“EFFECT OF ORGANIC AND INORGANIC FERTILIZATION ON DEPTH WISE DISTRIBUTION OF DIFFERENT FORMS OF PHOSPHORUS AND POTASSIUM IN *VERTISOL*”

M. Sc. (Ag.) THESIS

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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"EFFECT OF ORGANIC AND INORGANIC FERTILIZATION ON DEPTH WISE DISTRIBUTION OF DIFFERENT FORMS OF PHOSPHORUS AND POTASSIUM IN *VERTISOL*"

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CERTIFICATE–I

This is to certify that the thesis entitled **"EFFECT OF ORGANIC AND INORGANIC FERTILIZATION ON DEPTH WISE DISTRIBUTION OF DIFFERENT FORMS OF PHOSPHORUS AND POTASSIUM IN *VERTISOL*"** submitted in partial fulfillment of the requirements for the degree of **"Master of Science in Agriculture"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **KU. TRIPTI NAYAK** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been only acknowledged by him.

Date:

Chairman

Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	**:Dr. R.K. Bajpai**	------------------------------
Member	**: Dr. R.N. Singh**	------------------------------
Member	**:Dr. N. Pandey**	------------------------------
Member	**:Dr. A. K. Singh**	------------------------------

CERTIFICATE–II

This is to certify that the thesis entitled **"EFFECT OF ORGANIC AND INORGANIC FERTILIZATION ON DEPTH WISE DISTRIBUTION OF DIFFERENT FORMS OF PHOSPHORUS AND POTASSIUM IN *VERTISOL*"** submitted by **KU. TRIPTI NAYAK** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfillment of the requirements for the degree of **M.Sc. (Ag.)** in the **Department of Soil Science and Agricultural Chemistry** has been approved by external examiner and Student's Advisory Committee after oral examination.

Date: 24/8/13 **EXTERNAL EXAMINER**

Major Advisor ______________________

Head of the Department / Section ______________________

Dean / Dean Faculty ______________________

Director of Instructions ______________________

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Abbreviations	Full form
50% NPK	50% of the recommended optimum NPK fertilizer schedule (50:30:20::N:P_2O_5:K_2O)
100% NPK	100% of the recommended optimum NPK dose (100:60:40::N:P_2O_5:K_2O)
150% NPK	150% of the recommended optimum NPK dose (150:90:60::N:P_2O_5:K_2O)
100% NPK + Zn	100% of recommended optimum NPK + $ZnSO_4$ @10kg /ha in *Rabi crops* only (100:60:40::N:P_2O_5:K_2O +$ZnSO_4$)
100% NP	100% N and P of recommended N dose of fertilizer (100:60:0::N:P_2O_5:K_2O)
100% N	100% N of recommended optimum N dose (100:0:0::N: P_2O_5:K_2O)
100% NPK + FYM	100%NPK + FYM (5 t /ha in *kharif crop* only)
50% NPK + BGA	50% NPK +BGA (10 Kg/ha dry culture in *kharif* crop only)
50% NPK + GM	50% NPK+GM (Sown in site cut and mixed in soil in *kharif* season only)
T	Treatment
D	Soil depth
TxD	Interaction of treatment and soil depth
K fraction	Potassium fraction
WS-K	Water soluble potassium
AV-K	Available potassium
Ex-K	Exchangeable potassium
NEx-K	Non exchangeable potassium
P fraction	Phosphorus fraction
S-P	Saloid phosphorus
Al-P	Aluminium phosphorus
Fe-P	Iron phosphorus
R-P	Reductant phosphorus
Ca-P	Calcium phosphorus

Introduction

CHAPTER-I

INTRODUCTION

Phosphorus and potassium are recognized as the second and third most important nutritional factor respectively, limiting the yields of field crops after nitrogen and required for maximum crop production. These two primary nutrients play a vital role in crop nutrition and their availability in soil is governed by their forms (both organic and inorganic) and prevailing soil chemical environment.

Phosphorus is an essential element for plant growth. Therefore, maintenance of an adequate amount of soil P through application of inorganic and organic P is critical for the sustainability of cropping system (Sharpley *et al.*, 1994). For phosphorus requirement plants depend on inorganic form of phosphorus. It has now been established that saloid-P, Al-P, Fe-P, R-P and Ca-P are the major soil inorganic fractions and their relative proportion depends upon various factor (Jaggi, 1991). The availability and fractions of soil P may change due to long-term continuous P fertilization besides its yield-increasing effect (Fan *et al.*,2003; Lai *et al*., 2003). Many researches have found that soil phosphorus availability would increase after long-term fertilizer P application (Halvorson and Black, 1985; Samadi and Gilkes, 1998; Fan *et al*., 2003; Lai *et al*., 2003; Zhang *et al*., 2004). However, such an effect of fertilizer P application varies with climatic condition, soil type, and soil test method employed, as well as the rate of fertilizer P applied (Zhang *et al*.,2004). However, soil Olsen-P can increase with fertilization rates after long-term fertilization in calcareous soils has not been well understood. The knowledge of soil P fractions is important for investigating soil P availability, and several kinds of fractionation methods are available for different soil types (Chang and Jackson, 1957; Hedley *et al*., 1982; Jiang and Gu, 1989). In calcareous soils, soil inorganic P (Pi) represents the dominant component of the soil P pool, accounting for about 75%–85% of soil total P in calcareous soils in China (Jiang and Gu, 1989). Soil P was divided into various fractions such as Ca-P (HCl extractable P), Fe- and Al-P (non-occluded Fe- and Al-bound P), and occluded P (Chang and Jackson, 1957; Solis and Torrent, 1989). However, in calcareous soils, the majority of P exists in the various Ca-bound forms and there is a great difference in P availability among the Ca-P fractions.

Phosphorus in soil is present in both organic and inorganic forms. In general, inorganic P is the predominant form of soil P, constituting 20 to 80% of the total P in the surface layer (Tomar 2003).It is the inorganic fraction, which is more intimately related to phosphate nutrition to plants in agricultural soils. Plant availability of inorganic P can be limited by the formation of sparingly soluble calcium phosphate in alkaline and calcareous soils; by adsorption onto Fe and Al oxides in acid soils and by formation of Fe and Al phosphate complexes with humic acids (Gerke 1992). The nature and distribution of different forms of P have provided useful information for assessing the available P status of soil and for estimating the degree of chemical weathering of the soil, P deficiency, *etc*. Estimation of available P indicates only the amount of P present in soil solution and soil surface which is available to plants but it does not indicate about the relative contribution of different fractions of P towards available P. Thus understanding of the relationship between various forms of P, their interactions in soil and various factor influencing P availability to plants is essential for efficient P management in soil.

Compared with phosphorus, the chemistry of potassium in soils is relatively simple, at least in terms of the in which it occurs. Plant-available potassium includes potassium contained in the soil solution and the exchangeable K held on negatively charged exchange surfaces in the soil. It also includes a variable quantity of non-exchangeable K held within the soil minerals. However, the dynamic nature of potassium in soil-plant system makes its behavior unpredictable. Potassium being one of the most dynamic nutrients, its availability in different forms and combinations depends upon the equilibrium and kinetic reaction between forms of soil-K, soil moisture content, temperature and the concentrations of bivalent cations in solution and on the exchanger phase (Sparks and Huang, 1985). Similarly relationship of soil inorganic K fractions with its available pool, crop yield and uptake also exist (Prasad and Rokima, 1991, Bagvathi, *et al*, 1996 and Majumdar *et al*, 2002).

There is serious need to determine the amount of the relevant nutrients