value of 51 53 kg ha ^{1} and carbonate anion recorded the highest value of 72 84 kg ha ^{1} which was also significant

During season I and season II nitrogen uptake of plants at harvest revealed that the treatment differences were significant The lowest value of 52 24 kg ha ^{1} was recorded by T_1 while the highest value of 104 44 kg ha ^{1} was recorded by T_7 during season I On factorial analysis no phosphorus recorded the lowest value of 80 02 kg ha ^{1} and 100% phosphorus recorded the highest value of 89 35 kg ha ^{1} which was also significant Among the anions while no anions recorded the lowest value of 66 81 kg ha ^{1} carbonate anion recorded significantly highest value of 96 19 kg ha ^{1} and was significant During season II the lowest value of 54 88 kg ha ^{1} was recorded in T1 while the highest value of 96 14 kg ha 1 was recorded by T7 On factorial analysis no phosphorus recorded the lowest value of 73 20 kg ha 1 while 100% phosphorus recorded the highest value of 88 78 kg ha 1 which was significant Among the anions no anions recorded the lowest value of 65 92 kg ha 1 while carbonate anion recorded the highest value of 90 14 kg ha 1 which was again statistically significant

On pooled analysis nitrogen uptake of plants at harvest showed that the treatment differences were significant and that the lowest value of 54 56 kg ha 1 was recorded by T1 while the highest value of 100 29 kg ha 1 was recorded by T7 On factorial analysis no phosphorus recorded the lowest value of 76 61 kg ha 1 and 100% phosphorus recorded the highest value of 89 07 kg ha 1 Among the anions no anions recorded the lowest value of 66 37 kg ha 1 while carbonate anion recorded the significantly highest value of 93 17 kg ha 1 and were significant

4 1 16 Phosphorus uptake of cowpea

The data on phosphorus uptake of cowpea are given in Table 20 and Fig 7

It is seen that in respect of phosphorus uptake of plant at 30 DAS the treatment differences were significant both during season I and season II During season I the lowest value of 1 75 kg ha 1 was recorded by T1 while the highest value of 3 30 kg ha 1 was recorded by T7 On factorial analysis no phosphorus recorded the lowest value of 2 50 kg ha 1 and the highest value of 2 79 kg ha 1 was recorded by bo h 50% phosphorus and 100% phosphorus which was significant Among the anions no anions recorded the lowest value of 2 07 kg ha 1 and carbonate anion ecorded the highest value of 3 03 kg ha 1 and this was also significant

Table 20 P uptake of plants (kg ha [1]) in Experiment No 1

Treatment No	Season I			Season II			Pooled mean		
	30 DAS	at flowring	at harvest	30 DAS	at fowering	at harvest	30 DAS	at flowering	at harvest
T_1	1 75	7 80	10 90	2 09	7.37	10 70	1 92	7 58	10 80
T_2	2 69	12.30	17 30	3 04	11 12	15 37	2 87	11 71	16.34
T_3	2 85	13 09	17 99	3 06	11 49	15 67	2 96	12 29	16 83
T_4	2 70	12 24	17 20	2 99	10 74	15 89	2 84	11 49	16 54
T_5	2 02	9 43	13 28	2 50	8 94	12 88	2 26	9 18	13 08
T_6	3 02	14 09	19 23	3 46	12 16	17 53	3 24	13 13	18 38
T_7	3 30	15 30	21 14	3 67	13 35	19 49	3 49	14.33	20 32
T_8	2 80	12 78	17 91	2 84	11 17	16 62	2 82	11 98	17 26
T_9	2 44	11 45	16 24	2 89	10 45	15 83	2 66	10 95	16 04
T_{10}	2 90	13 53	18 61	3 26	11 82	17 54	3 08	12 68	18 08
T_{11}	2 93	13 58	18 98	3.59	11 37	19 26	3 26	12 47	19 12
T_{12}	2 89	13 31	18 53	3 52	12 69	18 95	3 20	13 00	18 74
SEm +	0 018	0 127	0 311	0 079	0 118	0 300	0 043	0 087	0 216
C D (0 05)	0 104	0 371	0 914	0 230	0 347	0 879	0 123	0 247	0 618
FACTORS									
A Fert. P									
1 No P	2 50	11 36	15 85	2 80	10 18	14 41	2 65	10 77	15 13
2 50% P	2 79	12 90	17 89	3 12	11 41	16 63	2 95	12 15	17 26
3 100% P	2 79	12 97	18 09	3 32	11 58	17 90	3 05	12 27	17 99
C D (0 05)	0 052	0 186	0 457	0 115	0 173	0 440	0 062	0 124	0.309
B Anions									
1 No anions	2 07	9 56	13 47	2 49	8 92	13 14	2 28	9 24	13 31
2 OH	2 87	13.31	18 38	3 25	11 70	16 82	3 06	12 51	17 60
3 CO_3	3 03	13 99	19 37	3 44	12 07	18 14	3 24	13 03	18 76
4 SO_3	2 79	12 78	17 88	3 12	11.53	17 15	2 95	12 16	17 52
C D (0 05)	0 060	0 214	0 527	0 133	0 200	0 508	0 071	0 143	0 357

highest value of 12 07 kg ha ^{1} was recorded by carbonate anion and here again the treatment differences were significant

On pooled analysis phosphorus uptake of plants at the time of flowering showed that the treatments were statistically significant and the lowest value of 7 58 kg ha ^{1} was recorded T_1 while the highest value of 14 33 kg ha ^{1} was recorded in T_7 Among the fertilizer phosphorus factors no phosphorus recorded the lowest value of 10 77 kg ha ^{1} while the highest value of 12 27 kg ha ^{1} was recorded by 100% phosphorus and again statistically significant Among the anion factors no anions gave the lowest value of 9 24 kg ha ^{1} while carbonate anion showed the highest value of 13 03 kg ha ^{1}which was also significant

The data on phosphorus uptake at harvest showed that the treatments were statistically significant both during season I and season II During season I T_1 recorded the lowest value of 10 90 kg ha ^{1} whereas T_7 showed the highest value of 21 14 kg ha ^{1} Among the fertilizer phosphorus factors no phosphorus recorded the lowest value of 15 85 kg ha ^{1} while the highest value of 18 09 kg ha ^{1} was recorded by 100% phosphorus and was significant Among the anion treatments the lowest value of 13 47 kg ha ^{1} was recorded by no anion treatment while the highest value of 19 37 kg ha ^{1} was recorded by carbonate anion and were significant During season II the lowest value of 10 70 kg ha ^{1} was recorded by T_1 while the highest value of 19 49 kg ha ^{1} was registered by T_7 Among the fertilizer phosphorus factors no phosphorus recorded the lowest value of 14 41 kg ha ^{1} while the highest value of 17 90 kg ha ^{1} was recorded by 100% phosphorus and that the differences were significant Among the anion factors the lowest value of 13 14 kg ha ^{1} was recorded by no anion whereas the highest value of 18 14 kg ha ^{1} was recorded by carbonate anion and was also significant

On pooled analysis phosphorus uptake at harvest showed that the treatment differences were significant and that T_1 recorded the lowest value of 10 80 kg ha ^{1} where as T_7 registered the highest value of 20 32 kg ha ^{1} Among the fertilizer phosphorus factors the lowest value of 15 13 kg ha ^{1} was recorded by no phosphorus treatment whereas 100% phosphorus recorded the highest value of 17 99 kg ha ^{1} and were also significant Among the anion treatments no anions recorded the lowest value of 13 31 kg ha ^{1} whereas carbonate anion recorded the highest value of 18 76 kg ha ^{1} and that differences were statistically significant

4 2 Experiement No 2 (effect of synthetic chelates as soil amendments)

4.2 1 Physical properites of soil

Soil physical properties under this experiment are given in Table 21

4 2 1 1 Bulk density of the soil

During season I and season II the bulk density of the soil did not show any significant difference after harvest

4 2 1 2 Water holding capacity of the soil

Water holding capacity of the soil showed significance after harvest during season I as well as season II During season I the value was 28 18% before sowing and after harvest T_5 recorded the lowest value of 28 46% and T_3 recorded the highest value of 31 51% Among the phosphorus levels no phosphorus recorded the highest value of 31 16% while 50% recorded the lowest value of 29 00% which was significant Chelates showed no response

During season II the water holding capacity before sowing was 29 23% After harvest T_5 registered the lowest value of 31 68% while T_7 registered the highest

Table 21 Physical properties of the soil in experiment No 2

Physical properties	Bulk dens ty (g cm 3)		Water holding capacity (%)		Mean weight diameter of aggregates from wet sieving analysis (mm)	
Experiment season	Season I	Season II	Season I	Season II	Season I	Season II
a **Before sowing**	1 21	1 23	28 18	29 23	0 90	0 79
b **After harvest**						
Treatment No						
T_1	1 31	1 30	31 22	32 82	0 97	1 10
T_2	1 33	1 31	30 74	32 83	1 01	1 04
T_3	1 31	1 30	31 51	32 39	0 99	1 06
T_4	1 31	1 33	28 81	32 53	1 03	1 01
T_5	1.33	1 29	28 46	31 68	1 01	1 08
T_6	1 33	1 32	29 73	32 76	1 03	1 11
T_7	1 30	1 32	29 18	33 74	1 05	1 08
T_8	1 30	1 32	30 65	31 91	1 00	1 05
T_9	1 32	1 31	29 73	31 70	1 03	1 07
SEm $\pm$	0 015	0 018	0 481	0 402	0 031	0 026
C D (0 05)		—	1 441	1 219	—	
FACTORS						
A. Fert. P						
1 No P	1 31	1.30	31 16	32 68	0 99	1 07
2 50%P	1.32	1 31	29 00	32 32	1 03	1 07
3 100%P	1 31	1 32	29 85	32 45	1 03	1 07
C D (0 05)	—	—	0 832	—	—	
B Chelates						
1 No chelates	1 31	1 32	29 74	33 03	1 02	1 06
2 EDTA	1 32	1 31	29 95	32 14	1 01	1 06
3 DTPA	1 32	1 31	30 32	32 28	1 02	1 08
C D (0 05)				0 703		

Note In those places where C D is not given the F test is not significant at 5% level

value of 33 74% Phosphorus showed no significant response But among the chelates EDTA recorded the lowest value of 32 14% while no chelates recorded the h ghest value of 33 03% and was significant

4 2 1 3 Mean weight diameter of aggregates

During season I the mean weight diameter of aggregates before sowing was 0 90 mm which did not vary significantly after harvest

During season II also mean weight diameter which was 0 79 mm before sowing did not vary significantly after harvest

4.2 2 Chemical properties of the soil

Chemical properties in this experiment are gien in Table 22

4.2 2 1 Cation Exchange Capacity of the soil (C E C)

During season I C E C before sowing was 4 21 me 100 g ^{1} soil After harvest there was no response between treatments

During season II C E C before sowing was 4 28 me 100 g ^{1} soil After harvest again the treatments didnot show any response

On pooled analysis C E C of the soil before sowing was 4 25 me 100 g ^{1} soil Here again the treatments were not statistically significant after harvest

4 2.2.2 pH of the soil

During season I pH of the soil before sowing was 5 12 and after harvest the treatments were statistically significant while both T_1 and T_4 recorded the lowest value of 5 12 and T_5 T_8 and T_9 recorded the highest value of 5 14 Among the phosphorus levels no phosphorus and 50% phosphorus registered the lowest value

Table 22 Chemical properties of the soil in experiment No 2

Chemical Characteristics	CEC (me/100 g)			pH			Total Nitrogen (%)		
Experiment season	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
	1	2	3	4	5	6	7	8	9
a Before sowing	4 21	4 28	4 25	5 12	5 10	5 11	0 122	0 123	0 123
b After harvest Treatment No									
T_1	4 25	4 31	4 28	5 12	5 10	5 11	0 122	0 124	0 123
T_2	4 41	4 42	4 42	5 13	5 12	5 13	0 124	0 123	0 124
T_3	4 39	4 43	4 41	5 13	5 12	5 13	0 122	0 123	0 123
T_4	4 46	4 38	4 42	5 12	5 11	5 12	0 124	0 123	0 124
T_5	4 42	4 44	4 43	5 14	5 12	5 13	0 123	0 123	0 123
T_6	4 37	4 42	4 40	5 13	5 12	5 13	0 124	0 123	0 124
T_7	4 27	4 43	4 35	5 13	5 11	5 12	0 121	0 123	0 122
T_8	4 53	4 40	4 47	5 14	5 13	5 14	0 124	0 124	0 124
T_9	4 54	4 44	4 49	5 14	5 13	5 14	0 122	0 124	0 123
SEm $\pm$	0 116	0 079	0 070	0 003	0 002	0 002	0 0012	0 0010	0 0008
C D (0 05)	—	—		0 008	0 006	0 005	—		
FACTORS									
A. Fert. P									
1 No P	4 35	4 39	4 37	5 13	5 12	5 12	0 123	0 123	0 123
2 50%P	4 42	4 41	4 42	5 13	5 12	5 12	0 124	0 123	0 123
3 100%P	4 45	4 42	4 43	5 14	5 13	5 13	0 123	0 124	0 123
C D (0 05)		—		0 004	0 003	0 003		—	
B Chelates									
1 No chelates	4 32	4 37	4.35	5 12	5 11	5 12	0 122	0 123	0 123
2 EDTA	4 46	4 42	4 44	5 14	5 13	5 13	0 124	0 123	0 124
3 DTPA	4 44	4 43	4 43	5 13	5 12	5 13	0 123	0 124	0 123
C D (0 05)		—		0 004	0 003	0 003		—	—

Contd

Table 22 (Contd)

Chemical Characterist cs	Total phosphorus [P] (ppm)			P Fixing capacity (µg P g 1)			Organic matter content (%)		
Experiment season	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
	10	11	12	13	14	15	16	17	18
a Before sowing	371	376	374	28 7	28 4	28 6	2 19	2 22	2 21
b After harvest Treatment No									
T_1	364	368	366	28 6	28 4	28 5	2 18	2 21	2 20
T_2	361	366	364	28 8	28 5	28 7	2 17	2 20	2 19
T_3	360	362	361	28 8	28 8	28 8	2 18	2 20	2 19
T_4	362	365	363	28 7	28 7	28 7	2 17	2 20	2 19
T_5	359	363	361	28 8	28 7	28 8	2 16	2 19	2 18
T_6	358	364	361	28 7	28 7	28 7	2 16	2 19	2 18
T_7	360	366	363	28 7	28 6	28 7	2 16	2 19	2 17
T_8	361	365	363	28 8	28 5	28 6	2 15	2 17	2 16
T_9	362	364	363	28 7	28 5	28 6	2 15	2 18	2 16
SEm±	2 9	3 0	2 1	0 10	0 14	0 08	0 033	0 044	0 027
C D (0 05)	—	—	—	—	—	—	—	—	—
FACTORS									
A Fert. P									
1 No P	362	366	364	28 7	28 6	28 7	2 18	2 21	2 19
2 50%P	360	364	362	28 7	28 7	28 7	2 17	2 19	2 18
3 100%P	361	365	363	28 7	28 5	28 6	2 15	2 18	2 16
C D (0 05)	—	—	—	—	—	—	—	—	—
B Chelates									
1 No chelates	362	366	364	28 7	28 6	28 6	2 17	2 20	2 18
2 EDTA	360	365	363	28 8	28 6	28 7	2 16	2 19	2 18
3 DTPA	360	363	362	28 7	28 7	28 7	2 16	2 19	2 18
C D (0 05)	—	—	—	—	—	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

of 5 13 whereas 100% phosphorus recorded the highest value of 5 14 which was significant Among the chelates no chelates recorded the lowest value of 5 12 whereas EDTA recorded the highest value of 5 14 which was also significant

During season II pH of the soil before sowing was 5 10 Here again the treatments were statistically significant after harvest While T_1 recorded the lowest value of 5 10 both T_8 and T_9 recorded the highest value of 5 13 Among the fertilizer levels both no phosphorus and 50% phosphorus recorded the lowest value of 5 12 whereas 100% phosphorus recorded the highest value of 5 13 which was statistically significant Among the chelates while no chelates recorded the lowest value of 5 11 EDTA recorded the highest value of 5 13 and difference was statistically significant

On pooled analysis pH of the soil before sowing was 5 11 and after harvest the treatments were statistically significant Here T_1 recorded the lowest value of 5 11 while both T_8 and T_9 recorded the highest value of 5 14 Among the phosphorus levels no phosphorus and 50% phosphorus recorded the lowest value of 5 12 100% phosphorus recorded the highest value of 5 13 and the difference was significant Among chelates no chelates gave the value of 5 12 while EDTA as DTPA registered the highest value of 5 13 and hereagain the difference was statistically significant

4 ? 2.3 Total nitrogen content of the soil

During season I nitrogen content soil which was 0 122% before sowing did not differ significantly after harvest

During season II also the nitrogen content soil which was 0 123% before sowing did not differ significantly after h irvest

On pooled analysis nitrogen content of the soil before sowing recorded a value of 0 123% which did not differ significantly after harvest

4.2 2 4 Total phosphorus content of the soil

During season I it is observed that total phosphorus content of the soil before sowing was 371 ppm However after harvest the treatment differences were not statistically significant

During season II also the total phosphorus content of soil which was 376 ppm before sowing did not differ significantly after harvest

On pooled analysis total phosphorus was found to be 374 ppm before sowing However after harvest the treatment differences were not statistically significant

4.2.2 5 Phosphorus fixing capacity of the soil

The phosphorus fixing capacity of the soil 28 7 $\mu g\ P\ g^{-1}$ during season I which did not differ significantly after harvest

During season II the phosphorus fixing capacity of the soil before sowing was 28 4 $\mu g\ P\ g^{-1}$ and after harvest the treatment differences were not significant

On pooled analysis the phosphorus fixing capacity of the soil before sowing was found to be 28 6 $\mu g\ P\ g^{-1}$ and after harvest the treatments were not statistically significant

4 2 2 6 Organic matter content of the soil

During season I organic matter content of the soil before sowing was 2 19% The treatment differences were not statistically significant after harvest

During season II organic matter content of the soil before sowing was 2 22% Hereagain after harvest the treatment differences were not statistically significant

On pooled analysis organic matter content of the soil before sowing was 2 21% whereas after harvest there was no response between treatments

4.2.3 Available phosphorus content of the soil

The data on the available phosphorus content of the soil in this experiemnt are given in Table 23

During season I the available phosphorus content of the soil before sowing was 7 29 mg P kg^{1} which showed significance 30 days after sowing with respect to different treatments Here the lowest value of 9 97 mg P kg^{1} recorded by T_1 where as T_8 registered the highest value of 14 18 mg P kg^{1}

During season II the available phosphorus content of the soil exhibited the same trend as in the case of season I

In the season I the available phosphorus content of the soil after harvest recorded that the treatments differed significantly with T_1 registering the lowest value of 7 44 mg P kg^{1} whereas T_9 recording the highest value of 11 45 mg P kg^{1} Among the phosphorus levels no phosphorus recorded the lowest value of 8 81 mg P kg^{1} whereas the highest value of 10 88 mg P kg^{1} was recorded by 100% phosphorus This difference was statistically significant also In the case of chelates the lowest value of 8 96 mg P kg^{1} was recorded by no chelates whereas EDTA regis ered the significantly highest value of 10 35 mg P kg^{1} and was significant

In season II also the available phosphorus content of the soil after harvest recorded statistical significance among treatments Here T_1 recorded the lowest value o 8 21 mg P kg^{1} whereas T_8 registered the highest value of 11 18 mg P kg^{1}

Table 23 Available P content of the soil (mg P kg $^{-1}$) in Experiment No 2

Treatment No	Before sowing			30 DAS			After harvest		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
T_1	7 29	7 16	7 23	9 97	8 68	9.33	7 44	8 21	7 83
T_2	7 29	7 16	7 23	12 27	11 54	11 91	9.51	9 11	9.31
T_3	7 29	7 16	7 23	12 09	11 49	11 79	9 48	9 04	9 26
T_4	7 29	7 16	7 23	10 11	9 78	9 95	9 65	8 99	9.32
T_5	7 29	7 16	7 23	13 18	13 07	13 13	10 14	9 28	9 71
T_6	7 29	7 16	7 23	13 15	12 92	13 04	10 08	9 24	9 66
T_7	7 29	7 16	7 23	10 20	10 14	10 17	9 79	9 24	9 52
T_8	7 29	7 16	7 23	14 18	13 58	13 88	11 39	11 18	11 29
T_9	7 29	7 16	7 23	14 09	13 49	13 79	11 45	11 12	11 29
SEm±	0	0	0	0 634	0 409	0.377	0 396	0 297	0 247
C D (0 05)	—	—	—	1 901	1 225	1 088	1 186	0 890	0 713
FACTORS									
A Fert. P									
1 No P	7.29	7 16	7 23	11 44	10 57	11 01	8 81	8 79	8 80
2 50%P	7 29	7 16	7 23	12 15	11 92	12 04	9 96	9 17	9 57
3 100%P	7 29	7 16	7 23	12 82	12 40	12 61	10 88	10 52	10 70
C D (0 05)	—	—	—	—	0 707	0 628	0 685	0 514	0 412
B Chelates									
1 No chelates	7 29	7 16	7 23	10 09	9.54	9 82	8 96	8 82	8 89
2 EDTA	7 29	7 16	7 23	13 21	12 73	12 97	10 35	9 86	10 10
3 DTPA	7 29	7 16	7 23	13 11	12 63	12 87	10 34	9 80	10 07
C D (0 05)	—	—	—	1 097	0 707	0 628	0 685	0 514	0 412

Note In those places where C D is not given, the F test is not significant at 5% level

Among the fertilizer phosphorus levels no phosphorus gave the minimum value of 8 79 mg P kg^{1} while 100% phosphorus registered the highest value of 10 52 mg P kg^{1} On analysis these differences were found to be statistically significant Among the chelates DTPA recorded the lowest value of 9 80 mg P kg^{1} while EDTA recorded the highest value of 9 86 mg P kg^{1} which was also statistically significant

On pooled analysis also the available phosphorus soil after harvest gave the same results as given in the two seasons

4.2 4 Soil phosphorus fractions

The data on soil phosphorus fractions are given in Table 24 25 and 26

4.2 4 1 Saloid P of the soil (Sal-P)

In season I saloid P which was 16 1 ppm before sowing varied significantly at flowering T_1 registered the lowest value of 24 0 ppm whereas T_8 registered the highest value of 33 7 ppm Among the fertilizer phosphorus levels while no phosphorus registered the lowest value of 28 3 ppm 100% phosphorus registered the highest value of 29 9 ppm which was significant Among the chelates when no chelates recorded the lowest value of 24 6 ppm EDTA registered the highest value of 32 8 ppm Here again the difference was significant After harvest also treatments showed statistical significance Here both T_1 and T_4 gave the lowest value of 23 0 ppm whereas T_8 showed the highest value of 30 7 ppm When the phosphorus levels did not vary significantly chelates showed significant variations on analysis When no chelates recorded the least value of 23 1 ppm EDTA gave the highest value of 30 1 ppm

During season II saloid P of the soil before sowing was only 14 0 ppm and at flowering the treatments recorded statistical significance While T_1 gave the lowest

Table 24 Soil phosphorus (P) fractions (ppm) in Experiment No 2 for season I

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	16 1	45 0	28 2	18 5	15 1	18 1	230 0	371 0
b At flowering Treatment No								
T_1	24 0	41 0	26 0	21 0	17 0	18 0	219 7	366 7
T_2	32 0	35.3	24 3	22 0	17 0	17 7	217 0	365.3
T_3	29 0	35 7	24 7	21 7	17 0	17 7	218 3	364 0
T_4	24.3	40 7	26 3	20 7	16 7	18 0	219 0	365 7
T_5	32 7	35 0	24.3	21.3	17 3	17 7	217 7	364 7
T_6	30 0	36 7	24 0	20 7	17 0	17 7	217 3	363 3
T_7	25 3	40 0	26 0	20 3	16 7	17.3	217 0	362 7
T_8	33 7	34 7	23 7	21.3	17 3	17 7	217 0	365.3
T_9	30 7	36 7	24 7	21 3	17 0	18 0	219 0	366 7
SEm±	0 58	0 41	0 25	0 29	0 24	0 27	1 89	3 44
C D (0 05)	1 74	1 22	0 76	0 88	—	—	—	—
FACTORS								
A Fert. P								
1 No P	28 3	37 3	25 0	21 6	17 0	17 8	218 3	365.3
2 50%P	29 0	37 4	24 9	20 9	17 0	17 8	218 0	364 6
3 100%P	29 9	37 1	24 8	21 0	17 0	17 7	217 7	364 9
C D (0 05)	1 00	—	—	0 51	—	—	—	—
B Chelates								
1 No chelates	24 6	40 6	26 1	20 7	16 8	17 8	218 6	365 0
2 EDTA	32 8	35 0	24 1	21 6	17 2	17 7	217 2	365 1
3 DTPA	29 9	36 3	24 4	21 2	17 0	17 8	218 2	364 7
C D (0 05)	1 00	0 70	0 44	0 51	—	—	—	—

Contd

Table 24 (contd)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	23 0	40 3	25 7	20 7	17 0	18 0	219 3	364 0
T_2	30 0	34 7	23 7	21 7	16 3	17 7	217 3	361 3
T_3	28.3	35 3	24 0	21 0	17 0	17 7	217 0	360 3
T_4	23 0	39 3	25 7	21 0	17 0	18 0	218 0	361 7
T_5	29 7	35.3	23 7	20 0	17 0	17 3	216 3	359.3
T_6	26 7	35 7	24 0	20 7	17 0	17 7	216 7	358 3
T_7	23 3	39.3	25 3	20 3	16 3	17.3	217 7	359 7
T_8	30 7	34 3	23 0	20 7	17 3	17 0	217 7	360 7
T_9	26 7	36 3	24 0	21 0	17 0	18 0	219 3	362.3
SEm ±	0 45	0 29	0 26	0 33	0 19	0 25	1 78	2 92
C D (0 05)	1.36	0 86	0 79	—	—	—	—	—
FACTORS								
A Fert. P								
1 No P	27 1	36 8	24 4	21 1	16 8	17 8	217 9	361 9
2 50%P	26 4	36 8	24 4	20 6	17 0	17 8	217 0	359 8
3 100%P	26 9	36 7	24 1	20 7	16 9	17 4	218 2	360 9
C D (0 05)	—	—	—	—	—	—	—	—
B Chelates								
1 No chelates	23 1	39 7	25 6	20 7	16 8	17 8	218 3	361 8
2 EDTA	30 1	34 8	23 4	20 8	16 9	17 3	217 1	360 4
3 DTPA	27 2	35 8	24 0	20 9	17 0	17 8	217 7	360.3
C D (0 05)	0 79	0 50	0 46	—	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

Table 25 Soil phosphorus (P) fractions (ppm) in Experiment No 2 for season II

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	14 0	42 1	28 3	18 2	15 1	19 2	239 1	376 0
b At flowering								
Treatment No								
T_1	25 0	41 0	26 7	19 3	14 7	18 0	227 7	372.3
T_2	32 0	36 0	25 0	22 0	17 0	18 0	219 7	369 7
T_3	29 0	35 7	25 0	22 0	17 0	18 0	220 7	367.3
T_4	25 7	37 7	26 3	19 3	14 3	18 3	227 7	369.3
T_5	32 7	35 7	24 7	21 7	17 0	17 7	218 3	367 7
T_6	27.3	36 0	25 3	21 3	17 0	17 7	223 7	368.3
T_7	25 3	38 3	27 0	19 7	14 7	18 7	226 7	370.3
T_8	32 7	35 3	25 0	22 0	17 0	18 0	218 3	368.3
T_9	32 0	36 0	25 3	21 3	17 3	17 7	219 7	369 3
SEm±	0 87	0 47	0 32	0 29	0 23	0 25	2 53	3 96
C D (0 05)	2 60	1 42	0 95	0 86	0 68	0 76	7 57	—
FACTORS								
A Fert. P								
1 No P	28 7	37 6	25 6	21 1	16 2	18 0	222 7	370 7
2 50%P	28 6	36 4	25 4	20 8	16 1	17 9	223 2	368 6
3 100%P	30 0	36 6	25 8	21 0	16 3	18 1	221 6	368.3
C D (0 05)	—	0 82	—	—	—	—	—	—
B Chelates								
1 No chelates	25 3	37 6	26 7	19 4	14 6	18 3	227 3	370 7
2 EDTA	32 4	36 4	24 9	21 9	17 0	17 9	218 8	368 6
3 DTPA	29 4	36 6	25 2	21 6	17 1	17 8	221 3	368 3
C D (0 05)	1 50	0 82	0.55	0 50	0.39	0 44	4.37	—

Contd

Table 25 (Contd)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	25 0	40 0	26 0	19 0	14 7	18 0	225 7	368 3
T_2	26 7	35 7	23 7	21 7	17 0	17.3	224 3	366 3
T_3	23 3	35 0	24 7	22 0	17 0	17 7	222 7	362 3
T_4	23 7	37 3	26 0	19 0	14 7	18 7	225 7	365 0
T_5	24 7	35.3	24 0	21 3	17 0	17.3	223 7	363.3
T_6	24 3	35 3	25 0	21 0	17 0	17 3	223 7	363 7
T_7	24.3	37 3	26 7	20 0	15 0	18 7	224 7	365 7
T_8	25 7	35 0	25 0	21 0	17 0	17.3	223 7	364 7
T_9	24 7	35 7	24 7	21 0	17 0	17 7	223 7	364.3
SEm±	0 43	0.34	0 23	0 17	0 15	0.33	1 84	3 04
C D (0 05)	1 28	1 01	0 70	0 50	0 44	0 98	—	—
FACTORS								
A Fert. P								
1 No P	25 0	36 9	24 8	20 9	16 2	17 7	224 2	365 7
2 50%P	24 2	36 0	25 0	20 4	16 2	17 8	224 3	364 0
3 100%P	24 9	36 0	25 4	20 7	16 3	17 9	224 0	364 9
C D (0 05)	—	0.58	0 40	0 29	—	—	—	—
B Chelates								
1 No chelates	24 3	38 2	26 2	19.3	14 8	18 4	225 3	366 3
2 EDTA	25 7	35 3	24 2	21 3	17 0	17.3	223 9	364 8
3 DTPA	24 1	35 3	24 8	21.3	17 0	17 6	223 3	363 4
C D (0 05)	0 74	0 58	0 40	0 29	0 25	0.56	—	—

Note In those places where C D is not given the F test is not significant at 5% level

Table 26 Soil phosphorus (P) fractions (ppm) in Experiment No 2 (pooled mean)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	15 1	43 6	28 3	18 4	15 1	18 7	234 6	373 8
b At flowering								
Treatment No								
T_1	24 5	41 0	26 3	20 2	15 8	18 0	223 7	369 5
T_2	32 0	35 7	24 7	22 0	17 0	17 8	218 3	367.5
T_3	29 0	35 7	24 8	21 8	17 0	17 8	219 5	365 7
T_4	25 0	39 2	26 3	20 0	15 5	18 2	223 3	367.5
T_5	32 7	35.3	24.5	21 5	17 2	17 7	218 0	366 2
T_6	28 7	36 3	24 7	21 0	17 0	17 7	220 5	365 8
T_7	25 3	39 2	26 5	20 0	15 7	18 0	221 8	366.5
T_8	33 2	35 0	24 3	21 7	17 2	17 8	217 7	366 8
T_9	31 3	36 3	25 0	21 3	17 2	17 8	219 3	368 0
SEm±	0 52	0 31	0 20	0 21	0 16	0 19	1.58	2 62
C D (0 05)	1 51	0 90	0 59	0 59	0 47	—	4 55	—
FACTORS								
A Fert. P								
1 No P	28 5	37 4	25 3	21 3	16 6	17 9	220 5	367 6
2 50%P	28 8	36 9	25 2	20 8	16 6	17 8	220 6	366 5
3 100%P	29 9	36 8	25.3	21 0	16 7	17 9	219 6	367 1
C D (0 05)	0 87	—	—	0 34	—	—	—	—
B Chelates								
1 No chelates	24 9	39 8	26 4	20 1	15 7	18 1	222 9	367 8
2 EDTA	32 6	35.3	24 5	21 7	17 1	17 8	218 0	366 8
3 DTPA	29 7	36 1	24 8	21 4	17 1	17 8	219 8	366 5
C D (0 05)	0 87	0 52	0 34	0 34	0 27	—	2 63	—

Contd

Table 26 (Contd)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c. After harvest								
Treatment No								
T_1	24 0	40 2	25 8	19 8	15 8	18 0	222 5	366 2
T_2	28 3	35 2	23 7	21 7	16 7	17 5	220 8	363 8
T_3	25 8	35 2	24.3	21 5	17 0	17 7	219 8	361.3
T_4	23 3	38 3	25 8	20 0	15 8	18.3	221 8	363 3
T_5	27 2	35.3	23 8	20 7	17 0	17.3	220 0	361 3
T_6	25 5	35 5	24 5	20 8	17 0	17.5	220 2	361 0
T_7	23 8	38.3	26 0	20 2	15 7	18 0	221 2	362 7
T_8	28 2	34 7	24 0	20 8	17 2	17 2	220 7	362 7
T_9	25 7	36 0	24 3	21 0	17 0	17 8	221 5	363 3
SEm±	0.31	0 22	0 18	0 18	0 12	0 21	1 28	2 11
C D (0 05)	0 90	0 64	0.51	0 53	0 35	0 59	—	—
FACTORS								
A Fert. P								
1 No P	26 1	36 8	24 6	21 0	16 5	17 7	221 1	363 8
2 50%P	25 3	36 4	24 7	20 5	16 6	17 7	220 7	361 9
3 100%P	25 9	36 3	24 8	20 7	16 6	17 7	221 1	362 9
C D (0 05)	0.52	0.37	—	0 31	—	—	—	—
B Chelates								
1 No chelates	23 7	38 9	25 9	20 0	15 8	18 1	221 8	364 1
2 EDTA	27 9	35 1	23 8	21 1	16 9	17.3	220 5	362 6
3 DTPA	25 7	35 6	24 4	21 1	17 0	17 7	220 5	361 9
C D (0 05)	0 52	0 37	0 29	0 31	0 20	0 34	—	—

Note In those places where C D is not given the F test is not significant at 5% level

value of 25 0 ppm both T_5 and T_8 gave the highest value of 32 7 ppm There was no response for fertilizer phosphorus levels whereas chelates gave statistical significance Here no chelates gave the lowest value of 25 3 ppm while EDTA gave the highest value of 32 4 ppm After harvest of the experiment saloid P was found to vary significantly with T_3 recording the lowest value of 23 3 ppm while T_2 recording the highest value of 26 7 ppm When phosphorus levels were not significant chelates gave statistical significance With the case of chelates DTPA gave the lowest value of 24 1 ppm whereas EDTA gave the highest value of 25 7 ppm

Pooled analysis revealed a saloid P of 15 1 ppm before sowing At flowering treatments showed statistical significance The lowest value of 24 5 ppm was recorded in T_1 whereas T_8 gave the highest value of 33 2 ppm Fertilizer phosphorus levels also showed statistical significance Here no phosphorus recorded the lowest value of 28 5 ppm whereas the highest value of 29 9 ppm was recorded by 100% phosphorus treatment Chelates also showed significant differences on statistical analysis with the lowest value of 24 9 ppm recording in no chelates treatment whereas EDTA recording the highest value of 32 6 ppm After harvest also treatment varied significantly Here T_4 recorded the lowest value of 23 3 ppm whereas T_2 recorded the highest value of 28 3 ppm Here again phosphorus levels showed statistical significance 50% phosphorus showed the least value of 25 3 ppm whereas no phosphorus gave the highest value of 26 1 ppm In respect of chelate treatments no chelates gave the lowest value of 23 7 ppm whereas EDTA gave the highest value of 27 9 ppm which was also significant

4 2 4 2 Aluminium P of the soil (Al-P)

Aluminium P content of the soil which was 45 0 ppm before sowing recorded significant variations at flowering While T_8 recorded the lowest value of 34 7 ppm

T_1 recorded the highest value of 41 0 ppm However phosphorus levels did not differ significantly In the case of chelates when EDTA recorded the lowest value of 35 0 ppm no chelates registered the highest significant value of 40 6 ppm

After harvest treatments differed significantly Here T_8 recorded the lowest value of 34 3 ppm whereas T_1 recorded the highest value of 40 3 ppm Here again the phosphorus levels did not vary significantly However chelate treatments recorded significant variation on statistical analysis EDTA gave the lowest value of 34 8 ppm whereas no chelates gave the highest value of 39 7 ppm

During season II Aluminium P recorded a value of 42 1 ppm before sowing At flowering treatments differed statistically with T_8 recording the lowest value of 35 3 ppm and T_1 recording the highest value of 41 0 ppm Fertilizer phosphorus levels also varied significantly at flowering 50% phosphorus recorded the lowest value of 36 4 ppm whereas no phosphorus recorded the highest value of 37 6 ppm Chelate treatments also varied significanly Here EDTA recorded the lowest value of 36 4 ppm whereas no chelates recorded the highest value of 37 6 ppm

After harvest also the treatment combination varied significantly Both T_3 and T_8 registered the lowest value of 35 0 ppm whereas T_1 recorded the highest value of 40 0 ppm Phosphorus also significantly varied after harvest Both 50% phosphorus and 100% phosphorus recorded the lowest value of 36 0 ppm whereas no phosphorus recorded the highest value of 36 9 ppm In the case of chelates both EDTA and DTPA gave the lowest value of 35 3 ppm whereas no chelates the highest significant value of 38 2 ppm

Pooled analysis recorded an aluminium P of 43 6 ppm before sowing On pooled analysis also, the treatments gave significance at flowering Here T_8 recorded the lowest value of 35 0 ppm whereas T_1 recorded the highest value of

41 0 ppm Phosphorus levels did not show any response on pooled analysis However chelates recorded significant variation EDTA recorded the lowest value of 35 3 ppm whereas no chelates recorded the highest value of 39 8 ppm After harvest also the treatments varied significantly Here T_8 registered the lowest value of 34 7 ppm whereas T_1 recorded the highest value of 40 2 ppm Phosphorus levels also varied significantly after harvest with 100% phosphorus recording the lowest value of 36 3 ppm and no phosphorus recording the highest value of 36 8 ppm In respect of chelate treatments EDTA recorded the lowest value of 35 1 ppm whereas no chelates recorded the highest significant value of 38 9 ppm

4 2 4.3 Iron P of the soil (Fe P)

In season I Fe P before sowing was 28 2 ppm It is revealed that at flowering treatments recorded statistical significance At this stage T_8 recorded the lowest value of 23 7 ppm whereas T_4 recorded the highest value of 26 3 ppm However phosphorus levels did not vary significantly whereas chelate treatments varied significantly While EDTA showed the least value of 24 1 ppm no chelates recorded the highest value of 26 1 ppm After harvest also the treatments showed statistical significance Here T_8 recorded the lowest value of 23 0 ppm whereas both T_1 and T_4 recorded the highest value of 25 7 ppm Here again phosphorus levels did not vary significantly whereas chelates showed statistical significance At this stage EDTA recorded the lowest value of 23 4 ppm while no chelates recorded the highest value of 25 6 ppm

During season II Fe P before sowing was found to be 28 3 ppm which varied significantly at flowering due to different treatment combinations At this stage T_5 recorded the lowest value of 24 7 ppm whereas T_7 recorded the highest value of 27 0 ppm However phosphorus levels did not vary significantly whereas chelate application showed statistical significance When EDTA recorded the lowest value of 24 9 ppm no chelates recorded the highest value of 26 7 ppm

After harvest also the treatments varied significantly Here T_2 registered the lowes value of 23 7 ppm whereas T_7 recorded the highest value of 26 7 ppm Here again phosphorus levels varied significantly with no phosphorus recording the lowest value of 24 8 ppm and 100% phosphorus recording the highest value of 25 4 ppm Chelates also recorded statistical significance with EDTA recording the lowest value of 24 2 ppm whereas no chelates recorded the highest value of 26 2 ppm

On pooled analysis Fe P before sowing was found to give same value as that in season II (28 3 ppm) At flowering treatments varied significantly Here T_8 recorded the lowest value of 24 3 ppm whereas T_7 recorded the highest value of 26 5 ppm In pooled analysis also phosphorus levels did not vary significantly whereas chelates recorded statistical significance When the lowest value of 24 5 ppm was recorded by EDTA treatment no chelates registered the highest value of 26 4 ppm After harvest also the treatments were found to be significantly different Here T_2 recorded the lowest value of 23 7 ppm whereas T_7 recorded the highest value of 26 0 ppm Hereagain the phosphorus levels did not vary significantly whereas chelates showed statistical significance The lowest value of 23 8 ppm was recorded by EDTA whereas the highest value of 25 9 ppm was recorded by no chelates

4 2 4 4 Reductant soluble P of the soil (Red - P)

During the first season as well as second season Red P at flowering recorded statistical significance In the first season T_1 recorded the lowest value of 21 0 ppm whereas T_2 recorded the highest value of 22 0 ppm However with second season both T_1 and T_4 registered the lowest value of 19 3 ppm whereas the highest value of 22 0 ppm was recorded by T_2, T_3 and T_8 Phosphorus levels also varied significantly in the first season 50% phosphorus recorded the lowest value of 20 9 ppm whereas no phosphorus recorded the highest value of 21 6 ppm Chelate application also showed significant variation in Red P on statistical analysis in the first season while no chelates gave the lowest value of 20 7 ppm EDTA recorded the highest value of 21 6 ppm In second season there was no response with phosphorus levels where as chelates showed significant variation while no chelates gave the lowest value of 19 4 ppm EDTA recorded the highest value of 21 9 ppm

After harvest when the treatments did not show any statistical significance in season I they showed significance in season II In season II T_1 and T_4 recorded the lowest value of 19 0 ppm T_3 recorded the highest value of 22 0 ppm Phosphorus levels did not vary significantly in season I whereas it was significant in season II Thus in season II 50% phosphorus recorded the lowest value of 20 4 ppm whereas no phosphorus recorded the highest value of 20 9 ppm When chelates could not show statistical significance in season I it was significant in season II No chelates showed the lowest value of 19 3 ppm whereas both EDTA and DTPA showed the highest value of 21 3 ppm

On pooled analysis Red P before sowing was found to be 18 4 ppm At flowering both T_7 and T_4 recorded the lowest value of 20 0 ppm whereas T_2 recorded the highest significant value of 22 0 ppm Regarding phosphorus levels 50% phosphorus registered the lowest value of 20 8 ppm whereas no phosphorus recorded the highest significant value of 21 3 ppm Chelates also showed statistical significance Among chelates no chelates recorded the lowest value of 20 1 ppm whereas EDTA recorded the highest value of 21 7 ppm After harvest also the treatments varied significantly T_1 recording the lowest value of 19 8 ppm and T_2

recording the highest value of 21 7 ppm Phosphorus also varied significantly wherein 50% phosphorus recorded the lowest value of 20 5 ppm whereas no phosphorus recorded the highest value of 21 0 ppm Among the chelates no chelates recorded the lowest value of 20 0 ppm whereas both EDTA and DTPA and recorded the highest significant value of 21 1 ppm

4.2 4 5 Occluded P of the soil (Occl- P)

In season I treatments did not record any significant difference at flowering from 15 1 ppm recording before sowing Phosphorus as well as chelates also did not vary significantly not only at flowering but after harvest also

During the second season occluded P which was 15 1 ppm before sowing recorded significant variation at flowering When T_4 recorded the lowest value of 14 3 ppm and T_9 recorded the highest value of 17 3 ppm However phosphorus levels did not vary significantly whereas chelates application showed statistical significance Among the chelates no chelates recorded the lowest value of 14 6 ppm whereas DTPA recorded the highest value of 17 1 ppm After harvest also treatments recorded statistical significance Both T_1 and T_4 recorded the lowest value of 14 7 ppm whereas T_2, T_3 T_5 T_6 T_8 and T_9 recorded the highest value of 17 0 ppm While phosphorus levels could not vary significantly chelates recorded statistical significance Among chelates no chelates recorded the lowest value of 14 8 ppm whereas both EDTA and DTPA recorded the highest value of 17 0 ppm

On pooled analysis occluded P was found to be 15 1 ppm before sowing At flowering whereas T_4 recorded the lowest value of 15 5 ppm T_5 T_8 and T_9 recorded the highest value of 17 2 ppm While phosphorus levels did not vary significantly chelates recorded statistical significance Among chelates no chelates recorded the lowest value of 15 7 ppm whereas both EDTA and DTPA registered the hıghest value of 17 1 ppm After harvest also the treatments varıed sıgnıficantly Here T7 recorded the lowest value of 15 7 ppm whereas T8 recorded the hıghest value of 17 2 ppm While phosphorus levels dıd not vary sıgnıficantly chelates recorded statıstıcal sıgnıficance No chelates recorded the lowest value of 15 8 ppm and DTPA recorded the hıghest value of 17 0 ppm

4.2 4 6 Calcıum P of the soıl (Ca P)

Durıng season I the treatments dıd not record any sıgnıficant varıatıon at flowerıng Phosphorus levels and chelates also dıd not make any sıgnıficant varıatıon After harvest also Ca P of the soıl dıd not vary sıgnıficantly

Durıng season II Ca P of the soıl before sowıng was 19 2 ppm as compared to 18 1 ppm durıng the first season The treatment recorded sıgnıficant varıatıon at flowerıng T5 T6 and T9 recorded the lowest value of 17 7 ppm whereas T7 recorded the hıghest value of 18 7 ppm Phosphorus levels however dıd not show any statıstıcal sıgnıficance But chelates recorded statıstıcal sıgnıficance whereın DTPA recorded the lowest value of 17 8 ppm whereas no chelates recorded the hıghest value of 18 3 ppm Wıth respect to Ca P of the soıl after harvest also the treatments recorded sıgnıficant varıatıon T2 T5 T6 and T8 recorded the lowest value of 17 3 ppm whereas both T4 andT7 recorded the hıghest value of 18 7 ppm But at thıs stage phosphorus levels dıd not vary sıgnıficantly whereas chelates showed statıstıcal sıgnıficance Among chelates EDTA recorded the lowest value of 17 3 ppm whereas no chelates recorded the hıghest value of 18 4 ppm

On pooled analysıs of the data ıt was found that Ca P was 18 7 ppm before sowıng and that at flowerıng the treatments dıd not vary sıgnıficantly However Ca P after harvest recorded sıgnıficant varıatıon Whıle T8 recorded the lowest value of 17 2 ppm T4 recorded the hıghest value of 18 3 ppm Whıle phosphorus levels could not make any significant variation chelates showed statistical significance Among chelates EDTA recorded the lowest value of 17 3 ppm whereas no chelates recorded the highest value of 18 1 ppm

4.2 4 7 Organic P of the soil (Org P)

It was revealed that the treatments did not show any statistical significance in this character at flowering Phosphorus levels and chelates also did not show any statistical significance After harvest also the organic **P** of the soil did not vary significantly In the season II Organic P of the soil before sowing was 239 1 ppm which recorded significant varation at flowering While both T_1 and T_4 recorded the lowest value of 227 7 ppm T_5 and T_8 recorded the highest value of 218 3 ppm While phosphorus levels did not vary significantly chelates recorded statistical significance Among chelates EDTA recorded the lowest value of 218 8 ppm whereas no chelates recorded the highest value of 227 3 ppm After harvest the treatments did not show any statistical significance

On pooled analysis organic P of the soil was found to be 234 6 ppm before sowing and that at flowering the treatments showed statistical significance While T_8 recorded the lowest value of 217 7 ppm T_1 recorded the highest value of 223 7 ppm When phosphorus levels did not vary significantly chelates recorded statistical significance Among chelates EDTA recorded the lowest value of 218 0 ppm whereas no chelates recorded the highest value of 222 9 ppm

After harvest the various treatmentscould not record any significant variation

4 2 4 8 Total phosphorus content of the soil (Total P)

Total phosphorus content of the soil before sowing was found to be 371 0 ppm during season I At flowering the treatments did not record any statistical significance

After harvest also the treatments did not show any significant difference

During season II the total phosphorus content of the soil was 376 0 ppm before sowing At flowering there was no response between treatments

After harvest also there was no response between treatments

On pooled analysis the total phosphorus content of the soil before sowing was found to be 373 8 ppm At flowering the treatments did not record any response

After harvest also there was no response between treatments

4 2 5 Leaf Area Index (LAI) of cowpea

During season I leaf area index (LAI) at 30 DAS revealed that the treatment responses were not significant

LAI at flowering showed that the treatments were statistically significant during season I While T_1 recorded the lowest value of 4 49 T_5 recorded the highest value of 7 09 Phosphorus levels as well as chelates also were statistically significant Among phosphorus levels no phosphorus recorded the lowest value of 4 65 whereas 50% phosphorus recorded the highest value of 6 28 Among chelates no chelates recorded the lowest value of 5 15 whereas EDTA recorded the highest value of 5 96

In the case of season II also the treatments were statistically significant When T_1 recorded the lowest value of 4 55 T_5 recorded the highest value of 6 31 Levels of phosphorus and chelates also were statistically significant When no phosphorus recorded the lowest value of 4 67 50% phosphorus recorded the highest value of 5 79 Among chelates no chelates recorded the lowest value of 4 93 whereas EDTA recorded the highest value of 5 50

Table 27 Leaf Area Index (LAI) in Experiment No 2

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flowering
T_1	1 37	4 49	1 34	4 55
T_2	1 15	4 81	1 30	4 80
T_3	1 12	4 64	1 31	4 65
T_4	1 33	5 21	1 32	4 99
T_5	1 28	7 09	1 27	6 31
T_6	1 36	6 55	1 23	6 07
T_7	1 30	5 76	1 30	5 26
T_8	1 33	5 98	1 43	5 38
T_9	1 34	5 80	1 44	5 18
SEm±	0 071	0 107	0 104	0 088
C D (0 05)	—	0 322	—	0 264
FACTORS				
A Fert P				
1 No P	1 22	4 65	1 32	4 67
2 50% P	1 32	6 28	1 27	5 79
3 100% P	1 33	5 85	1 39	5 27
C D (0 05)	—	0 186	—	0 152
B Chelates				
1 No chelates	1 34	5 15	1 32	4 93
2 EDTA	1 26	5 96	1 33	5 50
3 DTPA	1 27	5 66	1 33	5 30
C D (0 05)	—	0 186	—	0 152

Note In those places where C D is not given the F test is not significant at 5% level

4.2 6 Leaf Area Ratio (LAR) of plants

The data on leaf area ratio (LAR) of the plants at different stages of the experiment are given in Table 28

During season I LAR of plants at 30 DAS showed that the treatments were statistically significant T_5 recorded the lowest value of 9 92 cm^2 g^{1} whereas T_1 recorded the highest value of 16 99 cm^2 g^{1} Among phosphorus levels 50% phosphorus recorded the lowest value of 11 85 cm^2 g^{1} whereas no phosphorus recorded the highest significant value of 14 58 cm^2 g^{1} Among chelates EDTA recorded the lowest value of 11 85 cm^2 g^{1} whereas no chelates recorded the highest significant value of 14 59 cm^2 g^{1}

During season II also LAR of plants at 30 DAS showed that the treatment differences were statistically significant While T_5 recorded the lowest value of 11 22 cm^2 g^{1} T_1 recorded the highest value of 16 32 cm^2 g^{1} While phosphorus levels showed statistical significance chelates did not record significance Among phosphorus levels 50% phosphorus recorded the lowest value of 12 45 cm^2 g^{1} whereas no phosphorus recorded the highest value of 15 64 cm^2 g^{1}

In season I LAR at flowering recorded no statistical significance

During season II also LAR of plants at flowering showed that the treatments were not statistically significant

4 2 7 Leaf Weight Ratio (LWR) of the plants

The data on leaf weight ratio (LWR) of the plants in the present experiment are given in Table 29

Table 28 Leaf Area Ratio (LAR) of the plants in Experiment No 2 ($cm^2 g^{-1}$)

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flower ng
T_1	16 99	14 75	16 32	16 01
T_2	13 34	14 73	14 95	15 88
T_3	13 41	14 76	15 64	16 07
T_4	14 12	14 57	14 74	15 95
T_5	9 92	14 75	11 22	16 10
T_6	11 50	14 81	11 39	16 02
T_7	12 66	14 83	14 33	16 06
T_8	12 29	14 69	14 78	15 87
T_9	12 62	14 49	15 48	15 98
SEm±	0 856	0 117	1 198	0 106
C D (0 05)	2 566	—	3 593	—
FACTORS				
A Fert P				
1 No P	14 58	14 75	15 64	15 99
2 50% P	11 85	14 71	12 45	16 03
3 100% P	12 52	14 67	14 86	15 97
C D (0 05)	1 481	—	2 074	—
B Chelates				
1 No chelates	14 59	14 72	15 13	16 01
2 EDTA	11 85	14 72	13 65	15 95
3 DTPA	12 51	14 69	14 17	16 02
C D (0 05)	1 481	—	—	—

Note In those places where C D is not g ven the F test is ι ot significant at 5% level

Table 29 Leaf Weight Ratio (LWR) of the plants in Experiment No 2

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flower g
T_1	0 465	0 318	0 331	0 338
T_2	0 470	0 318	0 303	0 338
T_3	0 465	0 318	0 332	0 341
T_4	0 469	0 317	0 335	0 337
T_5	0 469	0 321	0 335	0 337
T_6	0 479	0 319	0 331	0 336
T_7	0 475	0 318	0 345	0 336
T_8	0 472	0 319	0 333	0 336
T_9	0 465	0 318	0 334	0 336
SEm±	0 0055	0 0027	0 0114	0 0022
C D (0 05)	—	—	—	—
FACTORS				
A Fert P				
1 No P	0 467	0 318	0 322	0 339
2 50% P	0 472	0 319	0 334	0 337
3 100% P	0 470	0 318	0 338	0 336
C D (0 05)	—	—	—	—
B Chelates				
1 No chelates	0 469	0 318	0 337	0 337
2 EDTA	0 470	0 319	0 324	0 337
3 DTPA	0 469	0 318	0 332	0 338
C D (0 05)	—	—	—	—

Note In those places where C D s not given the F test is not signif ca it at 5% level

In season I LWR of plants at 30 DAS showed that the treatments were not statistically significant

The LWR of plants at 30 DAS showed that the treatments were not statistically significant during season II also

In season I LWR of plants at flowering showed that the treatments were not statistically significant The result of season II are in accordance with that of season I at flowering

4.2 8 Number of effective nodules per plant

The data on the number of effect nodules per plant are given in Table 30

In season I number of effective nodules at 30 DAS showed that the treatments were not statistically significant

In season II the number of effective nodules at 30 DAS revealed that the treatments were statistically significant While T_3 recorded the lowest value of 14 28 T_7 recorded the highest value of 16 53 When phosphorus levels varied significantly chelates could not record any significance Among phosphorus levels no phosphorus recorded the lowest value of 14 70 whereas 100% phosphorus recorded the highest value of 16 17

On pooled analysis the number of effective nodules per plant at 30 DAS showed that the treatments were not statistically significant

At flowering it was revealed that the treatments were not statistically significant during season I

During season II also the treatments were not statistically significant at flowering

Table 30 Number of effective nodules per plant in Experiment No 2

Treatment No	Season I		Season II		Pooled mean	
	30 DAS	at flowering	30 DAS	at flowering	30 DAS	at flowering
T_1	18 35	11 48	14 52	12 02	16 43	11 75
T_2	19 98	11 26	15 32	11 90	17 65	11.58
T_3	19 64	11 87	14 28	13 49	16 96	12 68
T_4	18 02	10 78	14 29	12 09	16 16	11 44
T_5	18 29	11 10	16 09	9 70	17 19	10 40
T_6	20 60	10 93	15 85	11 95	18 23	11 44
T_7	18 66	10 07	16 53	11 81	17 60	10 94
T_8	17 72	11 02	16 28	12 26	17 00	11 64
T_9	18 75	11 01	15 69	13 02	17 22	12 02
SEm±	0 878	0 761	0 607	0 746	0 534	0 533
C D (0 05)	—	—	1 819	—	—	—
FACTORS						
A Fert. P						
1 No P	19 32	11 54	14 70	12 47	17 01	12 00
2 50%P	18 97	10 94	15 41	11 25	17 19	11 09
3 100%P	18 38	10 70	16 17	12.37	17 27	11 53
C D (0 05)	—	—	1 050	—	—	—
B Chelates						
1 No chelates	18 34	10 77	15 11	11 97	16 73	11.37
2 EDTA	18 66	11 13	15 90	11 29	17 28	11 21
3 DTPA	19 67	11 27	15 27	12 82	17 47	12 05
C D (0 05)	—	—	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

On pooled analysis the number of effective nodules per plant at flowering showed that the treatment differences were not statistically significant

4.2 9 Dry weight nodules per plant

The data on dry weight of nodules per plant are given in Table 31

During season I it is revealed that neither treatment combinations nor individual factors were significant at 30 DAS

In the season II also the same trend of results were obtained

On pooled analysis also it is but natural that the results of season I and season II were observed at 30 DAS

In the season I and season II again the dry weight of nodules revealed that the trea ments were not statistically significant at flowering On pooled analysis also the treatments as well as levels of phosphorus and chelates could no register any response on this character at flowering

4 2 10 Yield components of cowpea

The data on yield components of cowpea are given in Table 32

4 2 10 1 Number of pods per plant

The data revealed that the treatments were statistically significant during season I T_1 recorded the lowest value of 1 49 pods per plant and T_5 recorded the highest value of 2 38 pods per plant On factorial analysis phosphorus levels and chelates also recorded significant response No chelates recorded the lowest value of 1 71 pods per plant while EDTA recorded the highest value of 1 99 pods per plant

Table 31 Dry weight of nodules per plant (mg) in Experiment No 2

Treatment No	Season I		Season II		Pooled mean	
	30 DAS	at flowering	30 DAS	at flowering	30 DAS	at flowering
T_1	146 0	88 4	115 0	71 5	130 5	80 0
T_2	142 3	95 2	126 0	78 9	134 2	87 0
T_3	155 0	93 9	112 3	87.3	133 7	90 6
T_4	139 3	101 0	113 0	84 6	126 2	92 8
T_5	145 0	97 3	113 0	78 5	129 0	87 9
T_6	134 3	100.3	111 7	82 6	123 0	91 5
T_7	149.3	94 5	112 0	77 7	130 7	86 1
T_8	139 7	98.3	119.3	78 6	129 5	88 5
T_9	136 3	96 6	119 0	79 0	127 7	87 8
SEm±	10 11	4 96	5 19	3 82	5 68	3 13
C D (0 05)	—	—	—	—	—	—
FACTORS						
A Fert. P						
1 No P	147 8	92 51	117 8	79 2	132 8	85 9
2 50%P	139 6	99 54	112 6	81 9	126 1	90 7
3 100%P	141 8	96 47	116 8	78 4	129.3	87 5
C D (0 05)	—	—	—	—	—	—
B Chelates						
1 No chelates	144 9	94 63	113 3	77 9	129 1	86 3
2 EDTA	142 3	96 96	119 4	78 7	130 9	87 8
3 DTPA	141 9	96 93	114 3	83 0	128 1	90 0
C D (0 05)	—	—	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

Table 32 Yield components of cowpea in Experiment No 2

Treatment No	No of pods / plant		No of seeds / pod		100 seed weight (g)		Pod length (cm)	
	Season I	Season II	Season I	Season II	Season I	Season II	Season I	Season II
T_1	1 49	1 95	15 4	14 9	9 21	8 69	15 7	14 9
T_2	1 60	2 06	15 4	14 9	9 22	8 69	15 7	14 9
T_3	1 55	1 99	15 4	14 9	9 21	8 69	15 7	14 9
T_4	1 74	2 14	15 4	14 9	9 21	8 69	15 7	14 8
T_5	2 38	2 69	15 4	14 9	9 20	8 70	15 6	14 9
T_6	2 17	2 60	15 5	14 8	9 22	8 70	15 7	14 9
T_7	1 91	2 24	15 4	15 0	9 21	8 69	15 7	14 9
T_8	2 01	2 32	15 4	14 9	9 21	8 69	15 7	14 9
T_9	1 95	2 22	15 4	14 9	9 21	8 69	15 7	14 8
SEm±	0 033	0 043	0 05	0 05	0 006	0 011	0 05	0 04
C D (0 05)	0 099	0 128	—	—	—	—	—	—
FACTORS								
A Fert. P								
1 No P	1.55	2 00	15 4	14 9	9 21	8 69	15 7	14 9
2 50%P	2 10	2 47	15 4	14 9	9 21	8 70	15 7	14 8
3 100%P	1 96	2 26	15 4	14 9	9 21	8 69	15 7	14 8
C D (0 05)	0 057	0 074	—	—	—	—	—	—
B Chelates								
1 No chelates	1 71	2 11	15 4	14 9	9 21	8 69	15 7	14 8
2 EDTA	1 99	2 35	15 4	14 9	9 21	8 69	15 7	14 9
3 DTPA	1 89	2 27	15 4	14 9	9 21	8 69	15 7	14 8
C D (0 05)	0 057	0 074	—	—	—	—	—	—

Note In those places where C.D is not given the F test is not significant at 5% level

During season II the number of pods per plant revealed that the treatments were statistically significant When T_1 recorded the lowest value of 1 95 pods per plant T_5 recorded the highest value of 2 69 pods per plant The phosphorus levels and chelates also varied significantly While no phosphorus recorded the lowest value of 2 00 pods per plant 50% phosphorus recorded the highest value of 2 47 pods per plant With respect to chelates no chelates recorded the lowest value of 2 11 pods per plant while EDTA recorded the highest value of 2 35 pods per plant

4.2 10.2 Number of seeds per pod

During season I the number of seeds per pod did not reveal any statistical significance

During season II also the number of seeds per pod showed that the treatments were not statistically significant

4.2 10.3 Hundred seed weight

During season I hundred seed weight revealed that the treatments were not statistically significant

During season II also it was revealed that the treatments were not significant

10 2 10 4 Pod length of cowpea

There was response for pod length of cowpea during season I as well as during season II with respect to various treatments

4 2 11 Grain yield of cowpea

The data on grain yield of cowpea are given in Table 33 and Fig 8

Table 33 Yields of grains and haulms (kg ha $^{-1}$) in Experiment No 2

Treatment No	Season I		Season II		Pooled mean	
	grains	haulms	grains	haulms	grains	haulms
T_1	565	3886	673	2821	619	3354
T_2	604	4033	712	2987	658	3510
T_3	585	3915	688	2833	637	3374
T_4	658	4142	738	3042	698	3592
T_5	900	4970	928	3675	914	4322
T_6	821	4709	897	3592	859	4150
T_7	721	4430	774	3165	747	3798
T_8	758	4501	799	3240	779	3870
T_9	738	4414	769	3148	754	3781
SEm±	12 4	40 8	14 8	50 3	9 7	32 4
C D (0 05)	37 1	122 4	44 4	150 7	28 9	93 4
FACTORS						
A. Fert. P						
1 No P	585	3945	691	2880	638	3413
2 50% P	793	4607	854	3436	824	4021
3 100% P	739	4448	781	3184	760	3816
C D (0 05)	21 4	70 7	25 6	87 0	16 1	53 9
B Chelates						
1 No chelates	648	4153	728	3009	688	3581
2 EDTA	754	4501	813	3301	783	3901
3 DTPA	715	4346	785	3191	750	3768
C D (0 05)	21 4	70 7	25 6	87 0	16 1	53 9

During season I it was revealed that the treatments were significant While T_1 recorded the lowest yield of 565 kg ha^{1} T_5 recorded the highest yield of 900 kg ha^{1} Phosphorus levels and chelates recorded significant differences in yield of cowpea With respect to phosphorus no phosphorus recorded the lowest yield of 585 kg ha^{1} whereas 50% phosphorus recorded the highest yield of 793 kg ha^{1} Among chelates no chelates recorded the lowest yield of 648 kg ha^{1} whereas EDTA recorded the highest yield of 754 kg ha^{1}

During season II also the treatments were significant in their effects with T_1 recording the lowest yield of 673 kg ha^{1} and T_5 recording the highest yield of 928 kg ha^{1} Phosphorus levels recorded significant response with no phosphorus recording the lowest yield of 691 kg ha^{1} and 50% phosphorus recording the highest yield of 854 kg ha^{1} Chelates also recorded significant response with no chelates recording the lowest yield of 728 kg ha^{1} and EDTA recording the highest yield of 813 kg ha^{1}

On pooled analysis of grain yield data, it was revealed that the treatments varied significantly on their effects T_1 recorded the lowest yield of 619 kg ha^{1} whereas T_5 recorded the highest yield of 914 kg ha^{1} Phosphorus leves and chelates also recorded significant influence while no phosphorus recorded the lowest yield of 638 kg ha^{1} 50% phosphorus recorded the highest yield of 824 kg ha^{1} Among chelates no chelates recorded the lowest yield of 688 kg ha^{1} whereas EDTA recorded the highest yield of 783 kg ha^{1}

4.2 12 Haulm yields of cowpea

The data on haulms yields of cowpea are given in Table 33

It was revealed that the treatments were statistically significant during season I T_1 recorded the lowest yield of 3866 kg ha^{1} whereas T_5 the highest yield of 4970 kg ha^{-1} Not only phosphorus levels but chelates also recorded significant influences on this character No phosphorus recorded the lowest haulm yield of 3945 kg ha^{-1} whereas 50% phosphorus recorded the highest yield of 4607 kg ha^{-1} Among chelates no chelates recorded the lowest yield of 4153 kg ha^{-1} whereas EDTA recorded the highest yield of 4501 kg ha^{-1}

In season II also haulm yield data recorded statistical significance Here again T_1 recorded the lowest yield of 2821 kg ha^{-1} whereas T_5 recorded the highest yield of 3675 kg ha^{-1} Phosphorus levels as well as chelates recorded significant influence The lowest yield of 2880 kg ha^{-1} was recorded by no phosphorus treatment whereas 50% phosphorus recorded the highest yield of 3436 kg ha^{-1} Among chelates no chelates recorded the lowest yield of 3009 kg ha^{-1} whereas EDTA recorded the highest yield of 3301 kg ha^{-1}

The pooled analysis of haulm yield data revealed that the treatments were statistically significant While the lowest yield of 3354 kg ha^{-1} was recorded by T_1 the highest yield of 4322 kg ha^{-1} was recorded by T_5 Phosphorus levels also varied significantly While no phosphorus recorded the lowest yield of 3413 kg ha^{-1} 50% phosphorus recorded the highest yield of 4021 kg ha^{-1} Chelates also recorded significant variation with no chelates recording the lowest haulm yield of 3581 kg ha^{-1} and EDTA giving the highest haulm yield of 3901 kg ha^{-1}

4.2 13 Harvest index of cowpea

The data on harvest index of cowpea are given in Table 34

During season I the data on harvest index of cowpea revealed that the treatments were significant The lowest value of 12 7% was recorded in T_1 whereas the highest value of 15 3% was recorded in T_5 Phosphorus levels also varied significantly While no phosphorus recorded the lowest value of 12 9% 50%

Table 34 Harvest ındex (%) ın Experıment No 2

Treatment No	Season I	Season II
T_1	12 7	19 3
T_2	13 0	19 2
T_3	13 0	19 5
T_4	13 7	19 5
T_5	15 3	20 2
T_6	14 8	20 0
T_7	14 0	19 6
T_8	14 4	19 8
T_9	14 3	19 6
SEm±	0 13	1 53
C D (0 05)	0 40	4 58
Factors		
A Fert P		
1 No P	12 9	19 3
2 50% P	14 6	19 9
3 100% P	14 3	19 7
C D (0 05)	0 23	0 26
B Chelates		
1 No chelates	13 5	19 5
2 EDTA	14 3	19 7
3 DTPA	14 1	19 7
C D (0 05)	0 23	—

Note In those places where C D ıs not g ve ı the F test ıs not s gnıfıcant at 5% level phosphorus recorded the highest value of 14 6% No chelates recorded the lowest value of 13 5% whereas EDTA recorded the highest significant value of 14 3%

During season II again the treatments were significant Here, when T_2 recorded the lowest value of 19 2% T_5 recorded the highest value of 20 2% Phosphorus levels also recorded statistical significance Phosphorus also recorded statistical significance When no phosphorus recorded the lowest value of 19 3% 50% phosphorus recorded the highest value of 19 9% Chelates however did not record any statistical significance in respect of this character

4.2 11 Protein content of cowpea grains

The data on protein content of cowpea grains are given in Table 35

During season I it was revealed that the treatments were significant While T_1 recorded the lowest value of 22 20% T_8 recorded the highest value of 23 25% Phosphorus levels as well as chelates also recorded significance Among the phosphorus levels the lowest value of 22 65% was recorded by no phosphorus treatment whereas the highest value of 23 16% was recorded by 100% phosphorus While no chelates recorded the lowest value of 22 75% DTPA registered the highest value of 23 08%

During season II again the treatments were found to be significant When T_1 recorded the lowest value of 22 19% T_9 recorded the highest value of 23 95% Phosphorus levels also were found to be significant When no phosphorus recorded the lowest value of 22 67% 100% phosphorus recorded the highest value of 23 76% Among chelates no chelates recorded the lowest value of 22 93% whereas DTPA recorded the highest value of 23 47%

Table 35 Protein content of grains (%) in Experiment No 2

Treatment No	Season I	Season II
T_1	22 20	22 19
T_2	22 84	22 88
T_3	22 90	22 95
T_4	22 92	23 07
T_5	23 05	23 59
T_6	23 22	23 51
T_7	23 12	23 54
T_8	23 25	23 80
T_9	23 11	23 95
SEm±	0 091	0 158
C D (0 05)	0 274	0 475
FACTORS		
A Fert P		
1 No P	22 65	22 67
2 50% P	23 06	23 39
3 100% P	23 16	23 76
C D (0 05)	0 158	0 274
B Chelates		
1 No chelates	22 75	22 93
2 EDTA	23 05	23 42
3 DTPA	23 08	23 47
C D (0 05)	0 158	0 274

4.2 15 Nitrogen uptake of plants at various stages

The data on nitrogen uptake of plants at various stages of the experiment are given Table 36 and Fig 9

During season I the nitrogen uptake of plants at 30 DAS revealed that the treatments were significant and that the lowest value of 18 78 kg ha^{1} was recorded by T$_1$ whereas the highest value of 30 66 kg ha^{1} was recorded T$_5$ Phosphorus levels also revealed significance in their effects No phosphorus recorded the lowest value of 19 51 kg ha^{1} whereas 50% phosphorus recorded the highest value of 26 78 kg ha^{1} Among chelates no chelates recorded the lowest value of 21 62 kg ha^{1} whereas EDTA recorded the highest value of 25 27 kg ha^{1}

During season II also the treatments were significant at 30 DAS Here T$_1$ recorded the lowest value of 19 95 kg ha^{1} whereas T$_5$ recorded the highest value of 27 51 kg ha^{1} Phosphorus levels and chelates also recorded significance While no phosphorus recorded the lowest value of 20 59 kg ha^{1} 50% phosphorus recorded the highest value of 25 24 kg ha^{1} Here again no chelates recorded the lowest value of 21 33 kg ha^{1} whereas EDTA recorded the highest value of 24 12 kg ha^{1}

On pooled analysis also the treatment combination phosphorus levels as well as chelates recorded significant variation in nitrogen uptake of plants at 30 DAS which quite agrees with the results of the season I and season II

Again at flowering also the treatments were statistically significant during season I and season II The results of pooled analysis at flowering quite agrees with that of season I and season II Here T$_1$ recorded the lowest value of 73 88 kg ha^{1} whereas T$_5$ recorded the highest value of 109 52 kg ha^{1} Among phosphorus levels no phosphorus recorded the lowest value of 75 94 kg ha^{1} whereas 50% phosphorus

Table 36 N uptake of plants (kg ha^{-1}) in Experiment No 2

Treatment No	Season I			Season II			Pooled mean		
	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest
T_1	18 78	74 74	87 57	19 95	73 02	76 52	19 37	73 88	82 04
T_2	20 14	80 21	93 47	21 13	76 96	82 44	20 63	78 59	87 96
T_3	19 62	77 25	90 08	20 68	73 45	78 75	20 15	75.35	84 42
T_4	22 01	88 09	97 14	21 62	79 77	83 83	21 82	83 93	90 49
T_5	30 66	119 23	121 26	27 51	99 80	103 19	29 09	109.52	112 22
T_6	27 67	109 15	112 38	26 58	97 15	100 12	27 13	103 15	106 25
T_7	24 07	96 36	104 65	22 41	82 21	87 94	23 24	89 28	96 29
T_8	25 02	100 95	107 86	23 72	85 42	91.30	24.37	93 18	99 58
T_9	25 21	98 87	106 01	22 69	82 17	88 27	23 95	90 25	97 14
SEm±	0 475	1 626	1 208	0 425	1 991	1 304	0 319	1 285	0 889
C D (0 05)	1 423	4 875	3 622	1 275	5 968	3 909	0 919	3 706	2 563
FACTORS									
A Fert. P									
1 No P	19 51	77 40	90.37	20.59	74 48	79 24	20 05	75 94	84 80
2 50%P	26 78	105 49	110 26	25 24	92 24	95 71	26 01	98 87	102 99
3 100%P	24 77	98 73	106 18	22 94	83 26	89 17	23 85	90 00	97 67
C D (0 05)	0 822	2 814	2 091	0 736	3 446	2 257	0 068	2 140	1 480
B Chelates									
1 No chelates	21 62	86 40	96 45	21.33	78.33	82 76	21 47	82.36	89 61
2 EDTA	25 27	100 13	107 53	24 12	87 39	92 31	24 70	93 76	99 92
3 DTPA	24 17	95 09	102 82	23.32	84 26	89 05	23 74	89 67	95 94
C D (0 05)	0 822	2 814	2 091	0 736	3 446	2 257	0 068	2 140	1 480

recorded the highest value of 98 87 kg ha^{1} When no chelates recorded the lowest value of 82 36 kg ha^{1} EDTA recorded the highest value of 93 76 kg ha^{1}

The nitrogen uptake of plants at harvest revealed that the treatments were statistically significant during season I and season II During this stage also the levels of phosphorus and chelates were significant The pooled analysis also reflected the results of season I and season II The lowest value of 82 04 kg ha^{1} was recorded by T_1 whereas the highest value of 112 22 kg ha^{1} was recorded by T_5 Among phosphorus levels no phosphorus recorded the lowest value of 84 80 kg ha^{1} whereas 50% phosphorus recorded the highest value of 102 99 kg ha^{1} Among chelates also no chelates recorded the lowest value of 89 61 kg ha^{1} whereas EDTA recorded the highest value of 99 92 kg ha^{1}

4 2 16 Phosphorus uptake of plants at various stages

The data on phosphorus uptake of plants at various stages are given in Table 37 and Fig 10

During season I as well as season II phosphorus uptake of plants at 30 DAS revealed that the treatments were significant In season I T_1 recorded the lowest value of 3 15 kg ha^{1} whereas T_5 recorded the highest value of 5 12 kg ha^{1} During season II also T_1 recorded the lowest value whereas T_5 recorded the highest value During both seasons phosphorus levels and chelates recorded significant influence in the uptake of phosphorus Among the levels of phosphorus no phosphorus recorded the lowest value whereas 50% phosphorus recorded the highest value during both seasons Similarly during both seasons no chelates recorded the lowest value whereas EDTA recorded the highest value among chelates

On pooled analysis again it was revealed that treatments were statistically significant Here again T_1 recorded the lowest value of 3 19 kg ha^{1} whereas T_5

Table 37 P uptake of plants (kg ha^{-1}) in Experiment No 2

Treatment No	Season I			Season II			Pooled mean		
	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest
T_1	3 15	13 66	18 86	3 23	12 88	15 22	3 19	13 27	17 04
T_2	3.38	14 71	19 74	3 44	13 94	16 25	3 41	14 32	18 00
T_3	3 31	14 20	19 27	3.31	13.34	15 57	3 31	13 77	17 42
T_4	3 73	16 10	20 48	3 33	14 31	16 60	3 53	15 20	18 54
T_5	5 12	21 77	25 57	4 48	18.34	20 50	4 80	20 05	23 03
T_6	4 66	19 92	24 09	4 34	17 69	20 07	4 50	18 81	22 08
T_7	4 09	17 55	22 19	3 60	15 19	17 49	3 84	16 37	19 84
T_8	4 34	18 64	22 90	3 86	15 86	18 09	4 10	17 25	20.50
T_9	4 24	18 21	22 47	3 69	15 17	17 63	3 97	16 69	20 05
SEm±	0 081	0 297	0 200	0 119	0 318	0 298	0 005	0 217	0 180
C D (0 05)	0 242	0 891	0 600	0 357	0 952	0 895	0 208	0 627	0 518
FACTORS									
A Fert. P									
1 No P	3 28	14 19	19 29	3 32	13.39	15 68	3 30	13 79	17 49
2 50%P	4 50	19 26	23.38	4 05	16 78	19 06	4 28	18 02	21 22
3 100%P	4 22	18 13	22 52	3 72	15 41	17 74	3 97	16 77	20 13
C D (0 05)	0 140	0.514	0 346	0 206	0 550	0 517	0 120	0 362	0 299
B Chelates									
1 No chelates	3 66	15 77	20 51	3 39	14 13	16 44	3 52	14 95	18 48
2 EDTA	4 28	18 37	22 74	3 93	16 05	18 28	4 11	17 21	20 51
3 DTPA	4 07	17 44	21 94	3 78	15 40	17 76	3 93	16 42	19 85
C D (0 05)	0 140	0 514	0 346	0 206	0 550	0 517	0 120	0 362	0 299

recorded the highest value of 4 80 $kg\ ha^{-1}$ Phosphorus levels and chelates also recorded significant influence Among phosphorus levels no phosphorus recorded the lowest value of 3 30 $kg\ ha^{-1}$ and 50% phosphorus recorded the highest value of 4 28 $kg\ ha^{-1}$ which is again in agreement with the result of season I and season II Among chelates again no chelates recorded the lowest value of 3 52 $kg\ ha^{-1}$ whereas EDTA recorded the highest value of 4 11 $kg\ ha^{-1}$

As in the case of 30 DAS at flowering also the treatments were significant Here again T_1 treatment the lowest value of 13 66 $kg\ ha^{-1}$ whereas T_5 recorded the highest value of 21 77 $kg\ ha^{-1}$ Phosphorus levels and chelates were also significant While no phosphorus recorded the lowest value of 14 19 $kg\ ha^{-1}$ 50% phosphorus recorded the highest value of 19 26 $kg\ ha^{-1}$ Among chelates no chelates recorded the lowest value of 15 77 $kg\ ha^{-1}$ whereas EDTA recorded the highest value of 18 37 $kg\ ha^{-1}$

During season II also the same results of season I were repeated at flowering

On pooled analysis also the observation reflected as in the case of season I and season II were repeated Here again T_1 recorded the lowest value of 13 27 $kg\ ha^{-1}$ whereas T_5 recorded the highest value of 20 05 $kg\ ha^{-1}$ Among phosphorus levels no phosphorus recorded the lowest value of 13 79 $kg\ ha^{-1}$ 50% phosphorus recorded the highest value of 18 02 $kg\ ha^{-1}$ While no chelates recorded the lowest value of 14 95 $kg\ ha^{-1}$ EDTA recorded the highest significant value of 17 21 $kg\ ha^{-1}$

During season I and season II again the same results obtained at flowering were repeated at harvest stage also

On pooled analysis also it was realized that the treatments were significant Here again T_1 recorded the lowest value of 17 04 $kg\ ha^{-1}$ whereas T_5 recorded the highest value of 23 03 kg ha^{1} Among phosphorus levels no phosphorus recorded the lowest value of 17 49 kg ha^{1} whereas 50% phosphorus recorded the highest value of 21 22 kg ha^{1} Among chelates no chelates recorded the lowest value of 18 48 kg ha^{1} whereas EDTA recorded the highest value of 20 51 kg ha^{1}

4.3 Experiment no.3 (Effect of microbial agents)

The results obtained from this experiment are presented in this part

4.3 1 Physical properties of the soil

The data on the physical properties of the soil under this experiment are given in Table 38

4.3 1 1 Bulk density of the soil

In the season I the bulk density of the soil before sowing was 1 22 g cm^{3} and that after harvest the treatments were not significant

In the season II the bulk density of the soil before sowing was 1 24 g cm^{3} Unlike season I the treatments were significant after harvest When T_1 T_6 and T_{12} recorded the lowest value of 1 28 g cm^{3} both T_3 and T_4 recorded the highest value of 1 5 g cm^{3} While phosphorus levels recorded significance microbial applications were not significant Among phosphorus levels 50% phosphorus recorded the lowest value of 1 30 g cm^{3} whereas no phosphorus recorded the highest value of 1 33 g cm^{3}

4 3 1 2 Water holding capacity of the soil

In season I the water holding capacity of the soil before sowing was 25 14% The treatments were significant after harvest Here T_5 recorded the lowest value of 28 8% whereas T_2 recorded the highest value of 31 55% Phosphorus levels were

Table 38 Physical properties of the soil in experiment No 3

Physical properties	Bulk density (g cm $^{-3}$)		Water holding capacity (%)		Mean weight diameter of aggregates from wet sieving analysis (mm)	
Experiment season	Season I	Season II	Season I	Season II	Season I	Season II
a **Before sowing**	1 22	1 24	25 14	26 68	0 88	0 77
b **After harvest**						
Treatment No						
T_1	1 32	1 28	31 52	28 77	0 84	0 92
T_2	1 33	1 33	31 55	28 13	1 16	1 26
T_3	1 30	1 35	30 54	29 80	0 80	0 86
T_4	1 32	1 35	28 91	28 65	1 25	1 23
T_5	1 30	1 30	28 18	30 65	0 83	0 84
T_6	1 33	1 28	29 59	29 40	1 18	1 23
T_7	1 35	1 29	29 04	29 38	0 78	0 88
T_8	1 32	1 32	30 51	31 08	1 17	1 26
T_9	1 31	1 33	29 37	29 39	0 87	0 95
T_{10}	1 33	1 33	29 77	29 74	1 23	1 27
T_{11}	1 33	1 31	29 31	29 91	0 88	1 03
T_{12}	1 34	1 28	30 76	29 85	1 22	1 30
SEm $\pm$	0 017	0 013	0 476	0 482	0 029	0 050
C D (0 05)		0 038	1 396	1 414	0 085	0 147
FACTORS						
A. Fert P						
1 No P	1 32	1 33	30 63	28 84	1 01	1 07
2 50%P	1 33	1 30	29.33	30 13	0 99	1 05
3 100%P	1 33	1 31	29 80	29 72	1 05	1 14
C D (0 05)	–	0 019	0 698	0 707	0 042	–
B Microbes						
1 No Microbes	1 31	1 31	29 69	29 60	0 85	0 90
2 VAM	1 33	1 31	30 30	29 09	1 19	1 25
3 PB	1 33	1 31	29 63	29 70	0 82	0 92
4 VAM+PB	1 33	1 32	30 06	29 86	1 21	1 27
C D (0 05)				–	0 049	0 085

Note In those places where C D is not given the F test is not significant at 5% level

also statistically significant When 50% phosphorus recorded the lowest value of 29 33% no phosphorus recorded the highest value of 30 63% However microbial applications were not significant

In the season II the water holding capacity of the soil before sowing was 26 68% It was observed that the treatments recorded statistical significance after harvest At his stage T_2 recorded the lowest value of 28 13% whereas T_8 recorded the highest value of 31 08% While phosphorus levels recorded significant variation microbial treatments were not significant Among phosphorus levels no phosphorus recorded the lowest value of 28 84% whereas 50% phosphorus recorded the highest value of 30 13%

4.3 1 3 Mean weight diameter of aggregates

The mean weight diameter of aggregates which was 0 88 mm before sowing recorded significant variation after harvest While T_7 recorded the lowest value of 0 78 mm T_4 recorded the highest value of 1 25 mm Phosphorus levels as well as microbial treatments also recorded significant variation while 50% phosphorus recorded the lowest value of 0 99 mm 100% phosphorus recorded the highest value of 1 05 mm Among microbial treatments phosphobacterin (PB) recorded the lowest value of 0 82 mm whereas VAM + phosphobacterin (PB) application recorded the highest value of 1 21 mm

In season II treatments recorded significance after harvest At this stage T_5 recorded the lowest value of 0 84 mm whereas T_{12} recorded the highest value of 1 30 mm While phosphorus levels were not significant microbial applications recorded statistical significance Among microbial applications no microbes recorded the lowest value of 0 90 mm whereas VAM + PB recorded the highest value of 1 27 mm

4.3 2 Chemical properties of the soil

The data on chemical properties of the soil are given in Table 39

4.3.2 1 Cation Exchange Capacity (C E C) of the soil

In the season I C E C of the soil before sowing was found to be 4 15 me 100 g^{-1} soil The treatments could not make any significant variation after harvest

In the season II C E C of the soil before sowing was 4 16 me 100 g^{-1} In season II also the treatments didnot reveal any significance

On pooled analysis also C E C of the soil recorded that the treatments had no significant response

4.3.2 2 pH of the soil

During season I pH of the soil before sowing was 5 12 and that after harvest the treatments recorded statistical significance While T_4, T_7 T_8 T_{11} and T_{12} recorded the lowest value of 5 08 T_9 recorded the highest value of 5 13 Phosphorus levels were not significant whereas microbial applications recorded significance When phosphobacterin and phosphobacterin along with VAM recorded the lowest value of 5 08 no microbes recorded the highest value of 5 12

In season II also the treatments recorded statistical significance When T_2 T_4, T_6 T_7 T_8 T_{10} and T_{12} recorded the lowest value of 5 08 T_9 recorded the highest value of 5 12 Here again phosphorus levels were not statistically significant whereas microbial applications recorded significance Among microbes VAM and VAM + PB recorded the lowest value of 5 08 where as no microbes recorded the highest value of 5 11

Table 39 Chemical properties of the soil in experiment No 3

Chemical Characteristics	CEC (me/100 g)			pH			Total Nitrogen (%)		
Experiment season	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
	1	2	3	4	5	6	7	8	9
a Before sowing	4 15	4 16	4 16	5 12	5 11	5 12	0 120	0 121	0 121
b After harvest									
Treatment No									
T_1	4 17	4 22	4 20	5 12	5 10	5 11	0 120	0 119	0 120
T_2	4 64	4 55	4 60	5 09	5 08	5 08	0 127	0 122	0 125
T_3	4 64	4 45	4 54	5 09	5 09	5 09	0 130	0 125	0 127
T_4	4 34	4 42	4 38	5 08	5 08	5 08	0 128	0 124	0 126
T_5	4 54	4 40	4 47	5 12	5 11	5 11	0 129	0 143	0 136
T_6	4 31	4 43	4 37	5 09	5 08	5 08	0 131	0 124	0 128
T_7	4 43	4 44	4 44	5 08	5 08	5 08	0 133	0 125	0 129
T_8	4 39	4 36	4 38	5 08	5 08	5 08	0 132	0 124	0 128
T_9	4 36	4 49	4 42	5 13	5 12	5 13	0 126	0 124	0 125
T_{10}	4 70	4 50	4 60	5 09	5 08	5 09	0 130	0 128	0 129
T_{11}	4 41	4 44	4 43	5 08	5 09	5 08	0 128	0 129	0 129
T_{12}	4 39	4 40	4 40	5 08	5 08	5 08	0 132	0 131	0 132
SEm ±	0 157	0 127	0 101	0 003	0 002	0 002	0 003	0 006	0 0036
C D (0 05)		–		0 007	0 007	0 005		–	
FACTORS									
A. Fert P									
1 No P	4 45	4 41	4 43	5 09	5 09	5 09	0 126	0 123	0 125
2 50%P	4 42	4 41	4 41	5 09	5 09	5 09	0 131	0 129	0 130
3 100%P	4 47	4 46	4 46	5 09	5 09	5 09	0 129	0 128	0 129
C D (0 05)			–				–		–
B Microbes									
1 No microbes	4 36	4 37	4 36	5 12	5 11	5 12	0 125	0 129	0 127
2 VAM	4 55	4 49	4 52	5 09	5 08	5 08	0 130	0 125	0 127
3 PB	4 49	4 44	4 47	5 08	5 09	5 08	0 130	0 126	0 128
4 VAM + PB	4 37	4 40	4 39	5 08	5 08	5 08	0 131	0 127	0 129
C D (0 05)			–	0 004	0 004	0 003			

Con d

Table 39 (Contd)

Chemical Characterist cs	Total phosphorus [P] (ppm)			P Fixing capacity (μg P g $^{-1}$)			Organic matter content (%)		
Experiment season	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
	10	11	12	13	14	15	16	17	18
a Before sowing	352	369	361	28 6	28 7	28 7	2 18	2 16	2 17
b After harvest									
Treatment No									
T_1	341	362	352	28 7	28 5	28 6	2 17	2 15	2 16
T_2	338	360	349	28 4	28 6	28 5	2 17	2 15	2 16
T_3	339	361	350	29 6	28 7	28 7	2 17	2 14	2 16
T_4	336	358	347	28 6	28 8	28 7	2 15	2 13	2 14
T_5	338	361	350	28 8	28 8	28 8	2 18	2 15	2 16
T_6	337	360	349	28 5	28 8	28 7	2 17	2 14	2 16
T_7	337	357	347	28 7	28 8	28 8	2 17	2 14	2 15
T_8	338	359	348	28 5	28 6	28 6	2 15	2 14	2 14
T_9	339	360	350	28 6	28 6	28 6	2 17	2 14	2 15
T_{10}	338	358	348	28 8	28 8	28 8	2 16	2 13	2 15
T_{11}	337	357	347	28 4	28 6	28 5	2 16	2 13	2 14
T_{12}	338	356	347	28 7	28 8	28 7	2 15	2 12	2 14
SEm±	2 2	3 4	2 1	0 12	0 14	0 09	0 045	0 061	0 038
C D (0 05)	—	—	—	—	—	—	—	—	—
FACTORS									
A Fert. P									
1 No P	339	360	349	28 6	28 6	28 6	2 17	2 14	2 16
2 50%P	338	359	349	28 6	28 8	28 7	2 17	2 14	2 15
3 100%P	338	358	348	28 6	28 7	28 7	2 16	2 13	2 15
C D (0 05)	—	—	—	—	—	—	—	—	—
B Microbes									
1 No m crobes	340	361	350	28 7	28 6	28 7	2 17	2 15	2 16
2 VAM	338	359	349	28 6	28 7	28 6	2 17	2 14	2 16
3 PB	338	359	348	28 6	28 7	28 7	2 17	2 14	2 15
4 VAM + PB	337	357	347	28 6	28 7	28 7	2 15	2 13	2 14
C D (0 05)	—	—	—	—	—	—	—	—	—

Note In those places where C D is not given, the F test is not significant at 5% level

On pooled analysis also the treatments recorded statistical significance T_2 T_4, T_6 T_7 T_8 T_{11} and T_{12} recorded the lowest value of 5 08 whereas T_9 recorded the highest value of 5 13 Here also phosphorus levels were not significant whereas microbial applications were significant All the microbial levels recorded a value of 5 08 whereas no microbes recorded the highest value of 5 12

4.3 2.3 Total nitrogen content of the soil

In season I the total nitrogen content of the soil before sowing was 0 120% It was observed that neither the treatment combinations nor phosphorus levels and microbial applications were statistically significant

In the season II also treatments were not significant

On pooled analysis the result of season I and season II were clearly confirmed wherein neither the treatment combinations nor levels of phosphorus and microbial applications were significant in their effects

4.3 2 4 Total phosphorus content of the soil

In season I the total phosphorus content of the soil before sowing was 352 ppm It was observed that the treatments were not significant after harvest

In season II the total phosphorus content of soil before sowing was 369 ppm After harvest the same results of season I were repeated

The pooled analysis was only a confirmation to the results of season I and season II

4 3 2 5 P fixing capcity of the soil

The phosphorus fixing capacity of soil before sowing found to be 28 6 μg P g^{-1} The treatments were not found to be significant after harvest

During season II also the results of season I were repeated

On pooled analysis the P fixing capacity of the soil before sowing was found to be 28 7 μg P g^{-1} As expected the treatments were not significant

4.3.2 6 Organic matter content of the soil

In season I the organic matter content of the soil before sowing was found to be 2 18% As in the case of P fixing capacity of the soil none of the treatment combination as well as individual treatments were significant In the season II also the results of season I were repeated

It is quite natural that during pooled analysis also the organic matter content of the soil which was 2 17% before sowing was not affected by treatment combinations as well as individual treatments

4.3.3 Available phosphorus content of the soil

The data on available phosphorus content of the soil during various stages of the experiment are given in Table-40

During season I it was observed that the available phosphorus content of the soil which was 8 16 mg P kg^{-1} after sowing was affected by various treatment combinations at 30 DAS T_1 recorded the lowest value of 9 89 mg P kg^{-1} whereas T_{12} recorded the highest value of 13 63 mg P kg^{-1} Phosphorus levels as well as microbial applications were statistically significant Among phosphorus levels no phosphorus recorded the lowest value of 10 86 mg P kg^{-1} whereas 100% phosphorus recorded the highest value of 13 22 mg P kg^{-1} When no microbes recorded the lowest value of 11 09 mg P kg^{-1} VAM + PB recorded the highest value of 13 04 mg P kg^{-1} After harvest also the treatments were significant T_1 recorded the the lowest value of 8 98 mg P kg^{-1} whereas T_{12} recorded the highest

Table 40 Available P content of the soil (mg P kg $^{-1}$) in Experiment No 3

Treatment No	Before sowing			30 DAS			After harvest		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
T_1	8 16	7 98	8 07	9 89	11 26	10 57	8 98	9 07	9 03
T_2	8 16	7 98	8 07	10.50	12 08	11 29	10 12	10 27	10 20
T_3	8 16	7 98	8 07	10 68	12 36	11 52	10 29	10 48	10 39
T_4	8 16	7 98	8 07	12 36	12 99	12 68	10 62	10 71	10 67
T_5	8 16	7 98	8 07	10 42	12 59	11 51	9 58	9 36	9 47
T_6	8 16	7 98	8 07	10 89	12 88	11 89	10 25	10 32	10 29
T_7	8 16	7 98	8 07	10 96	12 76	11 86	10.38	10 88	10 63
T_8	8 16	7 98	8 07	13 14	13 34	13 24	10 69	10 91	10 80
T_9	8 16	7 98	8 07	12 96	13 12	13 04	10 15	9 79	9 97
T_{10}	8 16	7 98	8 07	12 99	13 18	13 09	10.31	10 47	10 39
T_{11}	8 16	7 98	8 07	13 28	13 27	13 28	10 46	10 96	10 71
T_{12}	8 16	7 98	8 07	13 63	13 39	13 51	10 76	11 02	10 89
SEm±	0 00	0 00	0 00	0 540	0 788	0 477	0 322	0 452	0 277
C D (0 05)	—	—	—	1.583	—	1 364	0 946	1.325	0 792
FACTORS									
A Fert P									
1 No P	8 16	7 98	8 07	10 86	12 17	11 52	10 01	10 13	10 07
2 50%P	8 16	7 98	8 07	11 36	12 89	12 12	10 23	10 37	10 30
3 100%P	8 16	7 98	8 07	13 22	13 24	13 23	10 42	10 56	10 49
C D (0 05)	—	—	—	0 791	—	0 682	—	—	—
B Microbes									
1 No microbes	8 16	7 98	8 07	11 09	12 32	11 71	9 57	9 41	9 49
2 VAM	8 16	7 98	8 07	11 46	12 72	12 09	10 23	10 36	10 29
3 PB	8 16	7 98	8 07	11 64	12 80	12 22	10 38	10 78	10 58
4 VAM + PB	8 16	7 98	8 07	13 04	13 24	13 14	10 69	10 88	10 79
C D (0 05)	—	—	—	0 914	—	0 787	0 546	0 765	0 458

Note In those places where C D is not given the F test is not significant at 5% level

value of 10 76 mg P kg^{1} When phosphorus levels were not significant microbial applications were significant and no microbes recorded the lowest value of 9 57 mg P kg^{1} whereas VAM + PB recorded the highest value of 10 69 mg P kg^{1}

Unlike season I during season II the available phosphorus content of the soil which was 7 98 mg P kg^{1} before sowing was not affected by various treatment combinations at 30 DAS However after harvest the treatment combinations were statistically significant Here T_1 recorded the lowest value of 9 07 mg P kg^{1} whereas T_{12} recorded the highest value of 11 02 mg P kg^{1} When phosphorus levels were not significant microbial applications were significant No microbes recorded the lowest value of 9 41 mg P kg^{1} and VAM + PB applications recorded the highest value of 10 88 mg P kg^{1}

On pooled analysis it was observed that the phosphorus content of the soil before sowing was 8 07 mg P kg^{1} and that at 30 DAS the treatments were significant When T_1 recorded the lowest value of 10 57 mg P kg^{1} T_{12} recorded the highest value of 13 51 mg P kg^{1} Phosphorus levels were also significant Here no phosphorus recorded the lowest value of 11 52 mg P kg^{1} whereas 100% phosphorus recorded the highest value of 13 23 mg P kg^{1} Microbial applications also were significant When no microbes recorded the lowest value of 11 71 mg P kg^{1} VAM + PB recorded the highest value of 13 14 mg P kg^{1} After harvest also the treatments were significant Here again T_1 recorded the lowest value of 9 03 mg P kg^{1} whereas T_{12} recorded the highest value of 10 89 mg P kg^{1} However phosphorus levels were not significant microbial applications were found to be significant with no microbes recording the lowest value of 9 49 mg P kg^{1} whereas VAM + PB recording the highest value of 10 79 mg P kg^{1}

4.3 4 Soil phosphorus fractions

The data on the soil phosphorus fractions at various stages of the experiment are given in Table-41 42 and 43

4.3 4 1 Saloid P of the soil (Sal P)

During season I the saloid P before sowing was found to be 14 1 ppm and that at flowering the treatments were significant At this stage T_9 recorded the lowest value of 19 3 ppm whereas T_{12} recorded the highest value of 24 0 ppm Phosphorus levels were also significant No phosphorus recorded the lowest value of 19 9 ppm, whereas 100% phosphorus recorded the highest value of 22 1 ppm Microbial application also were significant When no microbes recorded the lowest value of 20 0 ppm, VAM + PB recorded the highest value of 22 3 ppm After harvest, again the treatments were significant When both T_1 and T_3 recorded the lowest value of 20 3 ppm, T_6 recorded the highest value of 23 3 ppm Phosphorus levles and microbial applications were also significant Among phosphorus levels no phosphorus recorded the lowest value of 20 9 ppm whereas 50% phosphorus recorded the highest value of 22 4 ppm Among microbial applications no microbes recorded the lowest value of 21 2 ppm whereas both VAM and VAM + PB recorded the highest value of 22 0 ppm

During season II also the saloid P was significantly affected by various treatment combinations before sowing Here T_1 recorded the lowest value of 20 0 ppm whereas T_{12} recorded the highest value of 28 0 ppm Not only phosphorus levels but microbial applications also were significant Among phosphorus levels 50% phosphorus recorded the lowest value of 22 3 ppm whereas 100% phosphorus recorded the highest value of 26 2 ppm Among microbial applications no microbes recorded the lowest value of 22 3 ppm whereas VAM + PB recorded the highest

Table 41 Soil phosphorus (P) fractions (ppm) in Experiment No 3 for season I

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	14 1	38 2	26 0	19 1	14 2	17 0	224 0	352 6
b At flowering Treatment No								
T_1	19 7	37 3	25 0	18 7	13 7	16 7	214 3	345.3
T_2	19 7	37 0	25 0	19 0	13 3	16 3	212 0	342.3
T_3	19 7	37 3	25 0	19 0	13 3	16 0	212 0	342 3
T_4	20 7	36.3	24 7	19 0	13 3	16 0	209 7	339 7
T_5	21 0	37 0	24 7	18 7	13 0	16 7	210 3	341.3
T_6	21 7	37 3	25 0	19 0	13 3	16 0	210 0	342.3
T_7	20 3	37 3	25 0	19 0	13 3	16 0	211 3	342 3
T_8	22.3	37 3	25 0	19 0	13 0	16 0	210 0	342 7
T_9	19.3	37 3	25 0	19 0	13 3	16 7	212 0	342 7
T_{10}	22.3	37 3	25 0	19 0	13 3	16 0	210 3	343.3
T_{11}	22 7	37 0	24 7	18 7	13 3	16 0	209 3	341 7
T_{12}	24 0	36 7	25 0	19 0	13 3	16 0	209 7	343 3
SEm±	0.50	0.51	0 30	0 23	0 31	0 19	2 58	4 08
C D (0 05)	1 47	—	—	—	—	0 56	—	—
FACTORS								
A Fert. P								
1 No P	19 9	37 0	24 9	18 9	13 4	16 3	212 0	342 4
2 50%P	21.3	37 3	24 9	18 9	13 2	16 2	210 4	342 2
3 100%P	22 1	37 1	24 9	18 9	13 3	16 2	210 3	342 8
C D (0 05)	0 74	—	—	—	—	—	—	—
B Microbes								
1 No microbes	20 0	37 2	24 9	18 8	13 3	16 7	212 2	343 1
2 VAM	21 2	37 2	25 0	19 0	13 3	16 1	210 8	342 7
3 PB	20 9	37 2	24 9	18 9	13 3	16 0	210 9	342 1
4 VAM + PB	22.3	36 8	24 9	19 0	13 2	16 0	209 8	341 9
C D (0 05)	0 85	—	—	—	—	0.33	—	—

Contd

Table 41 (contd)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	20 3	37 0	24 7	19 0	13 0	16 7	210 3	341 0
T_2	21 7	37 0	24 7	19 0	13 0	15 7	207 3	338.3
T_3	20 3	36 7	24 7	19 0	13 0	15 7	209 3	338 7
T_4	21.3	36 7	25 0	19 0	13 0	15 0	206 3	336 3
T_5	22 0	37 0	25 0	19 0	13 0	16 0	208 0	338.3
T_6	23 3	36 3	24 3	19 0	13 0	15 3	206 0	337 3
T_7	22 0	36 7	24 3	18 7	13 0	15 7	207 0	337 3
T_8	22 3	36 7	24 7	19 0	13 7	15 3	206 3	338 0
T_9	21.3	37 3	24 7	19 0	13 0	16 0	208 0	339 3
T_{10}	21 0	37 0	24.3	19 0	13 0	15 7	207 7	337 7
T_{11}	21 7	36 7	24 3	19 0	13 7	15 3	206 3	336 7
T_{12}	22.3	37 3	24.3	19 0	13 0	15 0	206 7	337 7
SEm±	0 35	0 26	0 31	0 09	0 13	0 28	1.34	2 24
C D (0 05)	1 04	—	—	—	—	0 83	—	—
FACTORS								
A Fert. P								
1 No P	20 9	36 8	24 8	19 0	13 0	15 8	208 3	338 6
2 50%P	22 4	36 7	24 6	18 9	13 2	15 6	206 8	337 8
3 100%P	21 6	37 1	24 4	19 0	13 1	15 5	207 2	337 8
C D (0 05)	0 52	—	—	—	—	—	—	—
B Microbes								
1 No microbes	21 2	37 1	24 8	19 0	13 0	16 2	208 8	339 6
2 VAM	22 0	36 8	24 4	19 0	13 0	15 6	207 0	337 8
3 PB	21.3	36 7	24 4	18 9	13 1	15 6	207 6	337 6
4 VAM + PB	22 0	36 9	24 7	19 0	13 2	15 1	206 4	337.3
C D (0 05)	0 60	—	—	—	—	0 48	—	—

Note In those places where C D is not given the F test is not significant at 5% level

Table 42 Soil phosphorus (P) fractions (ppm) in Experiment No 3 for season II

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	15 0	41 2	27 1	19 0	15 2	17 1	235 1	369 7
b At flowering								
Treatment No								
T_1	20 0	40 3	26 3	18 3	14 3	17 0	228 3	364 7
T_2	20 3	40 3	26 7	18 7	14 7	16 7	227 0	364 3
T_3	26 0	39 7	26.3	18 7	14 3	16.3	222 0	363.3
T_4	24 7	39 7	26 7	18 7	14 0	16 0	220 7	360.3
T_5	21 0	39 7	26 7	18 7	14 7	16 7	226 0	363 3
T_6	22 3	40 3	26 3	18.3	14 3	16 3	225 7	363 7
T_7	20 7	40 0	26.3	18.3	14 3	16 3	224 3	360.3
T_8	25.3	38 7	26 7	18 7	14 3	16 0	221 7	361 3
T_9	26 0	40 0	26 3	18 7	14 0	16 3	223 0	364.3
T_{10}	26 3	39 3	26.3	18.3	14 3	16 0	220 7	361 3
T_{11}	24 3	39 7	26 7	18 7	14 0	16 0	221 0	360.3
T_{12}	28 0	36 0	26 0	18 7	14 3	15 7	220 7	359 3
SEm±	0 44	0 41	0.35	0 34	0 29	0 25	2 41	3 91
C D (0 05)	1 28	1 21	—	—	—	0 75	—	—
FACTORS								
A Fert. P								
1 No P	22 8	40 0	26 5	18 6	14 3	16 5	224 5	363 2
2 50%P	22 3	39 7	26 5	18 5	14 4	16 3	224 4	362 2
3 100%P	26 2	38 8	26 3	18 6	14 2	16 0	221 3	361 3
C D (0 05)	0 64	0 61	—	—	—	0 37	—	—
B Microbes								
1 No microbes	22 3	40 0	26 4	18 6	14 3	16 7	225 8	364 1
2 VAM	23 0	40 0	26 4	18 4	14 4	16 3	224 4	363 1
3 PB	23 7	39 8	26 4	18 6	14 2	16 2	222 4	361.3
4 VAM + PB	26 0	38 1	26 4	18 7	14 2	15 9	221 0	360.3
C D (0 05)	0 74	0 70	—	—	—	0 43	—	—

Contd

Table 42 (contd)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	22 0	40 7	27 7	18 7	14 7	16 7	221 7	362 0
T_2	24.3	40 3	26 3	18 0	14 0	15 7	221 0	359 7
T_3	23 3	40 3	26 3	18.3	14 0	16 0	223 0	361 3
T_4	23 3	39 7	26.3	18 0	14 0	15 0	221 3	357 7
T_5	20 0	40 7	27 0	18 7	14 3	16 0	224 7	361.3
T_6	22.3	40 3	26 3	18.3	14 3	15.3	223 3	360.3
T_7	22 0	39 7	27 0	18 0	14 3	15 0	221 3	357 3
T_8	21 3	40 3	26 7	18 0	14 7	15 0	222 7	358 7
T_9	18 3	40 7	27 3	18 3	14 7	16 3	224 7	360 3
T_{10}	19.3	40.3	27 0	18 3	14 7	15 7	223 0	358.3
T_{11}	21 7	40 0	26 7	18 0	14 3	15 0	221 7	357.3
T_{12}	21 3	40 3	26 3	18 0	14 0	15 0	220 7	355 7
SEm±	0 48	0 48	0.34	0 24	0 28	0 22	2 17	3 44
C D (0 05)	1 41	—	—	—	—	0 64	—	—
FACTORS								
A Fert. P								
1 No P	23 3	40 3	26 7	18 3	14 2	15 8	221 8	360 2
2 50%P	21 4	40 3	26 8	18.3	14 4	15 3	223 0	359 4
3 100%P	20 2	40 3	26 8	18 2	14 4	15 5	222 5	357 9
C D (0 05)	0 71	—	—	—	—	0 32	—	—
B Microbes								
1 No microbes	20 1	40 7	27 3	18 6	14 6	16 3	223 7	361 2
2 VAM	22 0	40 3	26 6	18 2	14 3	15 6	222 4	359 4
3 PB	22 3	40 0	26 7	18 1	14 2	15.3	222 0	358 7
4 VAM + PB	22 0	40 1	26 4	18 0	14 2	15 0	221 6	357 3
C D (0 05)	0 81	—	—	—	—	0.37	—	—

Note In those places where C D is not given, the F test is not significant at 5% level

Table 43 Soil phosphorus (P) fractions (ppm) in Experiment No 3 (Pooled mean)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
a Before sowing	14 6	39 7	26 6	19 1	14 7	17 1	229 6	361 2
b At flowering								
Treatment No								
T_1	19 8	38 8	25 7	18 5	14 0	16 8	221 3	355 0
T_2	20 0	38 7	25 8	18 8	14 0	16 5	219 5	353.3
T_3	22 8	38.5	25 7	18 8	13 8	16 2	217 0	352 8
T_4	22 7	38 0	25 7	18 8	13 7	16 0	215 2	350 0
T_5	21 0	38.3	25 7	18 7	13 8	16 7	218 2	352 3
T_6	22 0	38 8	25 7	18 7	13 8	16 2	217 8	353 0
T_7	20 5	38 7	25 7	18 7	13 8	16 2	217 8	351 3
T_8	23 8	38 0	25 8	18 8	13 7	16 0	215 5	352 0
T_9	22 7	38 7	25 7	18 8	13 7	16 5	217 5	353 5
T_{10}	24 3	38 3	25 7	18 7	13 8	16 0	215 5	352 3
T_{11}	23 5	38 3	25 7	18 7	13 7	16 0	215 2	351 0
T_{12}	26 0	36 3	25 5	18 8	13 8	15 8	215 2	351 3
SEm±	0 33	0 33	0 23	0 21	0 21	0 16	1 76	2 82
C D (0 05)	0 95	0 93	—	—	—	0 46	—	—
FACTORS								
A Fert. P								
1 No P	21 3	38.5	25 7	18 8	13 9	16 4	218 3	352 8
2 50%P	21 8	38 5	25 7	18 7	13 8	16.3	217 4	352 2
3 100%P	24 1	37 9	25 6	18 8	13 8	16 1	215 8	352 0
C D (0 05)	0 47	0 47	—	—	—	0 23	—	—
B Microbes								
1 No microbes	21 2	38 6	25 7	18 7	13 8	16 7	219 0	353 6
2 VAM	22 1	38 6	25 7	18 7	13 9	16 2	217 6	352 9
3 PB	22 3	38 5	25 7	18 7	13 8	16 1	216 7	351 7
4 VAM + PB	24 2	37 4	25 7	18 8	13 7	15 9	215 4	351 1
C D (0 05)	0 55	0 54	—	—	—	0 26	—	—

Contd

Table 43 (contd)

Treatment/ period	Saloid P	Al P	Fe P	Red P	Occl P	Ca P	Org P	Total P
c After harvest								
Treatment No								
T_1	21 2	38 8	26 2	18 8	13 8	16 7	216 0	351 5
T_2	23 0	38 7	25 5	18 5	13 5	15 7	214 2	349 0
T_3	21 8	38 5	25 5	18 7	13 5	15 8	216 2	350 0
T_4	22 3	38 2	25 7	18 5	13 5	15 0	213 8	347 0
T_5	21 0	38 8	26 0	18 8	13 7	16 0	216 3	349 8
T_6	22 8	38 3	25 3	18 7	13 7	15 3	214 7	348 8
T_7	22 0	38 2	25 7	18.3	13 7	15.3	214 2	347 3
T_8	21 8	38 5	25 7	18.5	14 2	15 2	214 5	348 3
T_9	19 8	39 0	26 0	18 7	13 8	16 2	216 3	349 8
T_{10}	20 2	38 7	25 7	18 7	13 8	15 7	215 3	348 0
T_{11}	21 7	38 3	25 5	18 5	13 8	15 2	214 0	347 0
T_{12}	21 8	38 8	25 3	18.5	13 5	15 0	213 7	346 7
SEm±	0.30	0 27	0 23	0 13	0 16	0 18	1 28	2 05
C D (0 05)	0 85	—	0 67	0 38	—	0 51	—	—
FACTORS								
A Fert. P								
1 No P	22 1	38 5	25 7	18 6	13 6	15 8	215 0	349 4
2 50%P	21 9	38 5	25 7	18 6	13 8	15.5	214 9	348 6
3 100%P	20 9	38 7	25 6	18 6	13 8	15 5	214 8	347 9
C D (0 05)	0 43	—	—	—	—	0 25	—	—
B Microbes								
1 No microbes	20 7	38 9	26 1	18 8	13 8	16 3	216 2	350 4
2 VAM	22 0	38 6	25.5	18 6	13 7	15 6	214 7	348 6
3 PB	21 8	38 3	25 6	18 5	13 7	15 4	214 8	348 1
4 VAM + PB	22 0	38 5	25 6	18 5	13 7	15 1	214 0	347.3
C D (0 05)	0 49	—	0.38	0 22	—	0 29	—	—

Note In those places where C D is not given, the F test is not significant at 5% level

value of 26 0 ppm After harvest also the treatments recorded significance with T_2 recording the highest value of 24 3 ppm and T_9 recording the lowest value of 18 3 ppm Phosphorus levles and microbial application were also significant At this stage 100% phosphorus recorded the lowest value of 20 2 ppm whereas no phosphorus recorded the highest value of 21 3 ppm Among microbial applications no microbes recorded the lowest value of 20 1 ppm whereas PB recorded the highest value of 22 3 ppm

The pooled analysis revealed a clear picture on the influence of various treatment combinations at individual treatments on the saloid P of the soil averaged by two seasons It was observed that the treatments were significant at flowering When T_1 recorded the lowest value of 19 8 ppm T_{12} recorded the highest value of 26 0 ppm Phosphorus levels were also significant Here no phosphorus recorded the lowest value of 21 3 ppm whereas 100% phosphorus recorded the highest value of 24 1 ppm Microbial applications also were statistically significant Among microbes no microbes recorded the lowest value of 21 2 ppm whereas VAM + PB recorded the highest value of 24 2 ppm After harvest again the treatments were significant When T_9 recorded the lowest value of 19 8 ppm T_2 recorded the highest value of 23 0 ppm Phosphorus levles and microbial applications also were significant When 100% phosphorus recorded the lowest value of 20 9 ppm no phosphorus recorded the highest value of 22 1 ppm When no microbes recorded the lowest value of 20 7 ppm VAM as well as VAM + PB recorded the highest value of 22 0 ppm

4.3 4 2 Aluminium P of the soil (Al-P)

During season I Al P before sowing was observed to be 38 2 ppm At flowering the treatments were found to be not significant After harvest also the treatments were not statistically significant

In season II aluminium P which was 41 2 ppm before sowing was affected by the treatment at flowering T_{12} recorded the lowest value of 36 0 ppm whereas T_1 T_2 and T_6 recorded the highest value of 40 3 ppm Phosphorus levels were also found to be significant 100% phosphorus recorded the lowest value of 38 8 ppm whereas no phosphorus recorded the highest value of 40 0 ppm Microbial applications also were significant While VAM + PB recorded the lowest value of 38 1 ppm both no microbes and VAM recorded the highest value of 40 0 ppm After harvest however the treatments were not significant

On pooled analysis it was observed that Al P was 39 7 ppm before sowing and at flowering the treatments recorded significant response T_{12} recorded the lowest value of 36 3 ppm whereas T_2, T_7 and T_9 recorded the highest value of 38 7 ppm Phosphorus levels and microbial applications were also significant Among phosphorus levels 100% phosphorus recorded the lowest value of 37 9 ppm whereas both no phosphorus and 50% phosphorus recorded the highest value of 38 5 ppm Among microbial appliations VAM + PB recorded the lowest value of 38 5 ppm whereas both no microbes and VAM recorded the highest value of 37 4 ppm After the harvest however there was no response between treatments

4.3 4.3 Iron P of the soil (Fe P)

Fe P of the soil before sowing found to be 26 0 ppm during season I At flowering there was no response between treatments After harvest also there was no significant response between treatments

During season II Fe P of the soil which was 27 1 ppm before sowing was not influenced by the treatment combinations at flowering After the harvest also the treatments were not significant

On pooled analysis Fe P of the soil before sowing was found to be 26 6 ppm At flowering the treatments were not significant After harvest the treatments recorded significance when both T_6 and T_{12} recorded the lowest value of 25 3 ppm T_1 recorded the highest value of 26 2 ppm While phosphorus levels were not significant microbial applications recorded significance VAM recorded the lowest value of 25 5 ppm, whereas no microbes recorded the highest value of 26 1 ppm

4.3 4 4 Reductant soluble P of the soil (Red P)

During season I Red P of the soil before sowing was 19 1 ppm At flowering the treatments were not found to be significant After harvest also the treatments were not significant

In season II also the results of season I were repeated

In pooled analysis Red P of the soil before sowing was observed to be 19 1 ppm At flowering the treatments were not significant After harvest however the treatments were significant Both T_1 and T_5 recorded the highest value of 18 8 ppm whereas T_7 recorded the lowest value of 18 3 ppm Here again phosphorus levels were not significant whereas microbial applications were significant Both PB as well as VAM + PB recorded the lowest value of 18 5 ppm whereas no microbes recorded the highest value of 18 8 ppm

4.3 4 5 Occluded P of the soil (Occl P)

Occluded P of the soil before sowing was found to be 14 2 ppm At flowering the treatments were not found to be significant After harvest also the treatments were again not significant

During season II occluded P before sowing was found to be 15 2 ppm At flowering again the treatments were not significant After harvest also there was no response for treatments

During the pooled analysis occluded P before sowing was found to be 14 7 ppm At flowering and at harvest also the treatment combination as well as the individual factors followed the same pattern as that of season I and season II

4.3 4 6 Calcium P of the soil (Ca-P)

During season I Ca P of the soil before sowing was 17 0 ppm At flowering the treatments were found to be significant T_3 T_4, T_6 T_7 T_8 T_{10} T_{11} and T_{12} recorded the lowest value of 16 0 ppm and T_1 T_5 and T_9 recorded the highes value of 16 7 ppm However the phosphorus levels were not significant whereas microbial applications were found to be significant While PB as well as VAM + PB recorded the lowest value of 16 0 ppm no microbes recorded the highest value of 16 7 ppm After harvest the treatments were statistically significant While both T_4 and T_{12} recorded the lowest value of 15 0 ppm T_1 recorded the highest value of 16 7 ppm Phosphorus levels were not significant whereas microbial applications recorded significance VAM + PB recorded the lowest value of 15 1 ppm whereas no microbes recorded the highest value of 16 2 ppm

During season II Ca P of the soil before sowing was found to be 17 1 ppm At flowering again the treatments were significant When T_{12} recorded the lowest value of 15 7 ppm T_1 recorded the highest value of 17 0 ppm Phosphorus levels were also found to be significant 100% phosphorus recorded the lowest value of 16 0 ppm whereas no phosphorus recorded the highest value of 16 5 ppm Among microbial applications VAM + PB recorded the lowest value of 15 9 ppm whereas no microbes recorded the highest significant value of 16 7 ppm After harvest also the treatments recorded significance T_4, T_7 T_8 T_{11} and T_{12} recorded the lowest value of 15 0 ppm and T_1 recorded the highest value of 16 7 ppm Phosphorus levels as well as microbial applications were significant In this effects 50% phosphorus recorded the lowest value of 15 3 ppm whereas no phosphorus recorded the highest value of 15 8 ppm Among microbial applications VAM + PB recorded the lowest value of 15 0 ppm whereas no microbes recorded the highest value of 16 3 ppm

Pooled analysis of the data revealed that Ca P of the soil before sowing was 17 1 ppm At flowering the treatments were found to be statistically significant T_{12} recorded the lowest value of 15 8 ppm whereas T_1 recorded the highest value of 16 8 ppm Phosphorus levels and microbial applications where also significant 100% phosphorus recorded the lowest value of 16 1 ppm whereas no phosphorus recorded the highest value of 16 4 ppm Among microbial applications VAM + PB recorded the lowest value of 15 9 ppm whereas no microbes recorded the highest value of 16 7 ppm

After harvest again the treatments were significant Both T_4 and T_{12} recorded the lowest value of 15 0 ppm whereas T_1 recorded the highest value of 16 7 ppm Among phosphorus levels 50% phosphorus as well as 100% phosphorus recorded the lowest value of 15 5 ppm whereas no phosphorus recorded the highest significant value of 15 8 ppm Microbial applications also recorded statistical significance VAM + PB recorded the lowest value of 15 1 ppm whereas no microbes recorded the highest value of 16 3 ppm

4.3 4 7 Organic P of the soil (Org-P)

In season I organic P of the soil before sowing was 224 0 ppm At flowering the treatments were not significant After harvest also the treatments were not significant

During season II the organic P of the soil which was 235 1 ppm before sowing did not differ significantly at flowering

After harvest also the treatments were not significant

Pooled analysis of the data revealed that organic P was 229 6 ppm before sowing It was also revealed that the results obtained at flowering and after harvest are in agreement with the results of season I and season II

4 3 4 8 Total phosphorus content of the soil (Total-P)

During season I the total phosphorus content of the soil before sowing was 352 6 ppm At flowering and at harvest neither the treatment combinations nor the individual factors recorded significant influence on this character

During season II also it was revealed that neither the treatment combinations nor the individual factors recorded significant influence on the total phosphorus content of the soil

The pooled analysis of the data was only a confirmation of the results of the season I and season II

4 3 5 Leaf area index of plants (LAI)

The data on the leaf area index (LAI) of the plants are given in Table 44

In season I LAI at 30 DAS revealed that the treatments were not significant Phosphorus levels as well as microbial applications were also significant However at the time of flowering the treatments recorded significance At this stage T_1 recorded the lowest value of 3 68 whereas T_8 recorded the highest value of 5 54 Phosphorus levels as well as microbial applications were also significant When no phosphorus recorded the lowest value of 4 25 100% phosphorus recorded the

Table 44 Leaf Area Index (LAI) in Experiment No 3

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flowering
T_1	1 26	3 68	1 12	3 09
T_2	1 23	4 07	1 33	3 18
T_3	1 20	4 06	1 52	3 41
T_4	1 19	5 21	1 33	4 28
T_5	1 26	3 89	1 38	3 28
T_6	1 14	4 44	1 15	3 69
T_7	1 23	4 60	1 19	3 92
T_8	1 31	5 54	1 20	4 60
T_9	1 44	4 90	1 41	4 07
T_{10}	1 25	5 18	1 29	4 41
T_{11}	1 28	5 27	1 13	4 51
T_{12}	1 25	5 48	1 49	4 53
SEn ±	0 081	0 077	0 166	0 061
C D (0 05)	—	0 227	—	0 179
FACTORS				
A Fert P				
1 No P	1 22	4 25	1 33	3 49
2 50% P	1 23	4 62	1 23	3 87
3 100% P	1 31	5 21	1 33	4 38
C D (0 05)	—	0 113	—	0 089
B Microbes				
1 No microbes	1 32	4 16	1 30	3 48
2 VAM	1 20	4 56	1 26	3 76
3 PB	1 24	4 64	1 28	3 95
4 VAM + PB	1 25	5 41	1 34	4 47
C D (0 05)	—	0 131	—	0 103

Note In those places where C D is not given the F test s not s gn f cant at 5% level highest value of 5 21 When no microbes recorded the lowest value of 4 16 VAM + PB recorded the highest value of 5 41

During season II LAI at 30 DAS revealed that the treatments were not significant

At the time of flowering however the treatments were significant and the lowest value of 3 09 was recorded by T_1 and the highest value of 4 60 was recorded by T_8 Phosphorus levels were also significant While no phosphorus recorded the lowest value of 3 49 100% phosphorus recorded the highest value of 4 38 Among microbial applications no microbes recorded the lowest value of 3 48 whereas VAM + PB recorded the the highest significant value of 4 47

4.3 6 Leaf area ratio of plants (LAR)

The data on leaf area ratio of plants are given in Table 45

In season I the leaf area ratio (LAR) of plants at 30 DAS revealed that the treatments were significant When T_{12} recorded the lowest value of 10 68 cm^2 g^1 T_1 recorded the highest value of 15 80 cm^2 g^1 Phosphorus levels as well as microbial applications were also significant 100% phosphorus recorded the lowest value of 11 64 cm^2 g^1 whereas no phosphorus recorded the highest value of 13 59 cm^2 g^1 Among microbial applications VAM + PB recorded the lowest value of 10 81 cm^2 g^1 whereas no microbes recorded the highest value of 14 75 cm^2 g^1 At flowering neither the treatment combinations nor individual treatments could exert significant influence on this character

In season II LAR of plants at 30 DAS recorded that the treatments were significant T_{11} recorded the lowest value of 9 89 cm^2 g^1 whereas T_3 recorded the highest value of 17 58 cm^2 g^1 Among phosphorus levels 100% phosphorus

Table 45 Leaf Area Ratio (LAR) of the plants ($cm^2 g^{-1}$) in Experiment No 3

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flowering
T_1	15 80	11 05	14 29	10 52
T_2	14 00	10 97	16 59	10 42
T_3	13 67	10 99	17 58	10 42
T_4	10 91	11 02	12 14	10 35
T_5	14 95	11 01	16 79	10 40
T_6	11 78	10 97	12 14	10 18
T_7	12 16	11 03	11 84	10 33
T_8	10 83	10 90	10 20	10 35
T_9	13 50	10 97	13 60	10 39
T_{10}	11 09	11 12	11 21	10 20
T_{11}	11 30	11 02	9 89	10 42
T_{12}	10 68	10 92	12 82	10 35
SEm±	0 857	0 067	1 609	0 086
C D (0 05)	2 513	—	4 720	—
FACTORS				
A Fert P				
1 No P	13 59	11 01	15 15	10 43
2 50% P	12 43	10 98	12 74	10 32
3 100% P	11 64	11 01	11 88	10 34
C D (0 05)	1 256	—	2 360	—
B Microbes				
1 No n crobes	14 75	11 01	14 89	10 44
2 VAM	12 29	11 02	13 31	10 27
3 PB	12 38	11 01	13 10	10 39
4 VAM + PB	10 81	10 95	11 72	10 35
C D (0 05)	1 450	—	—	—

Note In those places where C D is not g ven the F test is not signif cant at 5% level recorded the lowest value of 11 88 cm^2 g^{1} whereas no phosphorus recorded the highest significant value of 15 15 cm^2 g^{1} However microbial applications did not record any significance

At the time of flowering the treatments did not record significance

4.3 7 Leaf weight ratio of plants (LWR)

The leaf weight ratio of plants (LWR) are given in Table 46

In the season I LWR of plants at 30 DAS recorded that the treatments were not significant At flowering also the treatments were not significant

In the season II also LWR of plants at 30 DAS revealed that the treatments were not significant At the time flowering also LWR of plants revealed that the treatments were not significant

4.3 8 Number of effective nodules per plant

The data on the number of effective nodule per plant are given in Table 47

In the season I the number of effective nodules per plant at 30 DAS revealed that the treatments were significant When T_2 recorded the lowest value of 19 3 T_{10} recorded the highest value of 22 4 Phosphorus levels were significant When no phosphorus recorded the lowest value of 20 1 100% phosphorus recorded the highest value of 21 7 Microbial applications however were not significant in their effects

At the time of flowering it was revealed that the treatments were not significant in their effects

During season II the number of effective nodules at 30 DAS revealed that the treatments were not significant

Table 46 Leaf Weight Ratio (LWR) of the plants in Experiment No 3

Treatment No	Season I		Season II	
	30 DAS	at flowering	30 DAS	at flowering
T_1	0 452	0 353	0 321	0 360
T_2	0 449	0 355	0 318	0 357
T_3	0 449	0 352	0 318	0 357
T_4	0 462	0 356	0 319	0 361
T_5	0 440	0353	0 323	0 360
T_6	0 440	0353	0 327	0 357
T_7	0 442	0 354	0 320	0 357
T_8	0 449	0 354	0 323	0 357
T_9	0 445	0 356	0 321	0 360
T_{10}	0 441	0 357	0 320	0 361
T_{11}	0 445	0 358	0 324	0 360
T_{12}	0 447	0 352	0 320	0 358
SEm±	0 0049	0 0024	0 0024	0 0017
C D (0 05)	—	—	—	—
FACTORS				
A Fert P				
1 No P	0 453	0 354	0 319	0 359
2 50% P	0 443	0 354	0 323	0 358
3 100% P	0 444	0 356	0 321	0 360
C D (0 05)	—	—	—	—
B Microbes				
1 No microbes	0 446	0 354	0 322	0 360
2 VAM	0 443	0 355	0 322	0 358
3 PB	0 445	0 355	0 321	0 358
4 VAM + PB	0 453	0 354	0 321	0 359
C D (0 05)	—	—	—	—

Note In those places where C D is not given the F test is not significant at 5% level

Table 47 Number of effectıve nodules per plant ın Experıment No 3

Treatment No	Season I		Season II		Pooled mean	
	30 DAS	at flowerıng	30 DAS	at flowerıng	30 DAS	at flowerıng
T_1	20 1	12 4	17 7	13 2	18 9	12 8
T_2	19 3	14 1	17.3	12 9	18.3	13.5
T_3	20 9	11 8	16 6	12 7	18 8	12 2
T_4	20 2	11 5	17 2	13 6	18 7	12 5
T_5	20 5	12 7	16 0	12.5	18.3	12 6
T_6	22 0	12 8	17 0	12 8	19 5	12 8
T_7	22 2	11 9	16.5	14 3	19 4	13 1
T_8	21 2	11 2	18 2	15 6	19 7	13 4
T_9	21 4	12 6	16 9	11 9	19 1	12 2
T_{10}	22 4	10 9	16 7	13 9	19 6	12 4
T_{11}	21 6	11 1	16 8	14 6	19 2	12 8
T_{12}	21 7	11 6	16 8	13 1	19 2	12 4
SEm±	0 62	0 95	0 94	0 78	0 56	0 61
C D (0 05)	1 83	—	—	—	—	—
FACTORS						
A Fert P						
1 No P	20 1	12 5	17 2	13 1	18 7	12 8
2 50% P	21 5	12 1	16 9	13 8	19 2	13 0
3 100% P	21 7	11 5	16 8	13 4	19.3	12 5
C.D (0 05)	0 92	—	—	—	—	—
B Mıcrobes						
1 No mıcrobes	20 7	12 6	16 9	12 5	18 8	12 5
2 VAM	21 2	12 6	17 0	13 2	19 1	12 9
3 PB	21 6	11 6	16 6	13 9	19 1	12 7
4 VAM + PB	21 0	11 4	17 4	14 1	19 2	12 7
C D (0 05)	—	—	—	—	—	—

Note In those places where C D ıs not gıven, the F test ıs not sıgnıfıcant at 5% level

At the time of flowering also the treatments did not reveal any significance

On pooled analysis it was revealed that the number effective nodules at 30 DAS did not vary significantly due to the treatment effects

At the time of flowering also the treatments did not show any significance

4.3 9 Dry weight of nodules per plants

The data on the dry weight of nodules oer plant are given in Table 48

The dry weight of nodules at 30 DAS revealed that the treatments were not significant during season I At flowering also the treatments were not significant

During season II also the dry weight of nodules at 30 DAS did not record any significant difference At flowering again the treatment were not significant

On pooled analysis of the data dry weight of nodules at 30 DAS revealed that the treatments were not significant At flowering again the treatments were not significant

4.3 10 Yield components of cowpea

The data on the yield components of cowpea are given in Table 49

4 3 10 1 Number of pods per plant

In season I the number of pods per plant revealed that treatments were significant T_1 recorded the lowest value of 1 55 pods per plant whereas T_8 recorded the highest value of 2 35 pods per palnt Phosphorus levels and microbial applications were also significant While no phosphorus recorded the lowest value of 1 79 pods per plant 100% phosphorus recorded the highest value of 2 19 pods

Table 48 Dry weight of nodules per plant (mg) in Experiment No 3

Treatment No	Season I		Season II		Pooled mean	
	30 DAS	at flowering	30 DAS	at flowering	30 DAS	at flowering
T_1	171 0	125 3	114 0	97 3	142.5	111.3
T_2	179.3	121 7	128.3	96 7	153 8	109 2
T_3	168 0	120 7	119 3	104 2	143 7	112 5
T_4	177 0	127 0	161 0	105 1	169 0	116 1
T_5	173 3	128 7	122 0	92 5	147 7	110 6
T_6	169 0	130 8	128 0	93 5	148 5	112 2
T_7	171 0	131 6	146 3	105 8	158 7	118 7
T_8	178 3	127 3	145 0	94 7	161 7	111 0
T_9	189 0	125 9	143 0	96 1	166 0	111 0
T_{10}	185.3	124 1	112 3	92 6	148 8	108 4
T_{11}	185 7	128 2	117 7	92 4	151 7	110.3
T_{12}	184 3	127 6	131 7	93 8	158 0	110 7
SEm±	7 87	5 58	20 66	3 65	11 05	3.33
C D (0 05)	—	—	—	—	—	—
FACTORS						
A Fert P						
1 No P	173 8	123 7	130 7	100 8	152 3	112 3
2 50% P	172 9	129 6	135 3	96 6	154 1	113 1
3 100% P	186 1	126 4	126 2	93 7	156 1	110 1
C D (0 05)	—	—	—	—	—	—
B Microbes						
1 No microbes	177 8	126 6	126 3	95 3	152 1	111 0
2 VAM	177 9	125 5	122 9	94 3	150 4	109 9
3 PB	174 9	126 8	127 8	100 8	151 3	113 8
4 VAM + PB	179 9	127 3	145 9	97 9	162 9	112 6
C D (0 05)	—	—	—	—	—	—

Note In those places where C D is not given, the F test is not significant at 5% level

Table 49 Yield components of cowpea in Experiment No 3

Treatment No	No of pods / plant		No of seeds / pod		100 seed weight (g)		Pod length (cm)	
	Season I	Season II	Season I	Season II	Season I	Season II	Season I	Season II
T_1	1 55	1 78	15 4	14 9	9 21	8 68	15 7	14 9
T_2	1 71	1 85	15 4	14 9	9 21	8 69	15 6	14 9
T_3	1 70	1 97	15 4	14 9	9 21	8 69	15 7	14 8
T_4	2 19	2 48	15 4	14 9	9 22	8 69	15 7	14 8
T_5	1 63	1 89	15 5	14 9	9 21	8 70	15 7	14 8
T_6	1 86	2 17	15 4	14 8	9 20	8 70	15 7	14 9
T_7	1 93	2 27	15 4	15 0	9 21	8 70	15 6	14 9
T_8	2 35	2 67	15 4	15 2	9 21	8 69	15 7	14 9
T_9	2 06	2 36	15 4	14 9	9 21	8 68	15 7	14 9
T_{10}	2 17	2 61	15 4	14 9	9 21	8 70	15 8	14 9
T_{11}	2 22	2 61	15 4	14 9	9 22	8 70	15 7	14 9
T_{12}	2 30	2 63	15 4	15 0	9 21	8 69	15 7	14 8
SEm±	0 028	0 029	0 05	0 11	0 004	0 010	0 05	0 05
C D (0 05)	0 082	0 085	—	—	—	—	—	—
FACTORS								
A Fert. P								
1 No P	1 79	2 02	15 4	14 9	9 21	8 69	15 7	14 8
2 50% P	1 94	2 25	15 4	15 0	9 21	8 70	15 7	14 9
3 100% P	2 19	2.55	15 4	14 9	9 21	8 69	15 7	14 9
C D (0 05)	0 041	0 042	—	—	—	—	—	—
B Microbes								
1 No microbes	1 74	2 01	15 4	14 9	9 21	8 69	15 7	14 9
2 VAM	1 92	2 21	15 4	14 9	9 21	8 70	15 7	14 9
3 PB	1 95	2 28	15 4	14 9	9 21	8 69	15 7	14 9
4 VAM + PB	2 28	2 59	15 4	15 0	9 21	8 69	15 7	14 8
C D (0 05)	0 047	0 049	—	—	—	—	—	—

Note In those places where C D is not given, the F test is not significant at 5% level

per plant In the case of microbes when no microbes reco ded the lowest value f 1 74 pods per plant VAM + PB recorded the highest value of 2 28 pods per plant

In the season II also the number of pods per plant revealed that the treatments were significant T_1 recorded the lowest value of 1 78 pods per plant whereas T_8 recorded the highest value of 2 67 pods per plant Phosphorus levels were also significant Here again no phosphorus recorded the lowest value of 2 02 pods per plant whereas 100% phosphorus recorded the highest value of 2 55 pods per plant Microbial applications also revealed significance Among microbial applications no microbes recorded the lowest value of 2 01 pods per plant whereas VAM + PB recorded the highest value of 2 59 pods pe plant

4.3 10 2 Number of seeds per pod

In the season I the number of seeds per pod did not differ significantly due to various treatment combinations In the season II also the various treatment combination and individual factors did not influence the number of pods per pla it significantly

4 3 10.3 Hundred seed weight of cowpea

The hundred seed weight revealed that the treatments were not significant in sea on I

In season II also the treatment combinations as well as individual reatments were not significant

4.3 10 4 Pod length of cowpea

In both seasons the pod length of cowpea revealed that the treatments were not significant

4.3.11 Grain yield of cowpea

The grain yield of cowpea are given in Table 50 and Fig 11

In season I grain yields of cowpea revealed that the treatments were significant T_1 recorded the lowest yield of 585 kg ha^{-1} whereas T_8 recorded the highest yield of 888 kg ha^{-1} Both phosphorus levels and microbial applications were significant While no phosphorus recorded the lowest yield of 676 kg ha^{-1} 100% phosphorus recorded the highest yield of 827 kg ha^{-1} Among microbial applications no microbes recorded the lowest yield of 660 kg ha^{-1} whereas VAM + PB recorded the highest yield of 863 kg ha^{-1}

In the season II also the treatments were significant in their effects T_1 recorded the lowest yield of 615 kg ha^{-1} whereas T_8 recorded the highest yield of 921 kg ha^{-1} Here again phosphorus levels and microbial applications registered significant effects No phosphorus recorded the lowest yield of 698 kg ha^{-1} whereas 100% phosphorus recorded the highest yield of 881 kg ha^{-1} Among microbial application no microbes recorded the lowest yield of 694 kg ha^{-1} whereas VAM + PB recorded the highest yield of 896 kg ha^{-1}

On pooled analysis of the data it was revealed that the treatments were significant Here again T_1 recorded the lowest yield of 600 kg ha^{-1} whereas T_8 recorded the highest yield of 905 kg ha^{-1} Phosphorus levels as well as microbial application were significant When no phosphorus recorded the lowest yield of 687 kg ha^{-1} 100% phosphorus recorded the highest yield of 854 kg ha^{-1} Among microbial applications no microbes recorded the lowest yield of 677 kg ha^{-1} whereas VAM + PB recorded the highest yield of 879 kg ha^{-1}

Table 50 Yields of grains and haulms (kg ha $^{-1}$) in Experiment No 3

Treatment No	Season I		Season II		Pooled mean	
	grains	haulms	grains	haulms	grains	haulms
T_1	585	4001	615	2770	600	3386
T_2	648	4362	638	2894	643	3628
T_3	642	4354	679	3021	661	3688
T_4	829	5097	858	3571	844	4334
T_5	615	4241	653	2952	634	3597
T_6	705	4574	749	3263	727	3918
T_7	728	4711	783	3383	756	4047
T_8	888	5334	921	3843	905	4589
T_9	779	4931	814	3476	797	4204
T_{10}	820	5082	900	3794	860	4438
T_{11}	839	5137	900	3722	869	4430
T_{12}	871	5311	908	3793	890	4552
SEm±	10 4	46 9	10 0	33 8	7 2	28 9
C D (0 05)	30 6	137 5	29 3	99 2	20 6	82 6
FACTORS						
A Fert. P						
1 No P	676	4454	698	3064	687	3759
2 50% P	734	4715	777	3360	755	4038
3 100% P	827	5115	881	3696	854	4406
C D (0 05)	15 3	68 7	14 6	49 6	10 3	41 3
B Microbes						
1 No microbes	660	4391	694	3066	677	3729
2 VAM	724	4673	762	3317	743	3995
3 PB	736	4734	787	3375	762	4055
4 VAM + PB	863	5248	896	3736	879	4492
C D (0 05)	17 7	79 4	16 9	57 3	11 9	47 7

Note In those places where C D is not given, the F test is not significant at 5% level

4.3 12 Haulms yield of cowpea

The data on haulms yield of cowpea are given in Table 50

During both seasons the treatments registered significant variation in the haulms yield At both seasons T_1 recorded the lowest yield whereas T_8 recorded the highest yield Phosphorus levels and microbial applications were also significant during both seasons No phosphorus recorded the lowest yield whereas 100% phosphorus recorded the highest yield Among microbial applications no microbes recorded the lowest yield whereas VAM + PB recorded the highest yield

On pooled analysis of the data revealed that the treatments were significant When T_1 recorded the lowest yield of 3386 kg ha^{1} T_8 recorded the highest yield of 4589 kg ha^{1} Phosphorus levels and microbial applications were also significant In the pooled analysis also no phosphorus recorded the lowest yield of 3759 kg ha^{1} whereas 100% phosphorus recorded the highest yield of 4406 kg ha^{1} Among microbial applications no microbes recorded the lowest yield of 3729 kg ha^{1} whereas VAM + PB recorded the highest yield of 4492 kg ha^{1}

4.3 13 Harvest index of cowpea

The data on the harvest index of cowpea are given in Table 51

In season I harvest index of cowpea recorded that the treatments were not significant whereas in season II the treatments were significant In season II both T_2 and T_5 recorded the lowest value of 18 1% whereas T_{11} recorded the the highest value of 19 5% Unlike season I phosphorus levels and microbial applications were significant in season II When no phosphorus recorded the lowest value of 18 5% 100% phosphorus recorded the highest value of 19 2% Among microbes no

Table 51 Harvest index (%) in Experiment No 3

Treatment No	Season I	Season II
T_1	12 8	18 2
T_2	12 9	18 1
T_3	12 8	18 4
T_4	14 0	19 4
T_5	12 7	18 1
T_6	13 4	18 7
T_7	13 4	18 8
T_8	14 3	19 3
T_9	13 7	19 0
T_{10}	13 9	19 2
T_{11}	14 0	19 5
T_{12}	14 1	19 3
SEm±	0 58	0 14
C D (0 05)	—	0 42
FACTORS		
A Fert P		
1 No P	13 1	18 5
2 50% P	13 4	18 7
3 100% P	13 9	19 2
C D (0 05)	—	0 21
B Microbes		
1 No microbes	13 0	18 4
2 VAM	13 4	18 6
3 PB	13 4	18 9
4 VAM + PB	14 1	19 4
C D (0 05)	—	0 24

Note In those places where C D is not given the F test is not significant at 5% level

microbes recorded the lowest value of 18 4% whereas VAM + PB recorded the highest value of 19 4% in season II

4.3 14 Protein content of grains

The data on protein content of cowpea grains are given in Table 52

The data on protein content of grains recorded that treatments were significant While T_1 recorded the lowest value of 22 07% T_{12} recorded the highest value of 23 35% Both phosphorus levels and microbial applications were significant No phosphorus recorded the lowest value of 22 32% whereas 100% phosphorus recorded the highest value of 23 21% Among microbial applications no microbes recorded the lowest value of 22 58% whereas VAM + PB recorded the highest value of 23 08%

In season II the same trend of results of season I were repeated

4.3 15 Nitrogen uptake of plants

Nitrogen uptake of plants in this experiment is given in Table 53 and Fig 12

In season I and season II nitrogen uptake of plants at 30 DAS were significant When the lowest value was recorded by T_1 the highest value was recorded by T_8 Phosphorus levels as well as microbial applications were significant Among phosphorus levels no phosphorus recorded the lowest value whereas 100% phosphorus recorded the highest value In the case of microbes no microbes recorded the lowest value whereas VAM + PB recorded the highest value

In season I and season II N uptake of plants at flowering were significant T_1 recorded the lowest value whereas T_{12} recorded the highest value Phosphorus levels and microbial applications also were significant In the case of phosphorus

Table 52 Protein content of grains (%) in Experiment No 3

Treat nent No	Season I	Season II
T_1	22 07	22 14
T_2	22 35	22 42
T_3	22 16	22 41
T_4	22 69	23 32
T_5	22 56	22 80
T_6	22 59	22 81
T_7	22 72	22 91
T_8	23 19	23 16
T_9	23 13	23 16
T_{10}	23 14	23 19
T_{11}	23 19	23 22
T_{12}	23 35	23 42
SEm±	0 046	0 034
C D (0 05)	0 133	0 100
FACTORS		
A Fert P		
1 No P	22 32	22 57
2 50% P	22 76	22 97
3 100% P	23 21	23 25
C D (0 05)	0 067	0 050
B Microbes		
1 No m crobes	22 58	22 70
2 VAM	22 70	22 81
3 PB	22 69	22 85
4 VAM + PB	23 08	23 30
C D (0 05)	0 077	0 058

Note In those places where C D is not g ven the F test is not sign f cant at 5% level

Table 53 N uptake of plants (kg ha ^{1}) in Experiment No 3

Treatment No	Season I			Season II			Pooled mean		
	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest
T_1	16 90	80 76	92 04	17 42	73 43	71 39	17 16	77 09	81 71
T_2	19 54	91 47	102 46	18 81	77 06	76 13	19 17	84 27	89 29
T_3	19 42	90 97	101 93	20 07	82 77	79 99	19 75	86 87	90 96
T_4	25 59	119 11	122 71	26 61	107 01	98 17	26 10	113 06	110 44
T_5	19 10	88 10	99 71	19 90	81 22	78 02	19 50	84 66	88 87
T_6	23 15	100 17	109 47	23 13	92 46	87 56	23 14	96 31	98 52
T_7	24 72	103 11	112 61	25 07	95 64	91 14	24 90	99 38	101 88
T_8	29 11	126 68	130 76	29 45	114 27	105 53	29 28	120 48	118 15
T_9	25 56	111 38	119 09	25 63	101 63	94.39	25 60	106 51	106 74
T_{10}	26 62	116 46	122 88	28 31	110 98	103 46	27 46	113 72	113 17
T_{11}	27 70	119 79	124 17	29 27	112 07	102 02	28 49	115 93	113 09
T_{12}	29 55	126 17	128 72	29 92	113.35	103 85	29 73	119 76	116 29
SEm±	0 405	1 688	1 183	0.337	1 381	0 915	0 264	1 091	0 748
C D (0 05)	1 189	4 952	3 469	0 990	4 051	2 685	0 753	3 115	2 136
FACTORS									
A Fert. P									
1 No P	20 36	95.58	104 78	20 73	85 07	81 42	20 54	90 32	93 10
2 50% P	24 02	104 52	113 14	24 39	95 90	90 56	24 20	100 21	101 85
3 100% P	27 36	118 45	123 71	28 29	109 51	100 93	27 82	113 98	112 32
C D (0 05)	0 595	2 478	1 734	0 495	2 025	1 343	0 377	1 558	1 068
B Microbes									
1 No microbes	20 52	93 41	103 61	20 98	85 43	81 27	20 75	89 42	92 44
2 VAM	23 10	102 70	111 60	23 42	93 50	89 05	23 26	98 10	100.33
3 PB	23 95	104 63	112 90	24 81	96 83	91 05	24 38	100 72	101 98
4 VAM + PB	28 08	123 99	127 40	28 66	111 54	102 52	28 37	117 77	114 96
C D (0 05)	0 687	2 859	2 003	0 571	2 339	1 550	0 435	1 799	1 233

no phosphorus gave the lowest value where as 100% phosphorus recorded the highest value Among microbes no microbes gave the lowest value whereas VAM + PB recorded the highest significant value

During both seasons at harvest treatments were significant and the lowest value was registered by T_1 whereas T_8 registered the highest value Phosphorus levels and microbial applications also were significant Among phosphorus no phosphorus gave the lowest value whereas 100% phosphorus gave the highest value Among microbes no microbes gave the lowest value whereas VAM + PB recorded the highest value

Pooled analysis of the two seasons at various stages of the experiment were only a mere confirmation of the two seasons results

4.3 16 Phosphorus uptake of plants

Phosphorus uptake of plants in this experiment is given in Table 54 and Fig 13

In season I and season II phosphorus uptake of plants at 30 DAS revealed that the treatment responses were significant Among the treatments T_1 recorded the lowest value whereas T_{12} recorded the highest value The phosphorus and microbial applications also recorded significant response With respect to phosphorus no phosphorus recorded the lowest value whereas 100% phosphorus recorded the highest significant value In the case of microbes no microbes recorded the lowest value whereas VAM + PB recorded the highest significant value

During both seasons phosphorus uptake of plants at flowering also gave significant response Among the treatments T_1 recorded the lowest value whereas

Table 54 P uptake of plants (kg ha $^{-1}$) in Experiment No 3

Treatment No	Season I			Season II			Pooled mean		
	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest	30 DAS	at flowering	at harvest
T_1	3 10	15 11	19 17	3 05	13 29	14 55	3 07	14 20	16 86
T_2	3 49	16 99	21 16	3 14	13 84	15 41	3 31	15 42	18 28
T_3	3.50	17 06	21 32	3 39	14 87	16 32	3 45	15 96	18 82
T_4	4 33	21 96	25 47	4 33	19 03	19 68	4 33	20 49	22 57
T_5	3 32	16 22	20 73	3 24	14 40	15 97	3 28	15 31	18 35
T_6	3 86	18 71	22 67	3 76	16 50	17 80	3 81	17 61	20 24
T_7	4 00	19 21	23 38	4 00	17 31	18 66	4 00	18 26	21 02
T_8	4 81	23 62	27 05	4 66	20 40	21 48	4 74	22 01	24 27
T_9	4 29	20 96	24 83	4 11	18 06	19 37	4 20	19 51	22 10
T_{10}	4 50	21 78	25 65	4 54	19 99	21 29	4 52	20 89	23 47
T_{11}	4 57	22 43	26 03	4 57	20 15	21 08	4 57	21 29	23 55
T_{12}	4 76	23 64	27 02	4 63	20 47	21 42	4 69	22 05	24 22
SEm±	0 070	0 302	0 259	0 048	0 227	0 204	0 043	0 189	0 165
C D (0 05)	0 206	0 886	0 759	0 142	0 665	0 598	0 122	0.540	0 471
FACTORS									
A Fert. P									
1 No P	3 60	17 78	21 78	3 47	15 26	16 49	3 54	16 52	19 13
2 50% P	4 00	19 44	23 46	3 92	17 15	18 48	3 96	18 30	20 97
3 100% P	4 53	22 20	25 88	4 46	19 67	20 79	4 50	20 94	23 34
C D (0 05)	0 103	0 443	0.379	0 071	0 333	0 299	0 061	0 270	0 235
B Microbes									
1 No microbes	3.57	17 43	21 57	3 47	15 25	16 63	3 52	16.34	19 10
2 VAM	3 95	19 16	23 16	3 81	16 78	18 17	3 88	17 97	20 66
3 PB	4 02	19 57	23 58	3 99	17 45	18 69	4 01	18 51	21 13
4 VAM + PB	4 63	23 07	26 52	4 54	19 97	20 86	4 59	21 52	23 69
C D (0 05)	0 119	0 512	0 438	0 082	0 384	0 345	0 070	0 312	0 272

T_8 recorded the highest significant value Phosphorus levels and microbial factors were also significant In the case of phosphorus no phosphorus gave the lowest P uptake whereas 100% phosphorus gave the the highest significant value In the case of microbes no microbes recorded the lowest P uptake whereas VAM + PB recorded the highest significant value

In both seasons phosphorus uptake at harvest showed that the treatments recorded significant response When T_1 recorded the lowest value T_8 recorded the highest significant value Phosphorus levels and microbial applications also were statistically significant When no phosphorus gave the lowest value 100% phosphorus gave the highest significant value Among microbes no microbes gave the lowest value of P uptake VAM + PB recorded the highest significant value of P uptake

The pooled analysis of the two seasons at various stages of the experiments were only a mere confirmation of the results of the two seasons

Discussion

5. DISCUSSION

5 1 Experiment No 1 (Effect of phosphorus desorbing anions)

5 1 1 Physical properties of the soil

Data on the physical properties of the soil are given in Table 4

It is revealed that important physical properties like bulk density water holding capacity and mean weight diameter of aggregates increased from sowing to harvest During the first season when the treatment effects were not significant in the case of bulk density and water holding capacity the data on mean weight diameter of aggregates registered significant difference between treatments when the lowest value of 0 92 mm was recorded in 100% P with no anions and the highest value of 1 13 mm was recorded in no phosphorus with hydroxyl anion

In respect of individual factors fertilizer phosphorus only could record significant difference that too only in the case of mean weight diatmeter of aggregates Here a striking observation was that the significance was shown in the reverse order wherein no phosphorus recorded the maximum value of 1 06 mm diameter None of the anions could record any significant influence on any one of the physical properties of the soils

In the case of season II all the physical properties of the soil increased from sowing to harvest The treatment effects were also significant in the case of mean weight diameter of aggregates during season II

Coming to the individual factors levels of phosphorus could exert significant influence only in the case of water holding capacity and mean weight diameter of aggregates In the case of water holding capacity the highest level of 100% P registered the highest water holding capacity of 30 57% while the 50% P level registered the highest value of 1 10 mm mean weight diameter

It was observed that with respect to anions silicate anion could record the highest value of 1 09 mm mean weight diameter of aggregates which was significantly superior to all the other anions including no anion treatment

In the case of bulk density it was observed that neither the treatment combinations nor the levels of P or anions could exert significant influence on this character It is quite natural that during both seasons the bulk density increased from sowing to harvest because during cultivation of any crop there occurs compactions of the soil resulting in an increase in the bulk density values It is a fact that bulk density of any soil is closely related to the soil structure According to Page and Willard (1946) the bulk density resulted in loss of pore space and corresponding increase in weight per unit volume of the soil Prabhakara (1970) observed a slightly higher bulk density in four crop relays

In the case of water holding capacity it is observed that the effects of treatments and levels were significant only during second crop season The data reveals the fact that the anions independently could not exert any significant influence on water holding capacity and its effects are being manifested only in combination with levels of phosphorus

The mean weight diameter of aggregates varied significantly with different treatment combinations as well as with different levels of phosphorus and with different anions except in season I during which the effects of different anions were not significant It is evident that there was increase as well as decrease in mean weight diameter of aggregates from sowing to harvest under different treatment combinations during season I whereas there was increase in the mean weight diameter of aggregates in season II indicating that there was no stability in this character The levels of P could also exert significant influence during both seasons but the effect was in the reverse order in season I whereas it was in the positive order in season II indicating again that there was no stability in this character The effects of anions also recorded both significant as well as non significant influences indicating there by that no stability could occur in this character

5 1 2 Chemical properties of the soil

The data on the chemical properties of the soil are given in Table 5

It could be observed from the data that there was no significant differences in the C E C of the soil either during season I or during season II or in the pooled analysis The same trend was observed with respect to levels of P as well as anion factors in both seasons as well as in the pooled analysis the results thus indicate the fact that C E C of the soil is not affected by either levels of P or by different anions or by their combinations This may be because of the fact that the C E C is an inherent character of the soil which is very much related to the nature of clay complex and its structure which remain unaltered by several external factors This finding is in agreement with the results reported by Bhatnagar et al (1977) It is observed from the data that the pH of the soil was increased from sowing to harvest in both season as well as in the pooled analysis The various treatment combinations as well as levels of P and different anions could also exert significant influence on pH of the soil except by the levels of P during the second season While the treatments no P with carbonate 50% P with hydroxide 50% P with carbonate 50% P with silicate 100% P with carbonate and 100% P with silicate recorded the maximum level of 5 17 in the pooled analysis also The lowest value of 5 12 was recorded by no P with no anions during first season and in the pooled analysis whereas during season II no P with no anions recorded the lowest pH value of 5 11

With respect to fertilizer P levels there was significant increase in pH values from no P to the highest P levels except during second season In respect of anions the highest value of 5 18 was recorded by carbonate anion during season I whereas silicate anion recorded the highest pH value of 5 16 during second season In the pooled analysis again the carbonate anion recorded the highest pH value of 5 17 The results that the different anions could raise the soil pH significantly over no anion treatment reveals the fact that the addition of any liming material could raise the soil pH substantially In the present study also the different anions were applied on a calcium base which could exert the liming effect on the pH of the soil (Kerala Agricultural University 1989 Tisdale et al 1985)

It was brought out from the data that the total nitrogen percentage of the soil was increased by different treatment combinations as well as by anions over the pre sowing data during season I season II as well as in the pooled analysis However there was no significant difference between the levels of phosphorus during both seasons as well as in the pooled analysis During first season the highest value of 0 133% of nitrogen was recorded by 50% P with hydroxide and 100% P with carbonate whereas no P with silicate recorded the highest value of 0 136% nitrogen in season II However in pooled analysis, no P with silicate could record the highest value of 0 134% nitrogen It is revealed that the lowest value of 0 124% nitrogen was recorded by no P with no anions and 100% P with no anions during first season whereas the above two treatments could record the lowest value of 0 126% during second season In the pooled analysis also no P with no anion and 100% P with no anions were responsible for recording the lowest value but with a different value of 0 125%

There was progressive increase in the total nitrogen percentage from no anion treatment to different anion treatments Among the different anions silicate anion recorded the highest value which was significantly superior to no anions treatment It was observed from the data that the levels of phosphorus by itself could not exert any significant influence on the total nitrogen percentage of the soil whereas in combination with various anions it could significantly influence the total nitrogen percentage of the soil The data further revealed that all the anions were superior in their effect over no anion treatment Thus it could be observed that the combined effect of different anions and levels of P could have promoted growth and development of cowpea which in turn would have exerted legume effect resulting in increased total nitrogen percentage of the soil The legume effect in promoting nitrogen content of the soil has been brought about by workers like Tisdale et al (1985)

In respect of total phosphorus content of the soil it was observed that neither the treatment combinations nor the levels of fertilizer P and the different anions could exert significant influence on this nutrient in both seasons as well as on pooled analysis It was also observed that the total phosphorus content of the soil decreased from what was present before sowing in both seasons as well as on pooled analysis The decrease in total phosphorus from sowing to harvest could be attributed to the depletion of soil phosphorus on account of the uptake of the test crop of cowpea

As regards to P fixing capacity of the soil also the different treatment combinations as well as the different levels of P and different anion could not exert any significant influence on this character The observation that the different treatments as well as their combinations were almost alike in their ability on the P fixing capcity closely brings out the fact that the P fixing capacity of the soil is mostly an inherent characteristic of the soil which is not very much influenced by external factors like phosphorus and anions

In respect of organic matter content of the soil the data clearly indicated the fact that neither the levels of phosphorus and the different anions nor their combinations had any influence on the organic matter content of the soil during both seasons as well as on pooled analysis This may be because of the fact that there was no significant increase in the organic matter content of the soil by way of addition of crop residues

5 1.3 Available phosphorus content of the soil

The data on the available phosphorus content of the soil are given in Table 6

The data revealed that the available P content of the soil increased upto 30 DAS and then decreased at the time of harvest in both seasons as well as in the pooled analysis In season I there was significant difference between the treatment combinations At 30 DAS no P with carbonate anion has given the highest value of 17 93 mg P kg ^{1} whereas no P with no anions has given the lowest value of 11 62 mg P kg ^{1} In the case of season II also the treatment combinations were significantly different with 50% P along with carbonate recorded the highest value of 16 55 mg P kg ^{1} whereas no P with no anions recorded the lowest value of 9 98 mg P kg ^{1} The data after harvest of the crop revealed that the treatment combinations were significantly different in season I whereas such differences could not be observed in season II With respect to pooled analysis there was significant difference between treatment combinations both at 30 DAS as well as after harvest

When individual factors are considered it was observed that the available P content of the soil was significantly increased from no P to 50% P at 30 DAS whereas at harvest it has increased from no P to 100% P during both seasons In the case of pooled analysis also the same trend of result was obtained and that the results were significant both at 30 DAS and at harvest

In the case of anions the available P increased from no anions to different anions and the differences were significant in season I season II and pooled analysis at 30 DAS while after harvest such significant differences were observed only in season I and pooled analysis

An overall picture of the results indicate the fact that various treatments individually and in combination exerted significant influence on the available P content of the soil throughout the growth period of the crop This could be attributed to the relatively higher pH values of the treated plots (Table 5) as reported by Murrmann and Peech (1969) The present results corroborate with the findings of Mariakulandai (1954) Hosoda and Takata (1957) Domning and Amberger (1988) and Subramonian and Gopalaswamy (1991)

5 1 4 Soil phosphorus fractions

The soil phosphorus fractions at different stages of the experiment are given in Table 7 8 and 9

It was revealed from the data that in season I when saloid P was significantly increased from sowing to flowering Al P and organic P were significantly reduced during the above period However other phosphorus fractions like Fe P Red P Occl P Ca P as well as total P remained almost unaltered with a tendency of reduction in most cases During season II also the same trend was repeatedly observed from sowing to flowering whereas in the case of pooled analysis although saloid P Al P and organic P behaved as in season I and season II Red P and Occluded P recorded significant reduction from sowing to flowering

In the case of season I the increasing trend observed from sowing to flowering continued beyond flowering thus reflecting in the data after harvest in the case of saloid P whereas significant reduction was observed in the case of Al P and organic P The same trend was repeatedly observed in season II also from flowering to harvest In the case of pooled analysis however the different soil P fractions behaved similar to that in season I and season II from sowing to flowering

As regards individual factors in season I at flowering significant differences were observed only in the case of Al P and organic P on account of levels of phosphorus applied In the case of Al P there was significant reduction from no P to 50% P and that the same trend was observed in the case of organic P also

While there was significant increase in saloid P fraction from no anion to different categories of anions at flowering in season I there observed significant reduction in Al P and organic P The same trend was repeatedly observed in season II also With regards to pooled analysis in addition to Al P and organic P Red P and occluded P also exerted a trend of reduction in the case of anions from no anions to different anions Saloid P exhibited the same increasing trend from no anions to different anions as in the case of season I

A closer examinations of the data after harvest brings out clearly the fact that the same trend of results obtained at flowering during season I and season II were repeated at harvest stage also On pooled analysis it was observed that in addition to saloid P Al P and organic P Fe P Occluded P and Ca P also exhibited significant response the value being more or less in a decreasing trend

An overall picture of the data on the P fractions of the soils revealed that saloid P was increased in various treatment combinations as well as factors like P and anions Al P and organic P recorded a significant reduction while Fe P Occluded P and Ca P recorded slight reduction in their values Saloid P being the water soluble P denotes the available P fractions of the soil The consequent reduction in Al P organic P Fe P Occluded P and Ca P clearely indicates the fact that the available P portion (Saloid P) finds its source mainly from Al P and organic P and slightly from Fe P occluded P and Ca P This corroborate with the findings of Singhania and Goswami (1978) Talashilkar and Patel (1979) Sharma et al (1980) Madhusoodanan Nair and Padmaja (1982) Kothandaraman (1975) Uzo et al (1975) Sudhir et al (1987) Agarwal et al (1987) Dikshit and Padihar (1988) and Al Mustafa (1988)

5 1 5 Leaf area index (LAI)

The data on LAI are presented in Table 10

It was observed that the treatment combinations could exert significant influence only at flowering in both seasons The LAI values increased progressively from 30 DAS to flowering during both seasons Although not significant the highest LAI value was shown by 100% P with silicate anions during both seasons Similarly 50% P with carbonate recorded the highest LAI values at flowering in both seasons (4 53 in season I and 3 48 in season II) It was also observed that the LAI values recorded both at 30 DAS and at flowering were comparatively lower in season II as compared to season I

The individual factors like fertilizer P and anions were also found to exert significant influence only at flowering during both seasons In the case of fertilizer P the LAI values increased from no P to 100% P at 30 DAS and at flowering during both seasons although 100% P could exert significant influence only at flowering during both seasons

Coming to anions all the anions recorded higher values of LAI over no anions treatment during both seasons at flowering However only carbonate anion could record significantly higher LAI values during both seasons Here again the lowest LAI values were recorded by no anion treatments

The increasing trend in LAI values from 30 DAS to flowering is in line with the growth pattern of cowpea which records higher LAI values towards flowering The possitive influence of available P on the LAI values is in agreement with the findings of Patel et al (1983) Geethakumari (1981) Jain et al (1986) Vasimalai and Subramonian (1980) Annie Philip (1993) and Tarila et al (1977)

The fact that 50% P with carbonate anion could record highest LAI values at flowering during both seasons indicate the fact that this treatment could enhance the number of leaves per unit area in combination with carbonate anion This complimentary influence of carbonate anion has been found to be significant When we look individual factors independently only 100% P could exert highest values of LAI whereas even 50% P could record significantly higher LAI values when it is applied in combination with carbonate anion This positive influence is again reflected in the individual effect of carbonate anion which recorded significantly higher LAI values at flowering during both seasons The favourable effect of phosphorus in increasing the number of leaves per unit area in legumes has been reported by several scientists like Geethakumari (1981) and Jain et al (1986)

The favourable influence of carbonate anion on the LAI values may be due to the possitive effect of increased available P in the soil brought about by carbonate anion The data on the available P content of the soil clearly indicated the fact that the carbonate anion could record high available P content during both seasons as well as on pooled analysis at 30 DAS (Table 6) The favourable influence of available P on the increased production of leaves thereby recording increased LAI values has been discussed earlier

The observation that all the LAI values during season II were comparatively lower than that of season I is quite convincing because of the fact that the rainfall conditions were not much favourable during season II which is evident from the data on weather parameters (Appendix I and Appendix II) The data revealed the fact that the total rainfall during second season was comparatively lower than that of the first season

5 1 6 Leaf Area Ratio (LAR)

The data on leaf area ratio are given in Table 11

The data indicated significant differences only at 30 DAS during season I whereas in season II the different treatment could exert significant influence both at 30 DAS and at flowering It was observed that no P with no anions recorded significantly higher LAI values at 30 DAS during both seasons In season I no P with no anions recorded a value of 26 56 $cm^2 g^{-1}$ where as in season II it has recorded a highest value of 21 47 $cm^2 g^{-1}$ In the case of LAR the values were comparatively lower in season II than in season I

When the individual factors are considered it was observed that the highest LAR values were recorded by no P treatment at 30 DAS during both seasons In the case of anion treatments also no anion has recorded significantly higher LAR values at 30 DAS during both seasons Between various anions silicate anion could record higher values than carbonate and hydroxide anions

In the earlier chatper it was observed that phosphorus could enhance the production of leaves and thereby enhance leaf area per unit of land area The data on LAR now indicate that phosphorus is capable of enhancing the thickness of leaves also This is how the treatment combination of no P and no anions could record highest LAR values at 30 DAS during both seasons A higher LAR values is indicative of the fact that the relative thickness of the leaves per unit leaf area will be comparatively less thereby recording lesser weight resulting in increased leaf area ratio In the present study also the higher values of LAR are indicative of comparatively lesser thickness of leaves on account of lesser P supply in the no P treatments This is being further illustrated in the same data whereby the LAR values progressively decreased with increasing levels of P

As in the case of LAI the LAR values also were lower in season II indicating the influence of rainfall which was lesser in season II as compared to season I The role of anions on the relative increase in available P would have resulted in decreased LAR values under different anions

5 1 7 Leaf Weight Ratio (LWR)

The data on leaf weight ratio of plants are given in Table 12

It was observed that significant influence of the treatments was recorded only in season II and that too at flowering LWR values were comparatively lower in no P with no anion plots which progressively increased under different levels of P and different anions

Among levels of fertilizer P no P recorded lowest values during both seasons at both critical stages although significance was observed only at flowering during season II The different anions also could not exert any influence on the leaf weight ratio values of the plants except at flowering in season II

Leaf weight ratio is the expression of combined influence of LAI over the relative thickness of leaves In the earlier sections we found that the available P has got positive influence in measurable terms on the LAI as well as the relative thickness of the leaves In the data on the leaf weight ratio it was observed that whenever there is an increase in supply of phosphorus the leaf weight ratio values also increased Among the anions carbonate anion was found to be more striking in its effect on the leaf weight ratio as seen n the data presented in the Table 12 which is attributed to high available P flux in the soil due to carbonate anion

5 1 8 **Number of effective nodules**

The data on the number of effective nodules per plant in the experiment are given in Table 13

It was observed from the data that the number of effective nodules per plant did not vary significantly at 30 DAS during season I whereas during season II and pooled analysis the data recorded significant variation On pooled analysis the number of effective nodules recorded maximum significant variation at 100% P with silicate Among the phosphorus levels during season II the data showed maximum response at 50% P level although this response was on par 100% P level But this trend was reversed at pooled analysis wherein 100% P gave maximum response which was again on par with 50% P Even when phosphorus levels could exert significant response none of the anions gave significant response at 30 DAS

At the flowering stage the number of nodules were not significant during season I whereas at season II and pooled analysis the data recorded significant response Although the effect was significant at flowering during season II and pooled analysis the results indicated that 50% P with no anions gave the lowest value whereas 100% P with no anions gave the highest value during season II

On verification of the effect of the levels of P on the nodule count at flowering it was revealed that the trend showed significance only during season II and as such could not be reflected in the pooled analysis On verification of the effect of anion on the nodule count it was observed that none of the anions could exert any significant response

An overall picture of the data revealed that nodule count was significant at 30 DAS only and that too with applied P both at 50% P and 100% P levels The positive effect of applied P on the nodule count was reported by several workers like George (1980) Ahlawat and Saraf (1982) Patel et al (1983) and Kumar and Verma (1988)

It could be observed from the data that the effective nodule count has decreased from 30 DAS to flowering This might possibly be due to the malfunctioning and Shrinkage of the nodule This is in agreement with the findings of Kumar and Verma (1988)

5 1 9 Dry weight of nodules

The data on the dry weight of nodules per plant are given in Table 14

The data revealed that the dry weight of nodules was significant at flowering and at 30 DAS during season I and season II In the pooled analysis of the data none of the results revealed significant response

At 30 DAS during season I 50% P with carbonate anion gave the maximum significant response whereas during season II 100% P with hydroxyl anion gave the maximum response

Among the levels of phosphorus none of the treatment could exert significant response during season I but during season II 100% P recorded maximum significant response Among the anions carbonate anion exerted maximum response during season I whereas during season II none of the anions could exert significant response

On verification of the data at flowering it was revealed that 100% P with carbonate gave the highest significant response during season I whereas during season II 50% P with no anions gave the highest response

Among the phosphorus levels 100% P gave the maximum significant response in season I whereas 50% P gave the maximum response during season II Among the anions none of the anions could exert significant response in both seasons

An overall picture of the data indicated that the dry weight of nodules exhibited highly erratic behaviour during both seasons This might probably be due to the fact that the size of nodules increased with decrease in the number so that the overall weight of nodules (on pooled) remained unchanged However the role of phosphorus on the dry wieght of nodules was evident in the present study Ahlawat and Saraf (1982) while studying the rooting and nodulation pattern in pigeon pea under different planting densities and phosphatic fertilization reported that application of phosphorus at 34 kg P ha^{-1} increased the weight of nodules than 17 kg P ha^{-1} Similarly Mali and Mali (1991) obtained increased dry weight of nodules by P fertilization in cowpea while studying on the response of promising cowpea genotypes to row spacing and phosphate levels

5 1 10 Yield components of cowpea

The data on the yield components of cowpea are given in Table 15

It was evident from the data that the numbe of pods per plant recorded significant variation during both seasons and 50% P with carbonate gave the maximum number of pods per plant With respect to fertilizer P levels 100% P gave the maximum pods per plant which was on par with 50% P This clearly brings out the fact that phosphorus has significant positive influence on the number of pods per plant This is in agreement with the findings of Jayaram and Ramiah

(1980) Shrivastava et al (1980) Puste and Jana (1988) Kalita and Kalita (1992) Sarkar (1992) Budhar et al (1991) and Durai Singh and Gopalaswamy (1991)

With regard to anions carbonate anion gave significantly highest pods per plant during both seasons Here again no anions treatment recorded the lowest values This shows that the different anions exerted positive influence on the available phosphorus content of the soil as evidenced in the data presented in Table 6 The positive influence of phosphorus in increasing the pods per plant were corroborated with the findings of several workers in the previous para The fact that combination of 50% phosphorus with carbonate anion gave the highest number of pods per plant indicate that the combination of carbonate anion can increase in the efficiency of P levels in this respect

The number of seeds per pod in this experiment did not record significant variation during both seasons Individual treatments like fertilizer phosphorus and anions also did not show any significant response This clearly indicates that the number of seeds per pod is make of a varietal character which cannot be modified by external influences

The data on hundred seed weight and pod length also were not significant with respect to treatments during both seasons The influence of phosphorus and anions were also not significant This shows that neither phosphorus nor anions or their combinations could influence these characters

5 1 11 Grain yield of cowpea

It was observed from the data that grain yield recorded significant response during both seasons and in pooled analysis While no P with no anions gave the minimum yield 50% P with carbonate gave the maximum yield The result of factorial analysis of phosphorus levels recorded that 100% P was significantly

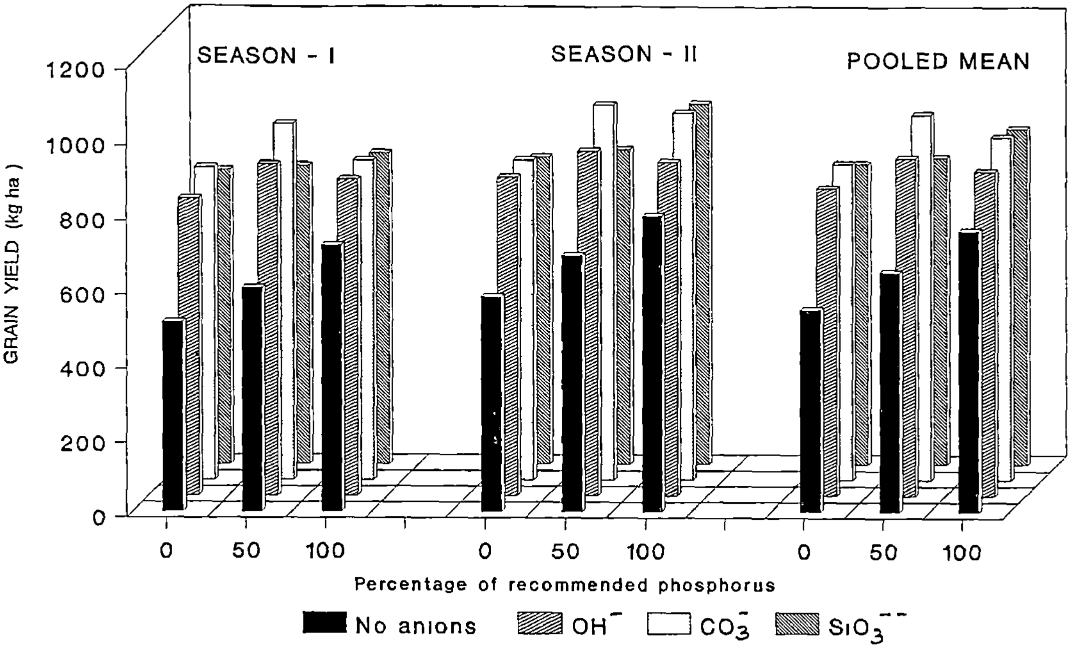


Fig 5 Grain yield of cowpea as affected by rates of fertilizer P and P desorbing anions

superior to 50% P during both seasons and pooled analysis brings out the fact that the influence of phosphorus is marked in respect to grain yield as revealed in this study This result perfectly corroborates with findings of Jayaram and Ramiah (1980) Srivastava and Verma (1982) Sharma and Arora (1982) Kalita and Kalita (1992) Sarkar (1992) Budhar et al (1991) Durai Singh and Gopalaswamy (1991) Dharam singh and Singh (1992) and Singh et al (1992)

With respect to anions while no anions recorded the lowest yield carbonate anion gave the highest significant yield In the earlier paragraph it was revealed that even 50% P in combination with carbonate could behave on par with 100% P which clearly reveals the superiority of carbonate anion in enhancing effect of phosphorus on yield of cowpea Influence of available phosphorus on yield of cowpea was discussed in the previous para which is further supported by the findings of Mathew and Koshy (1982)

5 1 12 Haulms yield of cowpea

The haulms yield of cowpea revealed that the treatments were significant in both seasons and in pooled analysis Here again 50% P with carbonate recorded the maximum significant response

As in the case of grain yield the influence of P in enhancing the haulms yield of cowpea was also proved beyond doubt in this experiment which is in agreement with the findings of Srivastava and Verma (1982) and Mathew and Koshy (1982)

With respect to anions haulms yield varied significantly from no anions to different anions w th carbonate anion gi ing the highest value during both seasons and in pooled analysis These results were better related to the higher levels of available phosphorus as discussed earlier

5 1 13 Harvest Index

With respect to harvest index of cowpea it was observed that the data of two seasons were irregular When the harvest index was not significant in season I it varied significantly in season II While going through the data of the second season, no P with hydroxyl anion gave the highest significant response When the individual factors were considered harvest index decreased with increasing levels of phosphorus significantly In the earlier discussion it is revealed that phosphorus could exert significant response in the yield of grain and bhusa However the relative influence was much higher in the case of haulms resulting in lower harvest index In the present study there was no stability in this character

5 1 14 Protein content of grains

During both seasons protein content of grains significantly differed with different treatments While 100% P with silicate gave the highest significant value no P with no anions gave the lowest value The role of phosphorus in enhancing protein content has been further fortified by the result that the protein content was increased with increasing phosphorus levels with 100% P giving the highest values during both seasons

Srivastava and Verma (1982) while studying on the effect of bacterial and inorganic fertilization on growth nodulation and quality of green gram reported that protein content increased with increasing levles of P Prasad and Sanoria (1981) while studying on the response of black gram to seed bacterisation and phosphorus reported highest seed protein content in black gram with 150 kgP_2O_5 ha^{-1} with and lowest with 50 kgP_2O_5 ha^{-1} Dwivedi and Singh (1982) reported while studying on the effect of phosphorus and sulphur application on the nutritional quality of different varieties of bengal gram that protein content was in the incre ising order and significant from 0 to 60 kgP_2O_5 ha [1] Negi and Thakur (1985) while studying on the effect of nitrogen phosphorus and rhizobium inoculation on the mash yield and N and P uptake reported that protein content in seeds of Vigna mungo was increased with increasing phosphorus rates Roshan Lal and Gangasar in (1988) while studying the influence of nitrogen and phosphorus on yield and quality of groundnut under irrigated conditions reported that the percent of protein content in groundnut was increased by the application of phosphorus at the rate of 40 kgP_2O_5 ha [1]

With respect to anions the protein content was significantly increased from no anions to various anions during both seasons which could also be attributed to high phosphorus availability due to the effect of anions as discussed earlier

5 1 15 Nitrogen uptake of plants

It was revealed that 50% P with carbonate recorded the highest value in respect of nitrogen uptake of plants during both seasons and in pooled analysis The results in respect of N uptake of plants are indicative of the overall influence of phosphorus on nitrogen uptake Singh et al (1981) while studying the effect of plant type plant population density and application of phosphatic fertilizer on the growth and yield of pigeonpea reported that phosphorus application increased the uptake of nitrogen Subbian and Ramiah (1981) while studying the influence of phosphorus molybdenum and rhizobium inoculation on the growth and grain yield of redgram reported that phosphorus application increased nitrogen uptake in redgram Hegde and Saraf (1982) while studying the effect of intercropping and P fertilization on nitrogen phosphorus and potassium concentration and uptake and productivity of pigeonpea reported that phosphatic fertilizer significantly increased nitrogen and phosphorus concentration and uptake of all nutrients Singh et al (1983) while studying the effect of planting pattern intercropping and

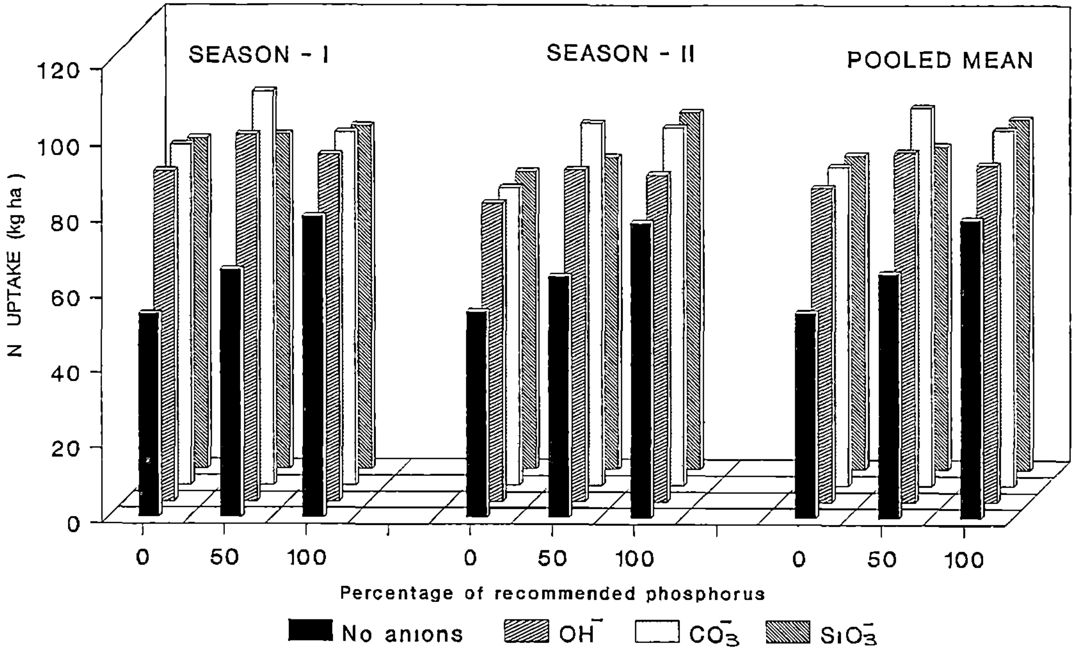


Fig 6 Nitrogen uptake of plants at harvest affected by rates of fertilizer P and P desorbing anions

application of phosphate on the yield of pigeon pea and the succeeding crop of wheat reported that in pigeon pea application of 17 kg P ha 1 increased nitrogen uptake Similarly Negi and Thakur (1985) while studying on the effect of nitrogen and phosphorus and rhizobium inoculation on mash yield and N and P uptake found that uptake of mtrogen was increased significantly with increased application of P_2O_5 rates from 0 60 kg ha 1 Jana et al (1990) while studying on the response of summer groundnut to phosphorus and potassium reported that application of phosphorus increased the uptake of nitrogen phosphorus and potassium in kernal of groundnut Thus the finding in the present study that application of phosphorus increased the N uptake of plants is in line with earlier findings In the earlier chapter we have seen that levels of phosphorus had significant influence on the protein content of grains As mtrogen is an integral part of protein it is quite natural that phosphorus could increase the uptake of nitrogen also

Among the anions N uptake was increased significantly from no anions to various anions at different stages of the experiment during both seasons and in pooled analysis The reason for this high N uptake could be attributed to higher yield and biomass production as evidenced in earlier sections

5 1 16 Phosphorus uptake of plants

It was observed that the phosphorus uptake pattern has been found to be similar to that of N uptake and as such the same discussion is applicable in this case also

With respect to fertilizer P levels P uptake increased from no P to 100% P at the different stages during both seasons and in pooled analysis This is in agreement with the findings of Othman et al (1991) Hegde and Saraf (1982) Singh et al

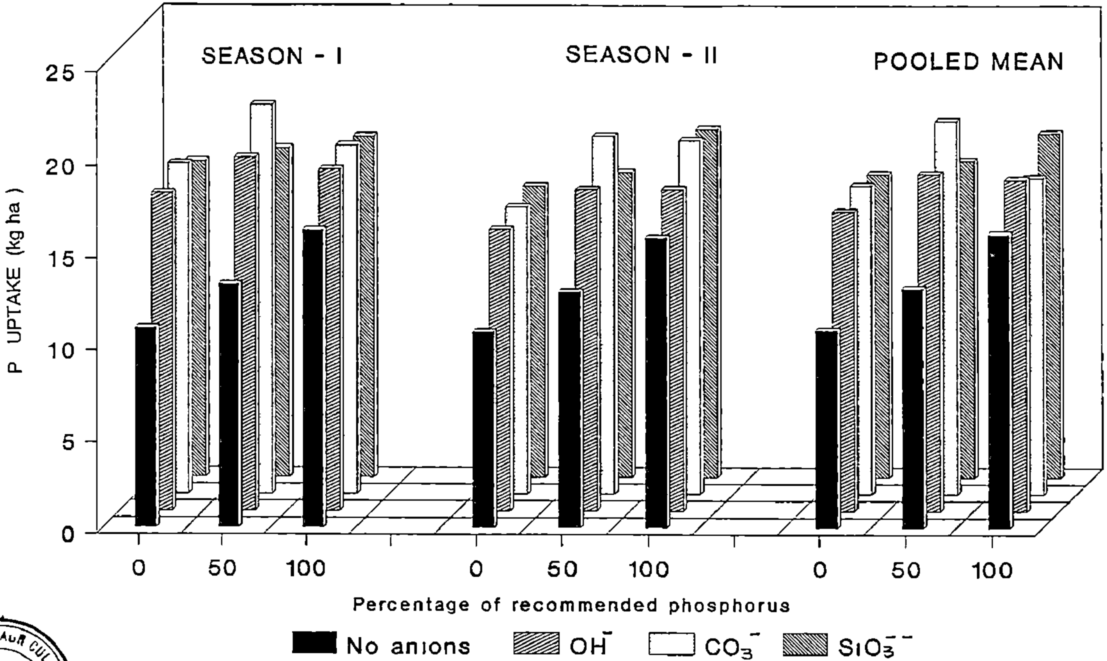


Fig 7 Phosphorus uptake of plants at harvest affected by rates of fertilizer P and P desorbing anions

(1983) Hoque et al (1984) Negi and Thakur (1985) Mishra and Anand (1989) Srivastava and Verma (1990) Jana et al (1990) and Kaushik and Jain (1991)

The result that carbonate anion could substantially enhance the uptake of phosphorus by plants are in agreement with the earlier findings that carbonate anions could enhance the available phosphorus content of the soil which in turn resulted in its uptake by plants

5 2 Experiment No 2 (Effect of chelating agents)

The results obtained on the effect of chelating agents are discussed in this section

5 2 1 Physical properties of the soil

Among the various physical properties tried bulk density did not vary significantly during both seasons due to various treatments and their combinations However it was revealed that the bulk density increased from sowing to harvest It is but natural that during the cultivation of any crop there occures compaction of soil resulting in increase in bulk density which is reflected in this case also This aspect has already been well discussed in the case of experiment no 1 The individual factors like levels of P and different chelates also could not influence the bulk density of the soil

In the respect of water holding capacity there occured significant difference between treatment combination during both seasons However different levels of phosphorus could influence this character only during first season with no P recording the highest values whereas chelates could exert significant influence only during second season

It was observed that water holding capacity increased from sowing to harvest which is against the normal result expected on the basis of the influence of various treatments and their combinations on the bulk density of the soil Because when the bulk density values increased during the progress of the crop the water holding capacity naturally should decrease However in the present case the water holding capacity increased during the progress of the crop This might probably be due to the fact that there was not that much degree of compaction in the soil It is interesting to note that the treatment combination no P with DTPA could produce the highest value of 31 51% which is again supported by the finding that no P treatment has resulted in the highest percentage of water holding capacity against higher levels of P during the first crop season Similarly among chelates DTPA could produce the highest percentage of water holding capacity during the first crop season indicating that a combination of no P with chelates could effectively increase the percentage of water holding capacity

It was observed that the mean weight diamter of aggregates increased from sowing to harvest However the different treatments either individually or in combination could not exert any influence on this character This increasing trend is in agreement with the observation on water holding capacity as there exists a positive relationship between the mean weight diameter of aggregates and water holding capacity

5 2 2 Chemical properties of the soil

The data on the C E C pH and total nitrogen revealed that the values in ıeased from sowing to harvest in the case of C E C and pH whereas the total nc trogen remained almost constant However significant increase among different combinations was observed only in the case of pH Here again the lowest value was recorded by the absolute control plot where as the highest value was recorded by 100% P in combination with either EDTA or DTPA

A review of the results on chemical properties of the soil by the influence of individual treatment also revealed that the different factors like levels of P and different chelates could significantly influence only in the case of pH of the soil Here again the 100% P and DTPA could significantly increase the soil pH It is therefore but natural that a combination of these two factors could enhance the pH values significantly

In the case of other chemical properties like total P P fixing capacity and organic matter conent it was observed that there was no significant difference brought about by various treatments and their combinations However the values in total P and percentage of organic matter content decreased from sowing to harvest whereas the P fixing capacity remained almost constant The reduction in total P at harvest may probably due to the absorption of phosphorus from the soil It is evident that P fixing capacity is an inherent property of the soil which is dependent on the clay complex and its structure which remain unaltered by several external factors The reduction in organic matter content of the soil might be due to the acid secretions of the plant which may decompose part of the organic matter and in the process of cropping there is no addition of organic matter since the crop residues are removed from the plot

5.2.3 Available P content of the soil

The result of the present experiment indicated that the available P content is increased from sowing to 30 DAS and there after decreased from 30 DAS to harvest AT 30 DAS the highest available P content was recorded by the treatment combination involving 100% P with EDTA, whereas the absolute control recorded the minimum value A detailed analysis about the role of individual factors also revealed that among the different levels of P 100% P was superior and among chelates EDTA was superior in this respect Therefore it is but natural that a combination of those factors could influence the available P content of the soil significantly

There is no wonder that addition of 100% P to the crop increased available P content of the soil over 50% P or no P Similarly in the case of chelates EDTA could enhance the P availability by the chelating action as reported by Mack Drake (1965)

The result on the available P content of the soil indicated that there occured substantial reduction in the available P content of the soil after 30 DAS which may be on account of higher uptake of phosphorus by the crop from 30 DAS to harvest (Table 37)

When we consider the influence of various treatment combinations it was observed that the influence pattern was in line with that at 30 DAS The pattern of influence in respect of individual factors like levels of P and different chelate was also similar to that at 30 DAS Thus here again, the treatment combination of 100% P along with either EDTA or DTPA recorded higher values of available P content of the soil Similarly 100% P and EDTA recorded higher values as compared to other levels of P and other chelates respectively

5 2 1 Soil Phosphorus fractions

The different P fractions recorded different pattern of change from sowing to flowering as revealed in the pooled analysis When saloid P reductant soluble P and occluded P increased from sowing to flowering the other P fractions like Al P Fe P Ca P Org P and Total P reduced from sowing to flowering The increase in saloid P is to be expected natrually on account of the fact that there occured reduction in Al P Fe P Ca P Organic P and Total P Thus a reduction in all the above fractions could bring about a proportionate increase in saloid P which is the soluble P fraction of the phosphorus in the soil There are several evidences in the literature to prove this phenomenon Talashilkar and Patel (1979) while studying the effect of organic matter on the availability of P from single super phosphate and rock phosphate reported that Fe P fractions formed the major portion of native inorganic P fractions Al P Fe P and Ca P fractions increased at both flowering and harvesting stages of rice growth while there was no appreciable increase in reductant soluble P fractions Islam (1970) while studying the transformation of inorganic P in flooded soils under rice cropping reported that increase in soluble P in acid soils was due to a decrease in Ca P Fe P and reductant soluble P concentration than in neutral soils Kothandaraman (1975) studied the soil phosphorus in major soil groups of Tamil Nadu and reported that Al P and Fe P contributed to the pool of available P in acid soils Uzo et al (1975) while studying on the forms of phosphorus m some important agricultural soils of Nigeria reported that Al P was the most available form of P to plants under upland conditions whereas Fe P was the major available P source under flooded conditions The result obtained in the present investigation is thus confirmed

When we come to verify the influence of various factors individually and in combination we find that the treatment combination of 100% P with EDTA could record highest values in respect of saloid P and occluded P whereas it could record only lowest values in respect of Al P Fe P and Organic P which clearly indicated the fact that this combinations could increase the saloid P content by exerting a reduction in fractions like Al P Fe P and Organic P

A review of the result on the influence of levels of phosphorus indicated that individually the different levels of P could not exert any influence on the various fractions of P except on saloid P and on reductant soluble P This again clearly brings out the fact that the reduction brought about by higher levels of P in the reductant soluble P fraction resulted in a proportionate increase in the saloid P fraction Since saloid P is the fraction of soluble P in the soil any addition of P fertilizers could increase the saloid P in soil

In respect of chelates it was again observed that as in the case of combinations individually also EDTA exerted significant positive effect on saloid P resulting in a proportionate reduction in Al P Fe P and organic P The influence of different chelates including EDTA on soluble P fractions has been reported by several workers like Mack Drake (1965) Jayachandran et al (1989) and Wolf (1988) It was observed from the data that there was not much reduction in various fractions of phosphorus from flowering to harvest indicating that maximum rate of uptake of P occures till flowering time in case of cowpea crop which is in line with findings of Geethakumari (1981)

It was also observed that the pattern of influence from flowering to harvest was almost similar to that from sowing to flowering as reflected in the data on saloid P fractions recorded after harvest Although the highest value of 28 3 ppm was brought about by no P with hydroxide the value of 28 2 ppm was recorded by 50% P with silicate which was on par with no P with hydroxide clearly indicating the fact that here again a combination of 100% P with EDTA was responsible for recording the higher content of saloid P fraction in the soil More over the same trend could exert a significant reduction in Al P also which was in line with the earlier findings

In the case of majority of P fractions the influence of different levels of P was not significant However among the chelates EDTA could not only significantly increase the saloid P content of the soil but also could make a significant reduction in Al P Fe P and Ca P which in turn made a proportionate increase in the saloid P content of the soil In the previous discussion we have seen that the various chelates including EDTA worked against retention of nutrients like P in the soil Several workers like Jayachandran et al (1989) and Mack Drake (1965) recorded this phenomenon in their reports which is in line with the above observation

5 2 5 Leaf Area Index (LAI)

The fact that significant variation could be observed only at flowering during both season indicates that the effects of various combinations were manifested only during flowering time Here again the maximum LAI value was recorded by 50% P with EDTA during both seasons This is quite natural on account of the fact that the individual effect of fertilizer P was highest at 50% P and that of chelates for EDTA during both seasons As such it was fully justified that a combination of the above two treatments could exert significant influence on the LAI of the plants The favourable influence of phosphorus in increasing the number of leaves in legumes has been reported by several worke s like Geethakumari (1981) and Jain et al (1986) The increase in LAI with higher levels of phosphorus has been reported by several workers like Patil et al (1983) Vasimalai and Subramanian (1980) Annie Philip (1993) and Tarila et al (1977) The role of EDTA in increasing the LAI may be through its indirect influence in making available more of the soluble phosphorus which might have enhanced the LAI of plants

5 2 6 Leaf Area Ratio (LAR)

The trend in leaf area ratio as recorded in Table 28 revealed that phosphorus was capable of enhancing the thickness of leaves along with its positive influence in increasing the number of leaves The same trend has been observed in respect of leaf area ratio values in experiment no 1 also In the present experiment no P treatment along with no chelates recorded the highest leaf area ratio values at 30 DAS indicating that in the absence of phosphorus and chelates leaves became very thin recording leaf area ratio values This is more evident when we look into the individual effect of P and chelates In the case of P as well as chelates no P and no chelates treatment recorded the higher leaf area ratio values which was indicative of their combined role on this regard

5.2 7 Leaf Weight Ratio (LWR)

A brief analysis of the Leaf Weight Ratio of plants in the present experiment revealed that there was no significant difference between treatments and the various factors both at 30 DAS and at flowering Both seasons gave the same results

Leaf weight ratio is the expression of combined influence of LAI over the relative thickness of leaves In the earlier sections we found that available P has got positive influence in measurable terms on the LAI as well as in the relative thickness of leaves The non significance in the present study revealed that there is no stability on the response of P availability to leaf weight ratio in cowpea

5 2 8 Number of nodules per plant

The observation that neither the treatment combinations nor the individual treatments could exert any influence on this character except a stray significance at

30 DAS during season II indicated that the different levels of P as well as different forms of chelates could not make any impact on this character This is quite evident when we look into the pooled mean value Another interesting observation is that in all treatments and treatment combinations the number of effective nodules per plant got substantially reduced from 30 DAS to flowering which may be due to disintegration of nodules followed by subsequent uptake by the plant which was again reflected in the uptake pattern of nitrogen as presented in Table 36 The reduction in the number of effective nodules at flowering has been reported by workers like Kumar and Verma (1988)

5 2 9 Dry weight of nodules

As in the case of number of effective nodules per plant the various treatments and their combinations could not exert any significant influence on the dry weight nodules per plant either in the individual season or in the pooled data Here again the finding that dry weight of nodules got reduced substantially from 30 DAS to flowering runs parallel to the observation on the number of effective nodules per plant Thus it could be agreed that the reduction in dry weight of nodules per plant may be due to reduction in number of nodules per plant as a result of degradation followed by higher uptake

5.2 10 Yield components of cowpea

Among the various treatments in experiment no 2 only in the case of number of pods per plant the various treatment and their combinations could make significant influence as revealed in Table 32 Thus it could be inferred that the number of seeds per pod hundred seed weight and pod length are all varietal characters which could not be altered by the external application of different treatments tried In this connection it may be pointed out that the same trend of result was recorded in experiment no 1 also and that the discussion there upon is applicable in this case also

5.2 11 Grain and Haulms yield of cowpea

A perusal of the data presented in Table 33 indicated that phosphorus at 50% level in combination with EDTA could significantly increase the grain yield as revealed from the pooled data This combination could excel not only the control treatment but 100% P in combination with different chelates also Thus it is seen that the P levels could be reduced to 50% to achieve the higher yield if it could be applied in conjunction with EDTA The data subsequently brings out the fact that the individual effects of P as well as chelates are in line with what has been observed in the case of combinations Thus 50% P individually could record higher grain yield of 824 kg ha $^{-1}$ as against 638 kg ha $^{-1}$ for no P and 760 kg ha $^{-1}$ for 100% P Similarly EDTA chelate could record significantly higher value of 783 kg ha $^{-1}$ as against 638 kg ha $^{-1}$ for no chelates and 750 kg ha $^{-1}$ for DTPA

Jayachandran et al (1989) while studying the effect of synthetic chelates on P availability reported that synthetic chelates could enhance the available P content in the soil In the present study the increased available P brought about by the chelating effect of EDTA would have enhanced the grain production in cowpea resulting in higher grain yield

The pooled analysis data on the haulm yield clearly brings out the fact that the pattern of variation brought about by various treatments and their combinations is exactly in line with that of the grain yield The discussion made in respect of grain yield is applicable to haulm yield also

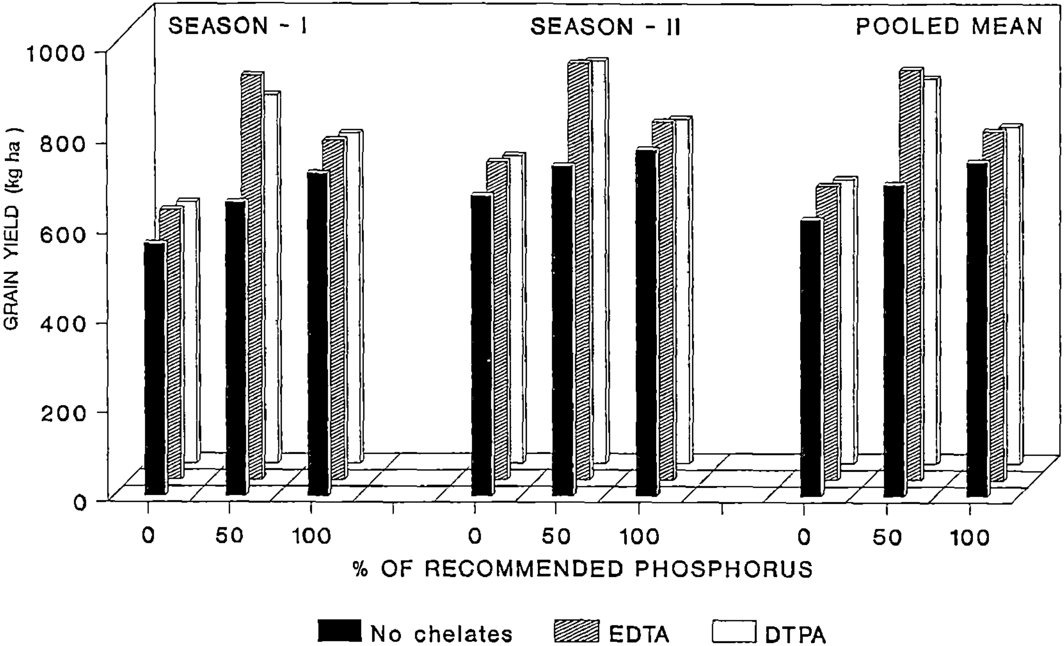


Fig 8 Grain yield of cowpea as affected by rates of fertilizer P and synthetic chelates

5 2 12 Harvest ındex of cowpea

It ıs very ınterestıng to note that ın respect of all the treatment combınatıons and ındıvıdual treatments the harvest ındıces were hıgher ın season II as compared to season I The graın yıeld and haulms yıeld presented ın Table 33 ındıcated that durıng the second season the haulm yıeld were comparatıvely lesser ın season II The lesser yıeld of haulms whıch ıs a reflectıon of the lesser vegetatıve growth would have been responsıble for hıgher harvest ındıces ın season II

The over all response of varıous treatment combınatıons ın both season I and season II reflect the performance of the crop ın terms of graın and straw yıeld presented ın Table 33 Thus whıle the lowest harvest ındex was no P recorded wıth no chelates / no P wıth EDTA whereas the hıghest harvest ındex was reported by 50% P wıth EDTA durıng both seasons When we consıder the ındıvıdual factors 50% P under fertılızer P and EDTA under chelates were gıvıng the hıghest harvest ındıces durıng both seasons Therefore there ıs no wonder that a combınatıon of the above two factors represented by 50% P wıth EDTA could gıve hıghest harvest ındıces durıng both seasons Here agaın, the role of EDTA along wıth 50% P could have promoted more of gram yıeld as compared to straw yıeld resultıng ın hıghest harvest ındex ın thıs partıcular treatment combınatıon The explanatıon gıven by Jayachandran et al (1989) holds good ın the case of harvest ındex also

5.2 13 Proteın content of graıns

The proteın content of graıns whıch ıs more or less a reflectıon of nıtrogen content of graın has been found to be hıghest ın 100% P wıth EDTA ın season I whereas ıt was hıghest ın 100% P wıth DTPA ın season II We have already seen ın the case of graın and haulms yıeld and harvest ındex that chelates could enhance P avaılabılıty ın the soıl Thıs ıncreased avaılable P combıned wıth addıtıonal applications of 100% P by way of treatment could have enhanced the uptake of nitrogen by the plant which would have further transmitted to the grain resulting in higher protein content Workers like Prasad and Sanoria (1981) Dwivedi and Singh (1982) Negi and Thakur (1985) Roshan Lal and Gangasaran (1988) Rajput et al (1991) Sasidhar (1978) and Geethakumari (1981) reported that higher levels of phosphorus enhanced nitrogen content in leguminous crops including cowpea As protein is a combination of major nutrients like N and P this increased P availability by application of 100% P and chelate could have enhanced P content by the plant which is in combination with nitrogen would have enhanced the protein content of the grain

5 2 14 Nitrogen uptake of cowpea

The uptake of any nutrient by the plant is the result of combined influence of percentage content of nutrient in grain and haulm and its yields Therefore it is quite convincing that the pooled data of both seasons at 30 DAS at flowering and harvest indicated that no P with no chelate recorded the lowest N uptake while 50% P with EDTA combinations recorded the highest N uptake In the case of yield data also the same trend has been observed (Table 33) There again the highest grain and haulms yield were recorded by 50% P with EDTA combination whereas the lowest yields were recorded by no P with no chelate combination

The effect of individual factors like fertilizer P and chelates indicated that 50% P and EDTA were responsible to give the highest N uptake values at all the three stages Therefore it is no wonder that a combination of the above two factors could give a higher N uptake Any variation observed in the percentage content of nitrogen in the plant could have been levelled of by the higher yields of grains and haulms recorded by 50% P with EDTA combination Hegde and Saraf (1982) reported that phosphorus increases nitrogen concentration in plants The reason

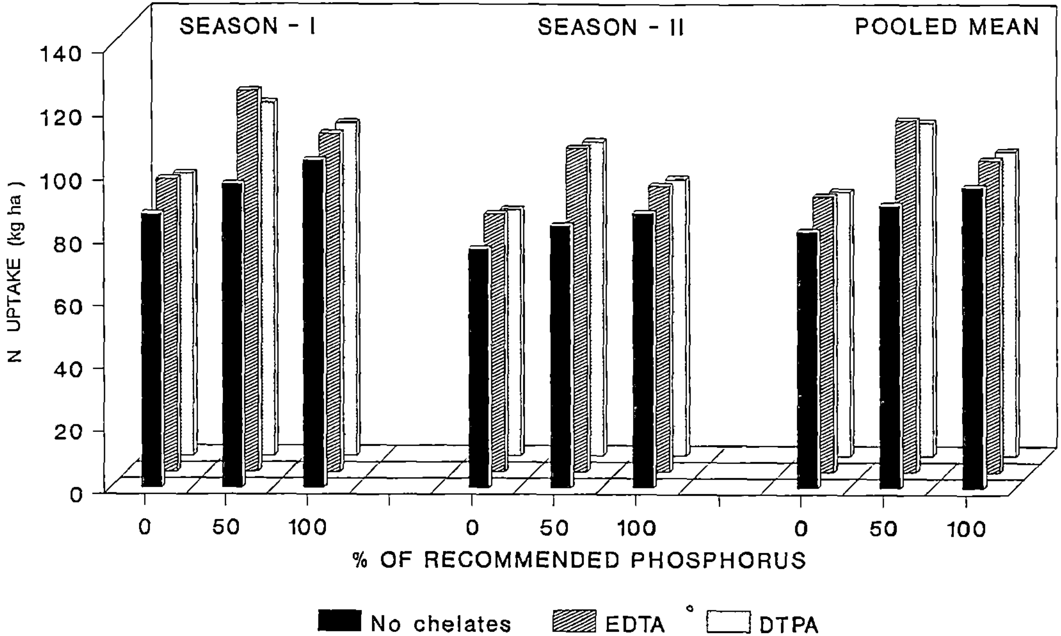


Fig 9 Nitrogen uptake of plants at harvest as affected by rates of fertilizer P and synthetic chelates

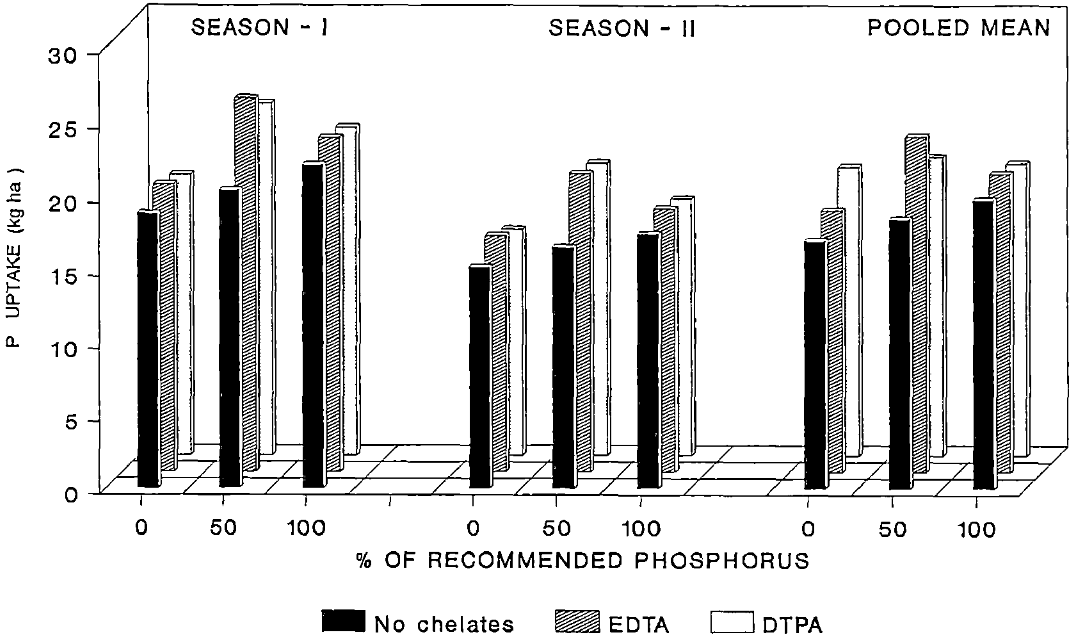


Fig 10 Phosphorus uptake of plants at harvest as affected by rates of fertilizer P and synthetic chelates

can be attributed to high P availability as evidenced in Table 23 Thus the effect of phosphorus in increasing the uptake of nitrogen has been reported by Singh et al (1981) Subbian and Ramiah (1981) Singh et al (1983) and Negi and Thakur (1985)

5.2 15 Phosphorus uptake of plants

It has been observed that the phosphorus uptake pattern followed the same trend as in the case of nitrogen uptake Thus the lowest P uptake has been recorded by no P with no chelate combination while the highest uptake has been recorded by 50% P with EDTA combination The response exhibited by individual factors also revealed the fact that 50% P among the fertilizer P treatment and EDTA among chelates have rendered the highest P uptake at all the three critical stages thus enabling the combination of 50% P with EDTA to facilitate the highest uptake of P The discussion made in respect of N uptake is also applicable to P uptake also

5 3 Experiment No 3 (Effect of microbial agents)

5 3 1 Physical properties of the soil

It was observed that the bulk density of the soil increased from sowing to harvest during both seasons This is quite relevent and true on account of the fact that the cultivation of any crop will tend to increase the bulk density of the soil Deterioration of soil structure takes place as a result of cultivation as observed by Sankaranarayana and Mehta (1967) When there is deterioration of soil structure naturally the bulk density will also tend to increase Page and Willard (1946) reported that the continuous cultivation resulted in loss of pore space and a corresponding increase in weight per unit volume of soil The adverse effect of cropping system on porespace and bulk density has been reported by Khan (1966)

Prabhakara (1970) observed a slightly higher bulk density in four crop relays in potatoes

A close examination of the result revealed the fact that the different treatments and their combinations could not exert any significant influence on bulk density of the soil although some erratic responses were observed during season II

In the case of water holding capacity and mean weight diameter of aggregates there were erratic responses in both seasons for various treatments and their combinations However a common observation was that the water holding capacity remained relatively stable from sowing to harvest

5.3 2 Chemical properties of the soil

In the case of C E C it was observed that there was no significant difference between the various treatments and their combinations during both seasons as well as on pooled analysis This may be because of the fact that the C E C is an inherent character of the soil which is very much related to the nature of clay complex which remain unaltered by the external factors This finding is m agreement with the report of Bhatnagar et al (1977) Similar observations recorded in the earlier two experiments strongly reinforces the deduction that C E C is a soil characteristic which remains relatively unaltered by external factors

The pooled mean data on pH revealed the fact that where ever combination of VAM phosphobacterin or their combined applications occured there happend a reduction in pH value However the level of phosphorus remained relatively dormant in its effect on soil pH This may be one of the facts which contributed to a non responsive nature for the different levels of phosphorus on pH of the soil However the data on the effect of different microbes indicated positive response of various microbes and their combined application on pH of the soil The role of microbes like VAM in producing organic acids has been reviewed by Barea (1991)

The total nitrogen percentage of the soil increased marginally from sowing to harvest although the relative increases brought about by the various treatments and their combinations were not statistically significant

As in the case of nitrogen other chemical properties of the soil like phosphorus P fixing capacity and organic matter content of the soil were also observed to be not influenced by various treatments and their combinations These observations were recorded not only during both seasons but in the pooled analysis also

5.3.3 Available phosphorus content of the soil

The general trend of the available phosphorus content of the soil was that it increased from sowing time to 30 DAS and came down after harvest to a level little higher than what was before sowing This trend was reflected in all the treatment combinations as well as individual treatments Among the different treatment combinations 100% P applied along with VAM and phosphobacterin recorded the highest available phosphorus both at 30 DAS as well as after harvest Similarly the lowest value has been recorded by no P with no microbes The fact that the treatment combination 100% P with VAM and phosphobacterin could record the highest content of available P is an indication that even under the highest application of phosphatic fertilizer, the activity of microbes under VAM and phosphobacterin were favourably enhanced resulting in higher levels of available P in the soil The data on the yield of grain (Table 33) clearly illustrated the fact that the crop of cowpea could respond to a level higher than 100% P as it was observed that the response was linear even at 100% phosphorus application It was further observed that the combination of 100% P along with VAM and phosphobacterin could record an yield which was significantly superior to 100% P alone which is a clear indication that the P available in the soil at 100% P fertilizer application may not be sufficiant for realizing the higher levels of grain yields

When we look into the individual effects of treatments it is observed that 100% P alone could not register higher levels of available phosphorus in the soil through out the growing period during both seasons which is again an indication that the combined application of VAM and phosphobacterin is required for the maximum expression of 100% P application on the available P content of the soil The positive influence of microorganisms like VAM in increasing the available phosphorus content of soil has been reviewed by Barea (1991) Santhi et al (1988) while studying the efficiency of VAM inoculation with different sources of phosphorus on the availability and uptake of nutrients reported that VAM inoculation significantly increased the available P content of the soil over control The effect of phosphobacterm in increasing the available phosphorus content of the soil has been reported by Tisdale et al (1985) Therefore it is quite natural that a combined effect of these two organisms could enhance the available phosphorus content of the soil significantly

5.3 1 Soil phosphorus fractions

The pooled data presented on the soil phosphorus fractions indicated that only the saloid P fractions increased from sowing to flowering whereas all the other fractions either decreased or remained without any appreciable change However this trend has not been maintained from flowering to harvest as it was observed that no difinite trend could be maintained from flowering to harvest Saloid P which almost represent the soluble P content of the soil recorded the highest value in the treatment combination of 100% P along with VAM and phosphobacterin which is an indication that it follows the trend of the available P content of the soil Ca P organic P Fe P and Al P formed the major sources of available P to contribute towards the saloid P of the soil Islam (1970) while studying the transformation of inorganic P in flooded soils under rice cropping reported that increase in the soluble P in acid soils was due to a decrease in Ca P Fe P and reductant soluble P concentrations Uzo et al (1975) while studying the forms of phosphorus in some important agricultural soils of Nigeria reported that Al P was the most available form of P to plants under upland conditions while Fe P was the major available P source under flooded conditions

5.3 5 Leaf Area Index of plants (LAI)

The influence of various treatment combinations on LAI could be seen only at flowering time during both seasons Here again the finding that the treatment combination 50% P with VAM and phosphobacterin which could record the highest LAI over 100% P alone is an indication that the role of VAM and phosphobacterin was significant which could record higher LAI values even at 50% P well over 100% P This is further illustrated by the fact that individually also VAM + phosphobacterin could record highest LAI values at flowering time during both seasons This is an indication that the influence of microbes could increase the available P content of the soil which in turn could enhance the LAI values This is in agreement with the findings of Vasimalai and Subramonain (1980) Geethakumari (1981) and Patil et al (1983)

5.3 6 Leaf Area Ratio of plants (LAR)

The general trend of the observation revealed the fact that there existed a decrease trend of leaf area ratio with increased availability of phosphorus markedly at 30 DAS and slightly at flowering This is clearly evident in the individual treatments and seperate effects of phosphorus and microbe. -- . again the peak values of the observation varied during various stages and seasons The higher leaf area ratio is an indication of lesser thickness of leaves and as such lower values show a higher thickness of leaves Therefore it is evident that the low value of leaf area ratio coupled with higher thickness is associated with higher availability of phosphorus and its uptake given in the previous and subsequent tables The effect of various treatments in increasing the available P has already been discussed in the earlier sections

5.3 7 Leaf Weight Ratio of plants (LWR)

The data on leaf weight ratio of plants revealed that the treatment effect was not significant during both seasons and at various stages Thus the non significant response of various treatments revealed the fact that there occured almost equal addition of leaf weight and plant weight in all the treatments However the data on this experiment is not in agreement with the result of the experiment no 1 which shows that there is no stability in this character with respect to phosphorus

5.3 8 Number of effective nodules

The overall picture of the data revealed that the number of effective nodules was not significantly different at 30 DAS and at flowering It may be noted that the number of effective nodules decreased from 30 DAS to flowering during both seasons and pooled analysis The fact that the number of nodules decreased at flowering revealed that some of the nodules would have disintegrated at the time of flowering This agrees with the report of Kumar and Verma (1988)

5.3 9 Yield components of cowpea

Among the various yield components number of pods per plant alone recorded statistical significance Here again absolute control treatment recorded the lowest value and the treatment combination of 50% P along with VAM and phosphobacterin recorded the highest value It was observed that the treatment values were more or less related to the available phosphorus content of the soil There was a distinct relationship between the number of pods per plant and available phosphorus content of soil as revealed by absorption of phosphorus as evidenced in Table-40 This finding agrees with the report of Kalita and Kalita (1992) Sarkar (1992) and Budhar et al (1991)

5 3 10 Grain and haulms yields of cowpea

The pooled analysis of the data revealed that absolute control gave the minimum yield while 50% P with VAM and phosphobacterin gave the highest yield Here also 50% P with VAM and phosphobacterin was significantly greater than that obtained in 100% P Thus the observation that the influence of VAM + phosphobacterin in association with 50% P is much superior to 100% P alone clearly brings out the fact that 50% P could be easily saved by applying VAM + phosphobacterin along with 50% P

With respect to fertilizer P 100% P gave significantly higher yield than the other levels Thus there is marked response of phosphorus in increasing the yield of cowpea These results were exhaustively discussed in the earlier experiments

With respect to the various micro organisms all the micro organic treatments were significantly superior to control with VAM + phosphobacterin giving the highest value Bethlenfalway (1985) while studying the plant response to mycorrhizal fungi host endophyte and soil effect reported that phosphorus

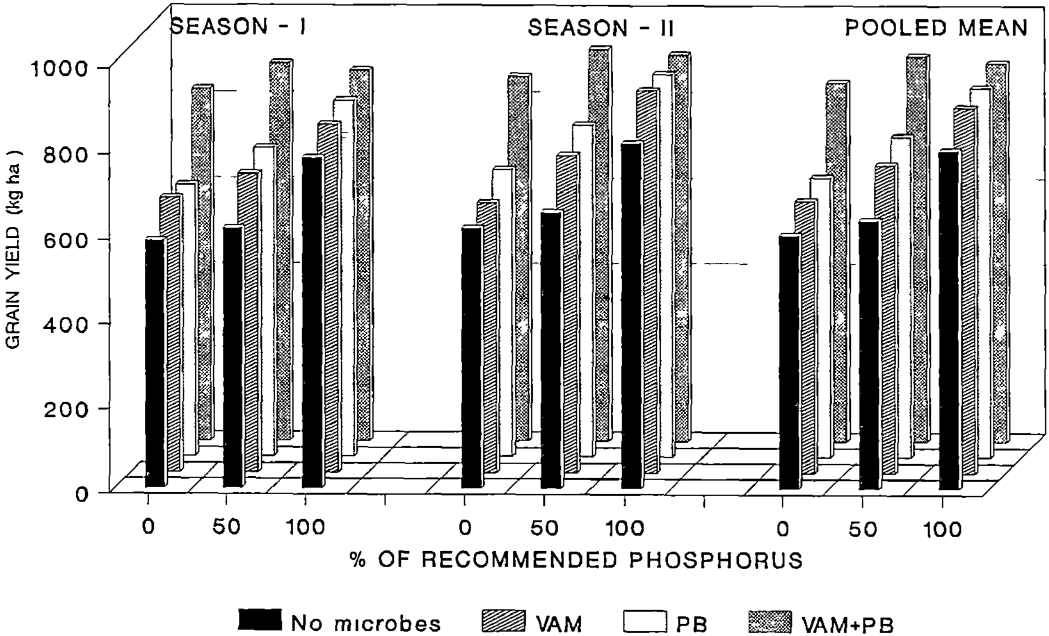


Fig 11 Grain yield of cowpea as affected by rates of fertilizer P and microbial agents

concentration increased significantly in all soyabean and some sorghum plants relative to non VAM controls as a result of VAM fungal colonisation This increased P concentration in plants might have helped in boosting the yield of cowpea in the present experiment Pacovsky et al (1986) reported that plants colonized with VAM fungi grew 3 6 times larger than P free control but attained only 35 to 65% of maximum growth possible with high fertilizer P input Bhatnagar et al (1979) studied the associative effect of inoculums of Rhizobium and Bacillus megaterium var phosphaticum on the yield of mungbean and soybean They have reported that the incorporation of a strain Bacillus megaterium in the case of mungbean and soybean gave a significantly higher yield than that obtained by the use of Rhizobium as inoculant Further they have reported that mixtures of Rhizobium and Bacillus megaterium with super phosphate and rock phosphate gave significantly higher yield from these crops The discussions made in respect of grain yield is applicable to haulms yield also

5.3 11 Harvest index of cowpea

It was revealed that the results on harvest index of cowpea in the two seasons varied very much There was no significant response during season I whereas there was significant response in season II In season II the treatment combination no P with VAM and 50% P alone gave the lowest value while 100% P with phosphobacterm gave the highest response With respect to fertilizer phosphorus 100% P gave significantly higher value which might probably be due to greater P availability in the treated plots This is in agreement with report of Srivastava and Verma (1982)

With respect to microbes VAM + phosphobacterin gave the highest value which was significantly superior to all other treatments Here again the higher availability of phosphorus might have contributed to the greater harvest index which is in agreement with the report of Srivastava and Verma (1982)

5.3 12 **Protein content of grains**

It was observed from the data of two seasons that absolute control gave the lowest protein content while 100% P with VAM and phosphobacterin gave the highest protein content which was highly significant Fertilizer levels also gave significant response with 100% P giving the highest value Since 100% P recorded the maximum availability of phosphorus in the soil it is but natural that it could record maximum protein content also Among the microbes VAM + phosphobacterin gave the maximum protein content of grains Here again the availability of phosphorus due to the inoculation of microbes gave the significantly higher protein content The increase in protein content by phosphorus has been reported by various workers like Prasad and Sanoria (1981) Dwivedi and Singh (1982) Negi and Thakur (1985) Roshan Lal and Gangasaran (1988) and Rajput et al (1991)

5 3 13 **Nitrogen uptake of plants**

The pooled analysis data on N uptake of plants revealed that absolute control gave the lowest value at all stages of the experiment while the treatment combination 100% P with VAM + phosphobacterin recorded the highest value only at 30 DAS While the treatment combination 50% P with VAM + phosphobacterin gave the the highest value both at flowering and harvest stages It may be noted that 50% P applied along with VAM and phosphobacterin recorded significantly higher uptake of nitrogen over 100% P applied alone Thus it is observed that the effect of microbes when applied together is very significant in increasing the uptake of nitrogen

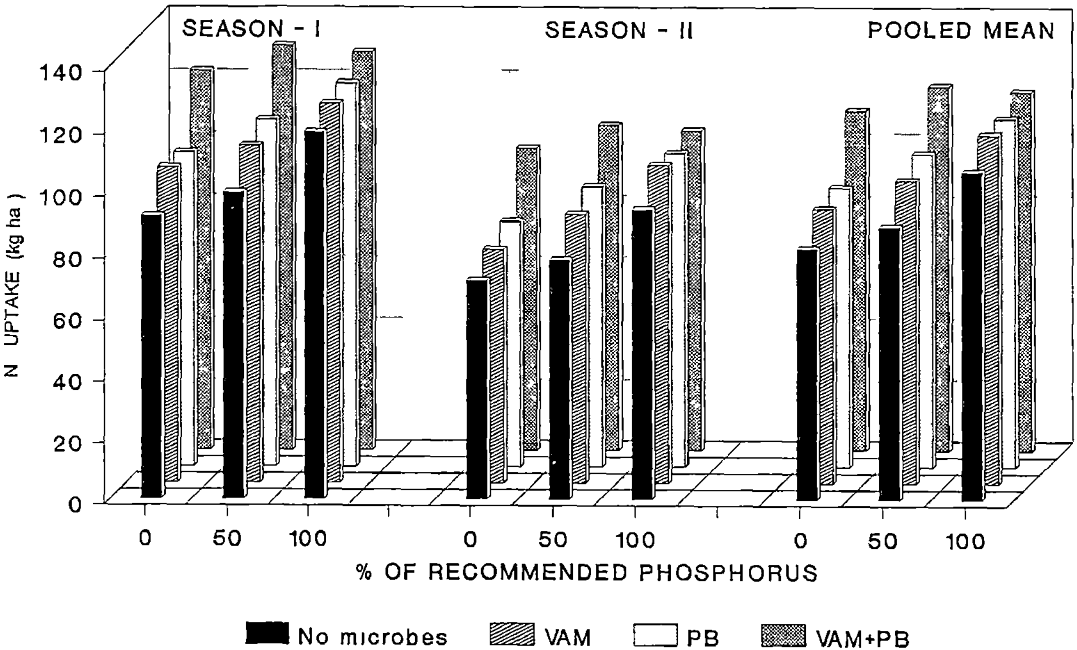


Fig 12 Nitrogen uptake of plants at harvest as affected by rates of fertilizer P and microbial agents

When we look into the effect of individual factors we could see that 100% P gave significantly higher N uptake than the lower levels Here again the effect of phosphorus in increasing N uptake is marked Among the microbial species tried VAM + phosphobacterm gave the significantly higher N uptake Subbian and Ramiah (1981) reported that phosphorus recorded N uptake in redgram Hegde and Saraf (1982) while studying the effect of inter cropping and P fertilization reported that in pigeon pea phosphorus significantly increased N concentration and uptake in plants The report of Negi and Thakur (1985) recorded that the uptake of nitrogen is increased by the application of phosphorus Srivastava and Verma (1990) also reported that N uptake was increased with phosphorus application In our trials also we have found that the treatments in question had given higher phosphorus availability than the control plots (Table-40) Here there is no wonder that the combined effects of phosphorus and microbes shall certainly increase the nitrogen uptake of the present crop The significant increase in the uptake of nitrogen with increasing levels of phosphorus might be due to positive influence on root development nitrogen fixation and high meristematic activity of plant which in turn resulted in greater accumulation of total dry matter and ultimately resulted in an increase in the uptake of nitrogen This finding is in agreement with the report of Subbian and Ramiah (1981) and Negi and Thakur (1985)

5.3 14 Phosphorus uptake of plants

The pooled analysis data on P uptake revealed that the absolute control gave the lowest value at all the stages while the treatment combination 50% P with VAM and phosphobacterin gave the highest value at 30 DAS and at harvest whereas the treatment 100% P with VAM and phosphobacterin gave the highest value at flowering Here in addition to the effect of phosphorus the effect of combined application of VAM and phosphobacterin is most marked

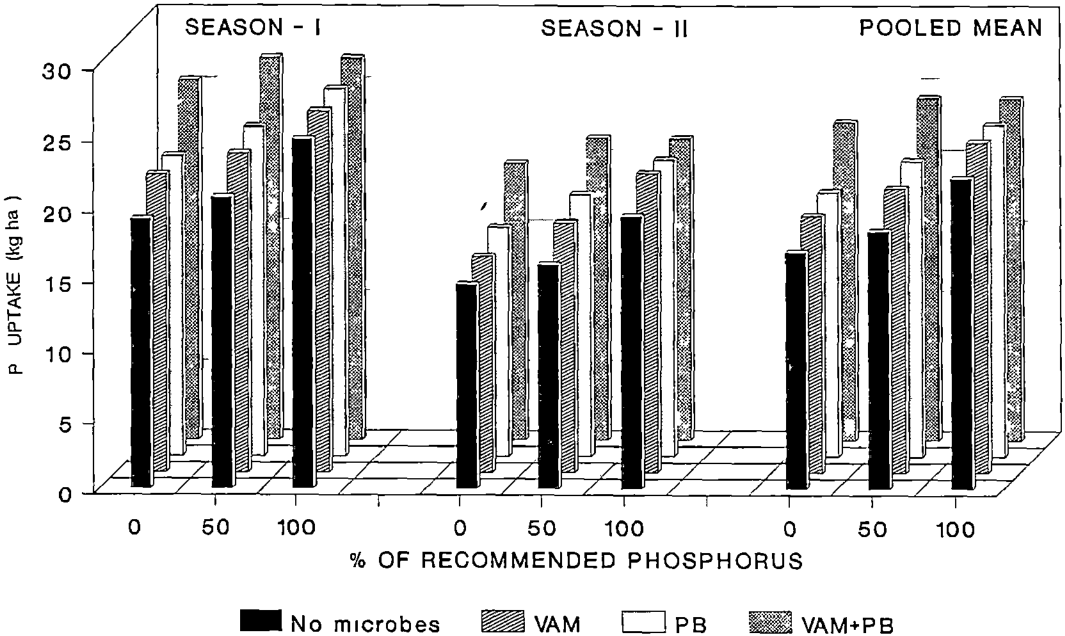


Fig 13 Phosphorus uptake of plants at harvest as affected by rates of fertilizer P and microbial agents

When we come to the individual factors 100% P gave significantly higher values at all stages Here again, the effect of phosphorus in increasing the P uptake is very much marked Among the microbes VAM + phosphobacterin gave the highest significant value The effect of these treatments in increasing the availability of phosphorus has been discussed previously Hegde and Saraf (1982) reported that application of phosphorus increased P uptake in pigeon pea Several other authors like Singh et al (1983) Hoque et al (1984) Srivastava and Verma (1990) Jana et al (1990) and Kaushik and Jain (1991) also reported the same The effect of microbes like VAM in increasing the P uptake has been reported by Rao et al (1986) Habte and Manjunath (1987) Miranda et al (1984) Santhi et al (1988) and Azcon et al (1982) In our study also we have comfirmed the fact that microbes and phosphorus could influence the phosphorus uptake of the cowpea crop In this study also the results showed that combined application of fertilizer phosphorus along with various microbes had pronounced effect on the availability and uptake of phosphorus by the test crop of cowpea

Summary

...cal and bio agents on phosphorus dynamics in the red loam soils of southern Kerala, three field experiments were conducted during two seasons in 1992 The first experiment was on the effect of chemical desorbing anions the second on the effect of chelating agents and third on the effect of microbial agents The summary of the findings of these experiments are presented in this chapter

6 1 Experiment No 1 (Effect of desorbing anions)

The treatments for this experiments were factorial combinations of three levels of phosphorus (No phosphorus 50% phosphorus and 100% phosphorus) and four anions (No anion hydroxide carbonate and silicate) The summary of the findings of this experiment is presented in this section

6 1 1 Physical properties of the soil

Physical properties like bulk density water holding capacity and mean weight diameter of the experiments were studied before planting and at harvest of the experiment None of these charecters showed significant response showing thereby that he treatments had no significant response on this character

6 1 2 Chemical properties of the soil

Chemical properties like C E C pH total nitrogen content total phosphorus content P fixing capacity and organic matter content were studied before planting and immediately after harvest of the experiment The characters like C E C total phosphorus content P fixing capacity and organic matter content did not show any significant response showing thereby that these characters were unaffected by the different treatment applications Other properties like pH and Nitrogen content were significantly influenced by the treatments showing thereby that the treatments had significant bearing on this character When both phosphorus levels and anions had significant affect on pH of the soil, N contents were affected only by the anion treatments

6 1 3 Available phosphorus content of the soil

Available phosphorus contents of the soil were studied before planting 30 DAS and at harvest of the experiment Available phosphorus contents were significantly influenced by the treatments as well as the various factors at 30 DAS and at harvest of the experiment There was an increasing trend in this character from sowing to 30 DAS and decreased highly at the time of harvest Thus it was revealed that the treatments had significant influence on the available phosphorus content of the soil

6 1 4 Soil phosphorus fractions

Soil phosphorus fractions were studied during three stages of the experiment like before sowing at flowering and at harvest of the crop There were significant increase in the saloid P at flowering and till harvest There was corresponding decrease in the Al P Fe P and organic P contents of the soil The increase in the saloid P content was from the corresponding decrease in the above soil P fractions

6 1 5 Leaf and leaf characters

Leaf and leaf characters like LAI LAR and LWR were studied at 30 DAS and during flowering stages There was significant increase in LAI at the time of flowering only LAR showed decrease in the character during both stages showing there by that the leaf thickness was increased by the treatment applications There was no significant response in the LWR except at flowering during season II showing that there was more or less the same ratio between leaf and plant weight

6 1 6 Number and weight of root nodules

There was significant increase in the number of nodules by the treatment application But the dry weight of nodules had no significant response showing that the size of nodules were increased when the nodule counts were decreased

6 1 7 Yield and yield components of cowpea

Yield components like number of pods per plant number of seeds per pod 100 seed weight and pod length were studied Among them number of pods per plant alone showed significant response None of the other characters were influenced by the treatments There was corresponding increase in the yield by the application of phosphorus and anion treatments Yields of haulm were also influenced by the anions and phosphorus applications

Among the treatments 50% P with carbonate anion gave the significantly highest yield showing that 50% of the recommended P can be saved by the application of carbonate anion in the form of calcium carbonate Harvest index also showed corresponding increase in their values which was significant during season II only Protein content was also increased by the phosphorus applications as well as by the anions

6 1 8 Nitrogen and phosphorus uptake

Nitrogen and phosphorus uptake were mceased significantly by the phosphorus and anion treatments during the three stages studied viz 30 DAS at flowering and at harvest 50% P with carbonate gave the highest response in all the stages studied This shows that 50% P with carbonate anion as calcium carbonate give the best results and hence can be recommended for adoption

6 2 Experiment No 2 (Effect of chelating agents)

The treatments for this experiment were factorial combinations of three levels of phosphorus (No phosphorus 50% phosphorus and 100% phosphorus) and three chelating agents (No chelates EDTA and DTPA) Summary of the results of this experiment is presented in this section

6 2 1 Physical properties of the soil

Physical properties like bulk density water holding capacity and mean weight diameter were studied before souring and at harvest of the experiment Bulk density increased from souring to harvest But there was no significant response between various treatments Water holding capacity and mean weight diameter also showed increasing trend from sowing to harvest But there was no significant response between various treatments Water holding capacity was reduced by the phosphorus as well as chelate applications But the response was not in the same manner during both seasons Mean weight diameter though increased from sowing to harvest there was no significant response with respect to various treatments at the time of harvest of the experiment

6 2 2 Chemical properties of the soil

Chemical properties of the soil like C E C pH Total N content total phosphorus content P fixing capacity and organic matter content were studied before and at harvest of the experiment C E C eventhough increased from sowing to harvest there was no significant difference between treaments, showing thereby that this character is unaffected by the chelates as well as phosphates pH increased from sowing to harvest and showed significant response at the time of harvest Both phosphorus as well as chelates increased the pH of the soil significantly This showed that 50% P with EDTA gave the significantlly highest pH of the soil The other characters such as total N content total P content P fixing capacity and organic matter content were unaltered by the treatment application This shows that the basic characteristics of the soil were not affected by the treatments

6 2.3 Available phosphorus content of the soil

Available phosphorus contents were studied before sowing at 30 DAS and at harvest of the experiment This value increased from sowing to 30 DAS and decreased slightly at the time of harvest The response were significant with respect to treatment combinations as well as various factors 100% P with EDTA gave the maximum values of pH and hence gave the maximum response with respect to pH of the soil Thus it is shown that the treatments had effect on the pH of the soil

6 2 4 Soil phosphorus fractions

Study of the soil phosphorus fractions was carried out during three stages of the experiment viz before sowing at flowering and at harvest Saloid P was significantly increased from sowing to flowering and till harvest There was no consequent reduction in Al P Fe P and organic P fractions There was no appreciable change in Ca P fraction of the soil Reductant soluble P also increased with respect to chelates and the whole treatments Oceluded P increased from sowing to flowering and the statistical difference between treatments was also significant on pooled analysis of the data

6 2 5 Leaf and leaf charcaters

Leaf characters like LAI LAR and LWR were studied at two stages ie 30 DAS and at flowering Significant incerase in LAI was obtained only at flowering with respect to fertilizer P and chelates Similarly LAR showed statistical significance on y at 30 DAS showing that the leaf thickness was increased with the application and availability of phosphorus In the case of LWR the data showed no statistical significance and hence showed that there was approximately the same proportion of leaf and plant dry weight in all the stages

6 2 6 Nodule and nodule characters

Nodule and nodule charactes were studied at two stages ie at 30 DAS and at flowering There was no statistical difference between treamtnes with respect to these characters This showed that there was no harmful or beneficial effect for chelates and phosphorus application on this character

6 2 7 Yield and yield components of cowpea

Yield components like number of pods per plant number of seeds per pod hundred seed weight and pod length were studied during the experiment Among these number of pods per plant only showed statistical significance None of the other characters showed response revealing thereby that only the pod number is affected by the various treatments 50% P with EDTA gave the maximum value showing the superiority of these treatment over others

Gram and haulm yield also showed significant response with 50% P with EDTA giving the maximum yield The superiority of this treatment over others was thus confirmed From the study of the harvest index of the data also there showed significant response with respect to fetiliser P and chelates and among the treatments tried 50% P with EDTA gave the highest significant value Thus the superiority of EDTA in enhancing the phosphorus availability is confirmed

In the case of protein content of grams there was significant response on this character The two season s data showed that 100% P with either EDTA or DTPA gave the maximum protein content On individual analysis 100% P and DTPA gave the maximum value for the crop These values were statistically superior over the other treatments Thus there were a marked effect of chelates in increasing the protein content of the cowpea grains

6 2 8 Nitrogen and phosphorus uptake of cowpea crop

N and P uptake of the cowpea crop were studied at 3 stages of the experiment ie 30 DAS at flowering and at the time of harvest There was statistical difference in all the three stages of the study Phosphorus levels and chelates also recorded statistical responses In all the stages 50% P with EDTA gave the maximum responses On factorial analysis also 50% P and EDTA gave the maximum response values This shows the superiority of EDTA in enhancing the P uptake and availability

6.3 Experiment No 3 (Effect of microbial agents)

The treatments for this experiment were factorial combinations of three levels of phosphorus (No phosphorus 50% phosphorus and 100% phosphorus) and four microbial agents (No microbes VAM PB and VAM + PB) the summary of the findings in this experiment is presented in this section

6.3 1 Physical porperties of the soil

The soil physical properties like bulk density water holding capacity and mean weight diameter of the experimental sites were carried out before sowing and immediately after harvest of the experimental crop There was increase in the bulk density of the soil but significant increases could be observed only during the second season There were significant mceases in the water holding capaicty of the soil as well as mean weight diameter from sowing to harvest But the treatment effect was in the reverse order in the case of water holding capacity and in positive order in the case of mean weight diameter of aggregate This showed that there was no deleterious effect on the soil physical properties due to the application of phosphorus and micro organisms The soil physical properties were only slightly improved by the treatments

6.3 2 Chemical properties of the soil

Chemical properties such a C E C pH total Nitrogen total phosphorus P fixing capacity and organic matter content were studied before and immediately after harvest of the crop The C E C of the soil was increased from sowing to harvest But the treatment differences were not significant The pH of the soil was decreased significantly by the treament applications Total nitrogen content of the soil was increased form sowing to harvest but the treatment difference was not statistically significant Total phosphorus content decreased from sowing to harvest But the treatment difference was not significant P fixing capacity remained almost the same without any significant difference between treatments Organic matter content has remained almost the same from sowing to harvest with the treatment difference showing no significant difference Thus it was revealed that soil chemical properties were unffected by the treatments like phosphorus levels and micro organisms

6 3 3 Available phosphorus content of the soil

The investigations on the available phosphorus content of the soil was done during three stages viz before sowing 30 DAS and at harvest of the crop The available P content increased from sowing to 30 DAS and decreased slightly at the time of harvest The treatment differneces were significant at 30 DAS and at the time of harvest the treatment with 100% P along with VAM and PB recording the highest value of available phosphorus content This shows that micro organisms have a beneficial role in the availability of phosphorus and their combined applications were the best for the crop under the study

6 3 4 Soil phosphorus fractions

Soil phosphorus fractions of the soil were studied at 3 stages of the study viz before sowing at flowering and at the time of harvest There was increase in the soloid P which is the soluble P fraction of the soil There were corresponding decreases in the Al P Ca P and organic P fractions which might have contributed to the increase in the saloid P content of the soil Other fractions did not show much variation The saloid P had significant increase Al P Ca P had significant decrease Organic P had reduction from sowing to flowering and till harvest But the treatment difference was not significant in the case of organic P

6.3 5 Leaf and leaf characters

Leaf and leaf characters like LAI LAR and LWR were studied in the present study LAI showed significant variation only at the time of flowering The treatment combination of 100% P with VAM and PB showed significantly highest value of LAI during the experiment The result was in the same manner in the case of individual factors also The LAR showed significant variation only at 30 DAS The treatment effect was in the reverse order showing thereby that the thickness of leaves were increased by the phosphorus availability Leaf Area Ratio was highest in the control plots showed that phosphorus is essential for the proper thickness of the leaves In the case of leaf weight ratios there was no significant influence with respect to various treatment which shows that the ratio of the leaf weight and plant weight has remained the same even under various treatments

6 3 6 Number and weight of nodules

There was no significant difference in the nodule number under various treatments But there was decline in the nodule count from 30 DAS to flowering which can be due to nodule disintegration at the time of flowering The dry weight of nodules also recorded the same trend as in the case of nodule number This showed that the nodule characters are not influenced by the phosphorus levels as well as by the microbial applications

6 3 7 Yield and yield components

Yield components such as number of pods per plant number of seeds per pod 100 seed weight and pod length were studied during the period of study Among these none were significant except the number of pods per plant The number of pods per plant was maximum in 50% P with VAM and PB applied together On individual factor analysis 100% P and VAM + PB recorded highest values This showed that the interaction effect was also significant The grain and haulm yield also showed the same trend as observed in the case of number of pods per plant This shows that number of pods per plant alone influenced the yield of cowpea and that 50% P with VAM and PB was the ideal treatment for getting maximum yield of cowpea and that 50% P with VAM and PB was the ideal treatment for getting maximum yield

Harvest index showed significant response only in the case of season II whereas in the case of season I no such significant responses were observed The highest harvest index was observed in the case of 100% P with PB in the seaon II which is close to 100% P with VAM and PB On individual factors 100% P and VAM + PB recorded the highest harvest index showing the superiority of this character The protein context was also in the positive order of the treatments with significant response 100% P with VAM + PB recorded the highest significant value This showed that phosphorus has a positive role in increasing the protein content of grains

6 3 8 Nitrogen and phosphorus uptake of cowpea

Nitrogen and phosphorus uptake of cowpea were studied during 3 stages of the experiment viz 30 DAS at flowering and at harvest In all the cases 100% P with VAM and PB recorded the highest significant value at 30 DAS During the other stages 50% P with VAM and PB recorded the highest significant value indicating that 50% P with VAM and PB is the optimum treatment With respect to individual factors 100% P and VAM + PB treatments showed the maximum uptake of N and P This shows that the interaction effect of factors were also significant and is under consideration

It is recommended that only 50% dose of the recommended P is required when carbonate anion m the form of calcium carbonate @ 400 Kg ha ^{1} is applied basally and incorporated in the soil Alternately EDTA solution at 10 ^{4}M concentration @ 50 ml per pe rplant 10 days after germination and repeated at 10 days interval for a total of five applications for cowpea or treating with phosphobacterin and VAM innoculation will save 50% of the recommended phosphorus for cowpea crops grown in red loam soils of southern Kerala

References

REFERENCES

Agarwal S Sıngh T A and Bhardwaj V (1987) Inorganıc soıl P fractıons and avaılable P as affected by long term fertılızatıon and croppıng pattern ın Naınıtal J Indıan Soc Soıl Scı. 35 25 28

Aggarwal S K. and Narang R S (1975) Effect of levels of P and N on soybean varıetıes Journal of Research (Haryana Agrıcultural Unıversıty) 5(4) 303 308

Al Mustafa, W.A. (1988) Soıl phosphorus fractıons and theır avaılabılıty to corn plants ın some Saudı calcarıous soıls Alexandrıa J Agrıc Res 33 (2) 297 312

Ahlawat I P S and Saraf C S (1982) Rootıng and nodulatıon pattern ın pıgeon pea under dıfferent plantıng densıtıes and phosphatıc fertılızatıon Indıan J Agron 27(2) 149 155

Annıe Phılıp (1993) Phosphorus and molybdenum nutrıtıon ın cowpea (Vıgna unguıculata (L) M Sc (Ag) Thesıs Kerala Agrıcultural Unıversıty College of Agrıculture Vellayanı

* Arınes J (1990) Aspectos fısıco quımıcos de la fıjactıon y movılızacıon bıologıca de nutrıents en sel suelo y su ıncıdencıa en la formacıon y efectos de las mıcorrızas V A In J L George J M Barea and J Olıveres (Eds) Fıjacıon y movılızacıon bıologıca de nutrıents Nuevas tendencıas. C S I C Madrıd

Aulakh M S Pasrıcha N S and Azad A.S (1990) Phosphorus and sulphur applıcatıon boosts oılseed productıon ın coarse textured soıls Indıan Farmıng 39 (10) 29 30

* Azcon R Borie P and Barea J M (1982) Exocellular acid phosphate activity of levender and wheat roots as affected by phytate and mycorrnizal inoculation Colloques de I INRA 13 83 85

* Baez Baez, J Fernandez Falcon M Eleizalde luzarraga B (1988) The influence of various anions on the desorption of phosphorus in Canary Island Soils Agrochimica 32 269 275

Bahl G S Pasricha N S Aulakh M S and Baddesha H S (1988) Influence of different grain legumes on the nitrogen availability in soil and fertilizer requirement of succeeding wheat crop Indian Journal of Ecology 15 (1) 99 101

* Baker D E (1960) Phosphorus equilibria and availability in soils Diss. Abstr. 21 1317 1318

Barea J M (1991) Vesicular Arbuscular Mycorrhizae as modifiers of soil fertility Advances in Soil Science 15 1 40

Ba.h i S K.M and Rao G R (1980) Effect of phosphorus deficiency on growth and metabolism in peanut (Arachis hypogoea) Indian J. Plant Physiol 23(3) 273 277

* Bastisse E M (1967) Equilibrium between soils and phosphates and silicate amon C r hebd Seanc Acad Agric Fr 53 39 45

Bethlenfalway G J Ulrich J M and Brown M S (1985) Plant response to mycorrhizal fungi host endophyte and soil effects Soil Sci Soc Am J 49 (5) 1164 1168

Bhatnagar R S Atri S C Mathur C S and Chaudhury R S (1977) Contribution of organic matter and clay to the C E C of Rajastan canal Soils Annals of the Arid Zone. **16** 433 438

Bhatnagar R S Jauhri K S and Iswaran V (1979) Associative effect of inoculation of Bacillus megaterium var phosphaticum and homologous Rhizobium on the yield of Vigna radiata and Glycine max Legume Res. **2** 106 108

* Binh T Bertrand R Burdin S and Pichot J (1974) A study of phosphorus in soils derived from volcanic rocks on the island of reunion (Mascareignes) The effect of calcium carbonate and silicate Agronomic Tropicale, **29** 663 674

Borggaard O K (1983) The influence of iron oxides on phosphate adsorption by soil J. Soil Sci. **34** 333 341

Bray R H and Kurtz L.T (1945) Determination of total organic and available forms of phosphorus in soils Soil Sci **59** 39 45

Budhar M N Ramaswamy C and Abdul Kareem (1991) Influence of spacing and phosphorus on blackgram (Phaseolus mungo) under rice (Oryza sativa) fallow condition Indian J Agron. **36** 217 218

* Chahal R S and Virmani S M (1973) Uptake and translocation of nutrients in groundnut II Phosphorus Oleagineux. **28** 579 581

Chaudhury S L and Bhatia P C (1971) Profits tripple when arhar is adequateley fertilized Indian Farming **20** (12) 27 30

Chaudhury S L Bhatia P C Sharma B M and Singh K (1971) Yield potential of Bengal Gram Indian J Agron 16 296 299

Chaudhury S L Ram S and Gajendra G (1975) Effect of P and N and inoculation on root nodulation and yield of gram Indian J Agron 20 (3) 290 291

Deshpande A M and Bathkal B G (1965) Effect of phosphorus on mung (Phaseolus aureus Roxb) Indian J Agron 10 271 273

Devarajan R Sheriff M M Ramanathan G and Selvakumary G (1980) Effect of phosphorus and zinc fertilization on yield content and its uptake by pulse crops Indian J Agric Res 14 47 52

* Domning B and Amberger A (1988) Influence of silicates on the availability of soil and fertilizer phosphates In Abfallstoffe als Dunger. Proc. of the 99th VDLUFA Congress, September 1987, Koblenz, German Federal Reublic, VDLUFA, Schriftenreiha No.23, Frank furt am Main German Federal Republic J D Sauarlander s Verlag 227 238

Dharam Singh and Singh R K (1992) Effect of level and depth of placement of phosphorus on Pigeon peas (Cajanus cajan) based intercropping systems under dryland conditions Indian J Agron 37 (1) 130 134

Dikshit P R and Padihar S K (1988) Effect of soil moisture regimes and applied P on inorganic phosphate fractions and avaialability of P to rice grown in vertisols Oryza 25 157 163

Dubey S K and Bıllore S D (1992) Phosphate solubılızıng mıcro organısms (PSM) as ınoculant and theır role ın augmentıng crop productıvıty ın Indıa a revıew Crop Res 5 11 24

Duraı Sıngh R and Gopalaswamy N (1991) Effect of plant geometry and levels of nıtrogen and phosphorus on the productıvıty of soybean (Glycıne max) Indıan J Agron 36(4) 545 548

Dwıvedı G K and Sıngh V P (1982) Effect of P and S applıcatıon on the nutrıtıon and qualıty of dıfferent varıtıes of Bengal gram Indıan J Agron 27 (1) 7 12

Evans G C (1972) The quantıtatıve analysıs of plant growth Blackwell Oxford pp 734

Ezedınma F O C (1965) The ınfluence of seed sıze and fertılızer on the development and yıeld of cowpea (Vıgna sınensıs Endl) Nıger Agrıc J 2 75 79

Fagerıa N K and Bajpaı M R (1971) Growth and quahlty of peas (Pısum satıvam L) as ınfluenced by ırrıgatıon phosphorus and spartın B ın semı arıd tract of Rajastan Indıan J Agrıc Res 5 233 238

Garg K P Sharma A K and Thakur B S (1970) Manurıng of cowpea studıes on the effect of dıfferent rates of phosphorus and molybdenum on the growth yıeld of cowpea fodder and resıdual effect on wheat Indıan J Agron 15 112 116

Geethakumarı V L (1981) Phosphorus nutrıtıon of cowpea (Vıgna sınesıs) M Sc (Ag) Thesıs Kerala Agrıcultural unıversıty

George Annamma (1980) Nutritional requirement of black gram (Vigna mungo (L) Hepper) M Sc (Ag) Thesis Kerala Agricultural University College of Agriculture Vellayani TVM

Gillman G P and Fox, R L (1980) Increases in the cation exchange capacity of variable charge soils following super phosphate application Soil Sci Soc Am J 44 934 938

G urley C J P Allan, D L and Russelle M P (1993) Differences in response to available phosphorus among white clover cultivars Agron J 85(2) 296 301

Govil B P and Prasad R (1974) Effect of the amounts of P fertilizer and the proportions of water soluble phosphorus in fertilizer tested on the P nutrition of sorghum JAS 177 179

Gupta R P and Dakshmamurthi C (1980) Procedures for physical analysis of soils and collections of Agrometeorological Data Division of Agricultural physics IARI New Delhi pp 20 25

Habte M and Manjunath A (1987) Soil solution phosphorus status and mycorrhizal dependency in Leucena leucocephala Applied and environmental microbiology 53(4) 797 801

H mpiah R and Sinha, M N (1979) Studies on the effect of phosphorus on grain and green fodder of soybean Journal of Research (Haryana Agricultural University) 9(4) 308 311

H in K K Ki S H Choon S L and Jun K P (1989) Effect of soil amendmends on the availability of phosphate in paddy soil Research Report of the Rural Development Administration, soil & fertilizer 31 23 28

Harley J L and Smith S E (1983) Mycorrhizal Symbiosis Academic press London

* Hartikainen H and Mohemmedi D (1991) Isotopic dilution and extraction tests in assessing chemical induced changes in soil phosphorus Acta Agriculturae Scandinovica 41(1) 99 103

Hayman D S (1982) Influence of soils and fertility on activity and survival of vesicular arbuscular mycorrhizal fungi Phytopathology 72 1119 1125

Hashimoto Y (1967) The suppressing effect of humates and nitro humates on phosphorus fixation in soil 4 Comparison between the suppressing effect of nitrohumates and EDTA J Sci Soil Manure Tokyo 37 605 611

Hayman D S and Mossae B (1972) Plant growth responses to vesicular arbuscular mycorrhiza III Increased uptake of labile P from soil New Phytol 71 41 47

Hegde D M and Saraf C S (1982) Effect of intercropping and P fertilization on nitrogen phosphorus and potassium concentration on the uptake and productivity of pigeon pea (Cajanus cajan (L) Hetsh) Zeitschriff fur Acker And P flarzenban 151(4) 307 314

Hesse P R (1971) A text book of Soil Chemical Analysis John Murray (Publishers) Ltd London pp 520

* Hingston F J and Raupach M (1967) The reaction between monosilicic acid and aluminium hydroxide Aust J Soil Res 5 295 309

Hingston F J Posner A M and Quirk, J P (1968) Specific adsorption of anions on goethite Int Congr Soil Science Tans Nineth 1 669 678

Hoque M S Mallik M S A Ali M I and Mhiya Z H (1984) Effect of phosphorus application and phosphorus absorption and yield of soybean in two soils of Bengladesh using ^{32}p as tracer J Nuclear Agric Biol 13(2) 44 47

Hosoda K and H Takata (1957) Effect of calcium silicate on a paddy rice field on black soil Field Crop Abstracts 2 167 168

Hung L L Sylvia D M , O Keefe D M (1990) Isolate selection and phosphorus interactions of vesicular arbuscular mycorrhizal fungus in biomass crops Soil Sci Soc Am J 54 762 768

ICRISAT (1988) Phosphorus in Indian vertisols Summary proceedings of a work shop 23 26 Aug 1988 ICRISAT center Patancheru India p 36

Islam N A (1970) Transformation of inorganic p in flooded soils under rice cropping Plant and Soil 33 535 544

* Ivarson K (1990) The longterm soil fertility experiments in Southern Sweden 4 Changes in inorganic and organic soil phosphorus fractions after a pot trial Acta Agriculturae Scandinavica 40(3) 205 215

Jackson M L (1958) Soil Chemical Analysis Prentice Hall of India Pvt Ltd

Jain G L (1981) Improved fertilizer practices for maize Indian Farming 31(8) 9 11

Jain V K Chauhan Y S and Jain P C (1986) Effect of different doses of phosphorus on growth yield and quality of cowpea (Vigna unguiculata (L) Walp) Madras Agric J 73(4) 139 202

Jana P K Ghatak S Barik A Biswas B C Sounda G and Mukherjee A K (1990) Response of Summer groundnut to phosphorus and potassium Indian J Agron 35(1&2) 137 143

Jayachandran, K Sehwab A F andHetrick B A D (1989) Mycorrhizal mediation of phosphorus availability Synthetic iron chelate effects on phosphorus solubilization Soil Sci Soc Am J 53(6) 1701 1706

Jayaram R and Ramiah S (1980) Response of cowpea (Vigna sinensis (L) Savi) to phosphorus and growth regulators Madras Agric J 67(1) 102 105

* Juan, A R Curayag L J and Pava H M (1986) Influence of phosphorus fertilization on pod yield and seed quality of three peanut varieties (Arachis hypogoea Linn) CMU J Agri Food and Nut 8(1) 33 62

Kadwe R S and Bhade N S (1973) Effect of Mo and P on growth uptake of nutrients and N fixation by urd Indian J Agric Res 7(1) 43 46

Kalita M M and Kalita B (1992) Effect of phosphorus and lime on green gram (Phaseolus radiatus) rapeseed (Brassica napus) sequence Indian J Agron 37(1) 151 153

Kalsi H S Kapur M L Sodhi J S and Rana D S (1982) Response of gram and mash to N and P application under rainfed conditions Indian J Agron 27(2) 173 174

Kapur M L Rana D S and Singh B (1982) Fertilizer responses of rainfed Bengal gram in cultivators field Fertilizer News 27(8) 34 35

Kaul J N and Sekhon H S (1975) Response of pigeon pea to dates of planting and phosphorus levels Indian J Agron 20(4) 376 377

Kaushik M K. and Jain, G L (1991) Effect of growth regulators soil conditions and phosphorus on production and nutrient uptake of summer groundnut (Arachis hypogoea) Indian J Agron 36(3) 405 407

Kerala Agricultural University (1989) Package of Practices Recommendations 1989 Directorate of Extension Mannuthy Kerala India

Kesavan G and Morachan Y B (1973) Response of soybean varieties to graded doses of N and P Madras Agric J 60(1) 23 26

* Kevt J Ondok J P Nicas J and Jarvis P G (1971) Method of growth analysis In Plant Photo synthetic production a mannual of methods by Sestak Z Catsky J and Jarvis P G (Eds) Dr W Junk N V Publisher the Haque pp 343 391

Khan S R (1966) Effect of cropping systems on certain physical properties of soil under irrigated conditions Pakistan J Soil Sci 2 23 30

Kothandaraman, G V (1975) Studies on soil phosphorus in major soil groups of Tamil Nadu Ph D Thesis TNAU Coimbatore

Krishna K.R and Dart P J (1984) Effect of mycorrhizal inoculation and soluble phosphorus fertilizer on growth and phosphorus uptake of pearl millet Plant and Soil 81(2) 247 256

Kumar A and Verma B S (1988) Root proliferation and nodulation of black gram (Vigna mungo (L) Hepper) in relation to N and P fertilization Indian Agric 32(3) 211 215

Kumaraswamy K. and Rajasekharan S (1990) Phosphobacterin biofertilizer more beneficial to sugarcane Kissanworld May 1990 pp 39

Kurdikeri C B Patil R V and Krishnamoorthi K (1973) Response of cowpea (Vigna catjang) to varying fertilizer levels Mysore J Agric Sci 7 170 174

Lin M L and Fox, R L (1986) External and internal p requirements of mycorrhizal and non mycorrhizal banana plants Proceedings of the 10th International plant nutrition colloquium Bittswille Maryland Aug 4 9 1986 No 178

M ck Drake (1965) Soil chemistry and plant nutrition In chemistry of the soil by Fireman E Bear (Ed) Oxford and IBH publishing Co New Delhi pp 445 473

Mahapatra I C and Yaduraja N T (1981) Rice production research and prospect In Quarter century of Agronomic Research in India (1955 80) ISA, 79 106

Mali O P and Mali A L (1991) Response of promising cowpea (Vigna unguiculata) genotypes to row spacing and phosphate levels Indian J Agric Sci 61(9) 672 673

Malik B S (1974) Response of cowpea to different soil moisture regimes and phosphate levels Indian J Hort 31 246 249

Madhusoodanan Nair K. and Padmaja P (1982) Efficiency of primed rock phosphate for grain production in rice Agric Res J Kerala 17 12 15

* Mata, R A and Sanchez P C (1970) Effect of method of application source and rate of P on the yield of cowpea (Vigna sinensis) grown on a savanna sandy loam soil in Monagas state Venezuela Oriente Agropecuario 2 27 39

Mathan K.K. and Durairaj D J (1967) Availability of phosphorus in Nilgiri soils Madras Agric J. 54 25 34

Mathew S Koshy M M (1982) Effect of lime Phosphorus and Rhizobium inoculation on the growth and yield of cowpea Agric Res. J. Kerala 20(2) 27 30

Mariakulandai A. (1954) Improvement of phosphate availability in the laterite soils of Nilgiris by application of silico phosphate J Indian Soc Soil Sci 3 15 22

Mehta N C Legg J O Goring C A I and Black C A. (1954) Determination of organic phosphorus in soils I Extraction method Proc Soil Sci Soc Am 18 443 449

Miranda J C C De Harris P J Wild A. (1989) Effects of soil and plant phosphorus concentrations on vesicular arbuscular mycorrhizae in sorghum plants New Phytologist 112 405 410

* Miranda J C C De Souca D M G De and Miranda L N De (1984) The effect of VAM fungi on P uptake and dry matter production in sorghum Revista Brasileino de ciencia do solo 8(1) 31 36

Mishra S N and Anand P Singh (1989) Studies on sulphur and phosphorus availability and uptake by groundnut Legume Research 12(4) 160 164

Morita, A. and Konishi S (1989) Relationship between vesicular arbuscular mycorrhizal infection as soil phosphorus concentration in tea fields Soil Science and plant Nutrition 35 139 143

* Mossae B Stribley D P and Tacon F L (1981) Ecology of mycorrhizae and mycorrhizal fungi Adv Microb Ecol 5 137 210

Murrmann P P Peech M (1969) Effect of pH on labile and soluble phosphate in soils Proc. Soil Sci Soc. Am 33 205 210

Nagaraj S and Kumar K. (1983) Nutrient uptake and partitioning in TMV 10 groundnut variety Mad Agric J 70 812 815

Nair R R (1966) Studies on the performance of five varieties of cowpea (Vigna sinensis) and their response to nitrogen and phosphorus fertilization M Sc (Ag) Thesis University of Kerala

* Namdeo K.N and Ghatge R N (1976) Response of Black gram (Phaseolus mungo (L)) to inoculam and levels of N and P with their economics Jawaharlal Nehru Krishi Vishwa Vidyalaya Research Journal 10(3) 264 266

N ingju D (1976) Effect of fertilizer management on seed sulphur content of cowpea Tropical Grain Legume Bulletin 4 6 8

Nejarve J M and Roneadori R W (1985) The interaction of vesicular arbuscular mycorrhizae and soil phosphorus fertility on growth of sweet potato (Ipomoea batatas) Field Crops Research 12(2) 181 185

Negi S C and Thakur R C (1985) Effect of nitrogen phosphorus and Rhizobium inoculation on mash yield and N and P uptake Himachal J Agric Res 11(1) 96 99

Noda M and Saio K (1952) Studies on the phosphate fixing capacity by iron and aluminium in soil 2 Complex forming action of silicic acid and humic acids with iron or aluminium phosphates J Sci Soil Man Japan 22 273 278

Obihara, C H and Russell E W (1972) Specific adsorption of silicate and phosphate by Soil J Soil Science 23 105 117

Othman W M W Lie T A. T Mannetee L. and Warsink G V (1991) Low level phosphorus supply affecting nodulation N_2 fixation and growth of cowpea (Vigna unguiculata (L) Walp) Plant and Soil 135(1) 67 74

Pacovsky R S Bethlenfalway S I Paul E A (1986) Comparison between P fertilized and mycorrhizal plants Crop Sci 26(1) 151 156

Page J B and Willard C J (1946) Cropping systems and soil prope ties Proc Soil Sci Soc Am 11 81 86

Pai de S C (1972) Effect of different levels of nitrogen and phosphorus on the growth and yield of Pusa Baisakhi mung Indian J Agron 17 239 241

Panwar K S Misra A S and Singh V V (1977) Response of blackgram to nitrogen and phosphorus Indian J Agron 22 (3) 149 152

Panwar R S and Singh K (1975) Effect of different spacings and phosphorus levels on the growth yield and chemical composition of moong variety Pusa

Baisakhi under early summer conditions Journal of Research (Haryana Agricultural University) 5(1) 91 93

Pasricha N S Aulakh M S Bahl G S and Baddesha H S (1987) Nutritional requirements of oilseed and pulse crops in Punjab (1975 86) Research Bulletin No 15 Punjab Agricultural University Ludhiana pp 92

Pat l M S Golka P R and Shobhana H K (1981) Growth and nutrient uptake by groundnut (Arachis hypogoea L) as influenced by levels of phosphorus and oil moisture Indian J Agric Chem 14(1 & 2) 33 37

Patel V C Radder G D and Kudasomannavat B T (1983) Growth analysis and pattern of dry matter accumulation and distribution of groundnut Mysore J Agric Sci 17(1) 21 76

Petersen G W and Corey R B (1966) A Modified Chang and Jackson Procedure for Routine Fractionation of Inorganic Soil Phosphates Soil Sci Soc Amer Proc 30 563 565

Pr l n kara J (1970) Soil Structure in relation to relay cropping M Sc Thesis Division of Agricultural physics IARI New Delhi

Prasad R Bhendia M L and Bains S S (1968) Response of grain legumes to levels and sources of P on different soils Indian J Agron 13 305 309

Prasad T and Sanoria (1981) Response of black gram to seed bacterisation and phosphorus Seeds and Farms 7(4) 31 32

Puste A M and Jana P K (1988) Effect of phosphorus and zinc on pigeon pea varieties grown during winter Indian J Agron 33(4) 399 404

Radford P J (1967) Growth Analysis formulae their use and abuse Crop Sci 7 171 175

Rajendran K Sivappah A N and Krishnamoorthy K K (1974a) Effect of fertilization on the yield and nutrient concentration of black gram Madras Agric J 61(8) 447 450

Rajendran K Sivappah A N and Krishnamoorthy K K (1974b) The availability of soil nutrients during the growth phase of black gram Madras Agric J 61(9) 782 784

Rajput R L Kaushik J P and Verma O P (1991) Yield and nutrient uptake in soybean (Glycine max) as affected by irrigation phosphorus and row spacing Indian J Agron 36(4) 580 581

Ramamoorthy B and Velayudham M (1976) Nitrogen Phosphorus and potassium in soil chemistry Forms and availability In Soil fertility Theory and practice by J S Kanwar (Ed) Indian council of Agricultural Research New Delhi p 156 201

* Ramos Hernandez S G and Aguilera Herrera N (1988) Effect of liming on phosphorus fixing soils Anales de Edafologia 47 747 768

Rana D S and Singh B (1979) Fertilizer management for rabi pulses Progressive Farming 15(10) 15 16

Rana N D and Chand G (1977) Phosphorus application for enhanced soybean yields Madras Agric J 64(12) 832 833

Rao J V and Bhardwaj R B (1980) Influence of residual fertility on green gram in intensive cropping system Indian J Agron 25 97 101

Rao M R and Bhardwaj R B L (1981) Direct residual and cumulative effect of phosphorus in wheat pigeonpea rotation Indian J Agric Sci 51 [illegible] 102

Rao N S S Tilak K V B R Singh C S Nair P V (1986) Cereal nitrogen fixation Proceedings of the work group meeting Pattancheru A P (ICRISAT) p 69 74

Rao R K and Patel A S (1975) Studies on the influence of nitrogen and phosphorus on dry matter and dry pod yield of three cowpea (Vigna sinensis (L)) selections Andhra Agri J 22 124 130

Rathi K S and Tripathi H N (1978) Studies on the time of sowing row spacing and phosphate fertilization of early maturing arhar variety T 21 in central U P Indian J Agron 23 233 237

Rathi S S Singh D and Malik R S (1974) Response of short duration arhar to dates of sowing row spacing and phosphate application Fertilizer News 19(2) 27 31

Ravankar H N and Bhade N N (1975) Effect of phosphate on yield uptake of N and phosphate and quality of Urd Mung and soybean Punjabrao Krishi Vidyapeeth Research Journal 3(2) 145 146

Roshan Lal and Gangasaran (1988) Influence of nitrogen and phosphorus on yield and quality of groundnut under irrigated conditions Indian J Agron 33(4) 460 468

Roy B and Misra S (1975) Effect of phosphate fertilization on the yield and other characteristics of soybean in north Bihar Indian J Agric Sci 45(3) 136 138

Roy R N and Wright B C (1974) Sorghum growth and nutrient uptake in relation to soil fertility II NPK uptake pattern by various plant parts Agron J 66 5 10

* Rueda E H Grassi R L Zenobi M E (1981) Influence of several chelating agents on the adsorption of zinc on Haematite Anales de Edafoligia Y Agrobiologia 40 251 257

Russelle M P Meyers L L McGraw R L (1989) Birdfoot trefoil seedling response to soil phosphorus and potassium availability indices Soil Sci Soc Am J 53(3) 828 836

* Saad H S Bamatraf A and Haidra, A (1988) Wheat response to soil P content in the central highlands of Yemen Amman (Jordan) Sept 1988 p 14

Sabale R N and Khuspe V S (1986) Effects of moisture phosphate and antitranspirants on growth dry matter and yield of summer groundnut J Maha Agric Univ 11(1) 9 13

Sahu S K (1973) Effect of Rhizobium inoculation and phosphate application on blackgram and Horsegram Madras Agric J 60(8) 989 994

* Salam M A Osman A Z and Basiouny H (1968) Interaction of the level and method of phosphorus fertilization on cowpea production in newly reclaimed soils Isotope Radn Res 1 33 39

Sankaranarayana, H S and Mehta B V (1967) Soil structure studies in chambal command area of Rajastan J Indian Soc Soil Sci 15(2) 77 78

Santhi R Kothandaraman G V and Rengarajan M (1988) Efficiency of VAM inoculation with different sources of phosphorus on the availability and uptake of nutrients and yield of green gram Proceedings, First asian conferences on mycorrhiza Madras India pp 166 168

Sarkar R K (1992) Response of Summer green gram (Phaseolus radiatus) to irrigation and phosphorus application Indian J Agron 37(1) 123 125

Sasidhar V K (1978) Studies on the effect of multiple cropping on soil fertility and crop yields in Wetland Ph D Thesis Department of Agronomy Kerala Agricultural University College of Agriculture Vellayani Trivandrum

Sawhney J S Sandhu K S and Moolani M K (1975) Effect of NPK application on the yield of blackgram on light soils Indian J Agron 29(4) 372 373

Saxena M C and Yadav D S (1975) Some agronomic considerations of pigeon pea and chickpea In Proceedings of International workshop on grain legumes pp 31 61 ICRISAT Hyderabad

Schubert A and Hayman D S (1986) Plant growth responses to vesicular arbuscular mycorrhiza XVI Effectiveness of different endophytes at different levels of soil phosphate New Phytol 103(1) 79 90

Sharma B M and Choudhury S L (1971) Response of Lentil to stage bound irrigations Inter row spacings and N P fertilization Fertilizer News 16(9) 42

Sharma R P and Arora R N (1982) Performance of cowpea var under different dates of sowing and levels of phosphorus Indian J Agron **27**(2) 197 198

Sharma P K Verma S P and Bhumbla D R (1980) Transformation of added P into inogranic P fraction in some acid soils of Himachal Predesh J Indian Soc Soil Sci **28** 450 453

Shelke D K and Khuspe V S (1980) Pattern of dry matter accumulation and uptake of phosphorus by Latur No 33 groundnut as influenced by different levels of irrigation phosphorus and antitranspirant during summer Indian J Agron **25**(3) 362 369

Shrivastava S N Namdeo K N Tripathi A R and Pandey R P (1980) Effect of row spacing and phosphorus level on black gram Vigna mungo var radiata Hepper) Madras Agric J **67**(12) 771 777

Singh A Ahlawat I P S and Lal R B (1983) Effect of planting pattern intercropping and application of phosphate on the yield of pigeon pea and the succeeding crop of wheat Indian J Agric Sci **53**(7) 556 562

* Singh A Prasad R and Saraf C S (1981) Effect of plant type plant population density and application of phosphatic fertilizer on the growth and yield of pigeon pea J Agric Sci Camb **97** 103 106

Singh D S and Singh R S (1986) Effect of phosphorus and Glomus fasciculatus inoculation on nitrogen fixation P uptake and yield of Lentil (Lens culinaris Medic) grown on an unsterilized sandy soil Environmental and Experimental Botany **26**(2) 185 190

Singh K and Prasad R (1975) It pays to fertilize arhar under rainfed conditions Fertilizer News 20(3) 28 30

Singh KP and Ahuja KN (1985) Dry matter accumulation oil content and nutrient uptake in groundnut (Arachis hypogoea L CV T 64) as affected by fertilizers and plant density Indian J Agron 30(1) 40 45

Singh M and Tiwari RC (1985) Response of oilseed and pulse crops to fertilizers in dry land Agriculture In Proceedings FAI NRS seminar on available Technology and strategies for promoting fertilizer use in dryland farming pp 147 159 Fertilizer Association of India New Delhi

Singh NP and Saxena MC (1973) Phosphorus fertilization of soybean Indian J Agric Sci 43(10) 925 929

Singh R Singh N and Sidhu GS (1968) Symbiotic nitrogen fixation by some summer (Kharif) legumes of Punjab Effect of phosphate on nitrogen fixation J Res Panjab Agric Univ 5 88 94

Singh RV Parmar MC and Singh PP (1992) Response of blackgram (Phaseolus mungo) to weed control and fertilizers Indian J Agron 37(1) 192 194

Singh T Aggarwal SK and Singh KP (1975) Effect of P and N levels on the grain yield and protein content of moong varieties Journal of Research (Haryana Agricultural University) 5(3) 231 235

Smghama RA and Goswami NN (1978) Transformation of applied phosphorus under submerged conditions of growing rice and wheat in a sequence J Indian Soc Soil Sci 26 193 197

Sinha H and Mandal S C (1955) Anion exchange and exchangeable phosphorus in some Bihar soils Sci & Cult 20 597 599

Sinha M N (1972) Effect of doses and method of phosphorus placement on growth yield and uptake of phosphorus by gram (Cicer arietinum) under rainfed conditions Indian J Agron 17 1 4

* Smith S E and Gianinazzi Pearson V (1988) Physiological interactions between symbionts in vesicular arubscular mycorrhizal plants Annu Rev Plant Physiol Plant Mol Biol 39 221 244

Smyth T J and Cravo M S (1990) Critical phosphorus levels for corn and cowpea in a Brazilian Amazon Oxisol Agronomy Journal 82(2) 309 312

Smyth T J and Sanchez P A (1980) Effect of lime silicate and phosphorus application to an Oxisol on phosphorus sorption and ion retention Soil Sci Soc Am J 44 500 505

Srivastava S N L and Verma S C (1982) Effect of bacterial and inorganic fertilization on growth nodulation and quality of green gram Indian J Agric Res 16(4) 223 229

Srivastava S N L and Verma S C (1990) Effect of nitrogen Rhizobium and techniques of phosphorus application on the uptake of nitrogen and phosphorus in field pea Agric Sci Digest 10(1) 37 40

Subba Rao N S (1982) Biofertilizers in Agriculture Oxfordand IBH publishing Co New Delhi p 186

Subbian P and Ramiah S (1981) Influence of phosphorus and molybdenum nutrition with Rhizobium inoculation on nutrient uptake pattern in Redgram Madras Agric J 68(5) 307 313

Subramonian S and Gopalaswamy A. (1991) Effect of moisture organic matter phosphate and silicate on availability of silicon and phosphorus in rice soils J Indian Soc Soil Sci 39 99 103

Sudhir Agarwal Singh T A and Bhardwaj V (1987) Inorganic Soil P fractions and available P as affected by long term fertilization and cropping pattern in Nainital J Indian Soc Soil Sci 35 25 28

Sundara Rao W V B (1968) Phosphorus solubilization by micro organisms Proc. All India Syposium on Agricultural Microbiology, Uni Agric Sci Bangalore pp 21 29

Surayawanshi B M and Chaudhary C S (1979) Response of gram to soil and foliar application of phosphorus Indian J Agric Res 13 18 22

Syvertsen J P and Graham J H (1990) Influence of vesicular arbusucular mycorrhizae and leaf age on net gas exchange of citrus leaves Plant Physiol 94(3) 1424 1428

Talashilkar S C and Patel M P (1979) Effect of Organic matter on the availability of P from single super phosphate and Rock Phosphate J Indian Soc Soil Sci 27 201 202

Tamar R A S Kushwaha H S and Tamar S P S (1990) Response of groundnut (Arachis hypogoea (L)) Varieties to P and Zn under rainfed conditions Indian J Agron 35(4) 391 394

Tandon, H L S (1987) Phosphorus research and agricultural production in India Fertiliser Development and Consultation Organisation New Delhi p 160

Tandon H L S (1993) Methods of Analysis of Soils, Plants, Waters and Fertilizers Fertilizers Development and Consultation Organisation New Delhi pp 144

Tarila A G I Orarod D P and Hdedipe N O (1977) Effect of phosphorus inoculation and light intensity on growth and development of the cowpea (Vigna unguiculata) Ann Bot 41(171) 75 83

Tisdale S L Nelson W L and Beaton J D (1985) Soil Fertility and Fertilizers (Fourth Edn) Macmillan Publishing Company New York p 754

Tripathi H P Gill P S and Kapoor N L (1977) Response of fodder varieties of cowpea to phosphorus application Forage Research 3 121 126

Upadhyaya L P and Sharma P (1977) Effect of time of sowing inter row spacing and fertility levels on the grain yield of Lentil Ind an J Agron 22(1) 41 42

Uzo F O Juo A S R and Feyemi A A A (1975) Form of phosphorus in some important Agricultural soils of Nigeria Soil Sci 120 212 218

Vasimalai M P and Subramoman S (1980) Response of redgram to irrigation and phosphorus Mad Agric J 67(8) 506 509

Vig A C Dev G and Bahl G S (1994) Characterisation of phosphorus in soils In phosphorus Researches in India by Dev G Potash and phosphate Institute of Canada India programme Gurgaon Haryana (India) p 14 36

Vıvekanandan M and Fıxen P E (1991) Croppıng Systems on mycorrhızal colonısatıon early growth and phosphorus uptake of corn Soıl Scı Soc Am J 55(1) 136 140

Vıswanathan T V Vıswambharan K and Chandrıka P (1978) Response of cowpea (Vıgna sınensıs Endl) to dıfferent levels of N P & K Agrıc Res J Kerala **16** 129 132

* Wang H D and Yuan T L (1989) Lıme effects on phosphorus retentıon and release ın four ultısols Proc Soıl Crop Scı Soc Florıda **48** 131 137

* Wheeler R W (1966) Chelatıon lımıng and partıal acıdulatıon of rock phosphate as factors affectıng plant recovery of soluble phosphorus from acıd soıls Dıss Abstr **26** 3573

Wolf A M (1988) Soıl property effects on the phosphorus bufferıng characterıstıcs of soıls Ph D Thesıs Pennsylvanıa State Unıversıty U S A

* Orgınals not seen

Appendices

APPENDIX - I

Weather data (weekly mean) for the experimental periods (Season I)

Weeks	Temperature (°C)		Relative humidity (%)		Total rainfall	Number of	Sunshine	Evaporation
	Maximum	Minimum	F N	A N	(mm)	rainy days	hours day [1]	(mm day [1])
1	31 1	23 6	92 3	71 7	199	5	3 4	2 7
2	29 2	23 2	92 7	78 1	428	7	1 6	2 5
3	30 1	24 8	91 1	78 1	65	4	4 0	2 7
4	30 0	25 1	89 0	75 0	0	0	5 8	4 3
5	30 3	24 2	86 7	76 6	29	5	5 3	3 7
6	29 3	23 1	90 4	80 1	83	3	4 7	3 0
7	29 1	22 9	91 0	77 1	78	4	4 1	2 4
8	30 1	22 9	90 4	72 3	17	2	5 3	3 6
9	28 7	22 4	89 3	87 7	42	4	3 0	3 0
10	28 9	23 1	92 0	82 7	10	1	3 9	3 4
11	29 0	23 8	92 1	79 1	15	2	5 8	2 9
12	29 6	23 7	90 4	75 9	3	1	7 1	4 2
13	29 5	23 4	91 1	77 3	27	2	5 1	4 0

APPENDIX II

[illegible] for the experimental periods (Season [illegible]

Weeks	Temperature (oC) Maximum	Temperature (oC) Minium	Relative humidity (%) F N	Relative humidity (%) A.N	Total rainfall (mm)	Number of rainy days	Sunshine hours day[1]	Evaporation (mm day 1)
1	30 2	22 5	90 1	76 0	155	5	2 6	3 0
2	29 3	22 7	91 1	77 7	189	4	3 0	2 3
3	29 6	23 8	92 7	74 3	3	1	6 2	3 8
4	29 8	23 6	89 9	73 6	6	1	8 0	4 4
5	28 5	22 7	90 6	83 1	60	1	7 3	3 0
6	29 0	23 1	89 3	70 0	5	2	5 0	2 7
7	29 1	22 9	92 7	79 7	253	5	2 1	1 3
8	30 6	23 3	93 7	74 6	12	1	4 7	2 2
9	30 8	22 9	91 3	66 0	10	1	5 5	2 8
10	30 5	22 0	85 6	67 3	12	1	7 5	2 6
11	30 3	22 2	89 4	64 6	0	0	4 6	2 9
12	31 1	22 4	91 3	73 0	4	1	6 8	2 5

APPENDIX III

CALENDER OF OPERATIONS

A. Experiment No I (P desorbing anions)

SEASON I

18 5 92	Layout and applying desorbing anions
1 6 92	Application of chemical fertilizers and planting
18 6 92	Thinning and weeding
21 6 92	Top dressing and earthing up
30 6 92	I sampling of plants & soil
3 7 92	Spaying insecticide and fungicide
18 7 92	II sampling of soil and plants at flowering
11 8 92	Removing border plants for harvesting
13 8 92	Taking observations and I harvesting of dry pods
22 8 92	Taking observations and harvesting of drypods
31 8 92	Taking observations and final harvest of grain and haulms and collection of soil and plant samples

SEASON II

21 9 92	Layout and applying desorbing anions and digging and incorporating
3 10 92	Application of chemical fertilizers and planting cowpea
20 10 92	Rectifying channels and bunds thinning and weeding of plots
23 10 92	top dressing and earthing up
29 10 92	Clearing around experimental plots
3 11 92	Sampling of cowpea plant and soil
9 11 92	Spraying fungicide and insecticide
18 11 92	Sampling of cowpea and soils at flowering
20 11 92	Spraying fungicide and insecticide

1 12 92	Spraying fingicide and insecticide
9 12 92	Applying insecticide taking observations and harvesting dry cowpea pods
16 12 92	Taking observations and harvesting and transporting cowpea pods
23 12 92	Final harvesting of cowpea pods and haulms and collection of soil and plant samples

B. Experiment No 2 (Effect of chelating agents)

SEASON I

18 5 92	Layout and digging the experimental plots
1 6 92	Applications of chemical fertilizers and planting
10 6 92	Application of chelates
18 6 92	Thinning and weeding of plots
20 6 92	Application of chelates
21 6 92	Top dressing and earthing up
30 6 92	Application of chelates first sampling of soil and plants
3 7 92	Spraying insecticide and fungicide
10 7 92	Application of chelates
18 7 92	Second sampling of plants and soil at flowering
20 7 92	Application of chelates
11 8 92	Removing border plants for harvesting
13 8 92	Taking observations and harvesting of dry pods
22 8 92	Taking observations and harvesting of dry pods
31 8 92	Taking observations and final harvesting of cowpea grains and haulms and collection of soil and plant samples

SEASON II

21 9 92	Layout and digging of plots
3 10 92	Application of chemical fertilizer and planting of cowpea

13 10 92	Application of chelates
20 10 92	Rectifying channels and bunds thinning and weeding of plots
23 10 92	Top dressing and earthing up and application of chelates
29 10 92	Cleaning around experimental plots
3 11 92	First sampling of cowpea plant and soil and application of chelates
9 11 92	Spraying fungicide and insecticide
13 11 92	Application of chelates
18 11 92	Sampling of cowpea and soils at flowering
20 11 92	Spraying fungicide and insecticide
23 11 92	Application of chelates
1 12 92	Spraying fungicide and insecticide
9 12 92	Applying insecticide taking observations and harvesting dry cowpea pods
16 12 92	Taking observations and harvesting dry cowpea pols
23 12 92	Taking observations final harvesting of dry cowpea pods and haulms and collection of soil and plant samples

C Experiment No.3 (Effect of microbial agents)

SEASON - I

18 5 92	Layout and digging the experimental plots
1 6 92	Application of chemical fertilizers and planting and applying inoculants
18 6 92	Thinning and weeding of plots
21 6 92	Top dressing and earthing up
30 6 92	First sampling of soil and plants
3 7 92	Spraying insecticide and fungicide
18 7 92	Second sampling of plants and soil at flowering
11 8 92	Removing border plants for harvesting
13 8 92	Taking observations and harvesting of dry pods

22 8 92	Taking observations and harvesting dry pods
31 8 92	Taking observation and final harvesting of cowpea grain and haulms and collection of soil and plant samples

SEASON II

21 9 92	Layout and digging plots
3 10 92	Application of chemical fertilizer and planting of cowpea inoculated with microbes
20 10 92	Rectifying channels and bunds thinning and weeding of plots
23 10 92	Top dressing and earthing up
29 10 92	Cleaning around experimental plots
3 11 92	First sampling of cowpea plant and soil
9 11 92	Spraying fungicide and insecticide
18 11 92	Sampling of cowpea and soils at flowering
20 11 92	Spraying fungicide and insecticide
1 12 92	Spraying fungicide and insecticide
9 12 92	Applying insecticide taking observations and harvesting of dry cowpea pods
16 12 92	Taking observations and harvesting dry cowpea pods
23 12 92	Taking observations final harvesting of dry cowpea pods and haulms and collection of soil and plant samples

APPENDIX IV

Economics of P desorbing anions on the yield and net profit of cowpea (area 1 ha)

Treatment	Cost of fertilizer P Rs	Cost of Chemical Rs	Labour cost Rs	Common Cultivation Cost Rs	Total Cost Rs	Return from Cowpea (Rs) @ Rs 15 per Kg	Net Profit Rs
T1				5638	5638	8175	2537
T2		600	80	5638	5718	12435	6717
T3		520	80	5638	6238	12780	6542
T4		6000	80	5638	11718	12150	432
T5	81		80	5638	5799	9690	3891
T6	81	600	160	5638	6479	13650	7171
T7	81	520	160	5638	6399	14745	8346
T8	81	6000	160	5638	11879	12390	511
T9	162		80	5638	5880	11370	5490
T10	162	600	160	5638	6560	13125	6565
T11	162	520	160	5638	6480	13860	7380
T12	162	6000	160	5638	11960	13545	1585

APPENDIX - V

CORRIGENDUM

Th- words after harvest appearing in the text be read as at harvest

ABSTRACT

Three field experiments were conducted at the Instructional Farm College of Agriculture Vellayani during 1992 93 for two season to study the effect of chemical and bio agents on phosphorus dynamics in the red loam soils of Southern Kerala

In the experimnet No 1 four treatments such as no anions hydroxide carbonate and silicate were tested under three levels of phosphorus such as no phosphorus 50% phosphorus and 100% phosphorus From the study it was revealed that carbonates have more desorbing power for phosphorus than the other anions tested These were reflected in the yield and yield attributes available phosphorus content of the soil soil phosphorus fractions nitrogen and phosphorus uptake of plants Among the combinations carbonate anion with 50% phosphorus gave the highest yield

In the experiment No 2 three treatments such as no chelates EDTA and DTPA were tested with three levels of phosphorus such as no phosphorus 50% phosphorus and 100% phosphorus From the study it has been revealed that EDTA gave better response than other chelates tested These were reflected in the yield yield attributes, available phosphorus content of the soil, soil phosphorus fractions nitrogen and phosphorus uptake of plants Among the combinations EDTA with 50% phosphorus gave the highest yield

In the experiment No 3 four levels of microbial agents such as no microbes VAM PB and VAM + PB were tested with three levels of phosphorus such as no phosphorus 50% phosphorus and 100% phosphorus From the study it has been revealed that VAM + PB gave the highest response This was reflected in the yield attributes available phosphorus content of the soil soil phosphorus fractions nitrogen and phosphorus uptake of plants Among the combinations VAM + PB with 50% phosphorus gave the highest yield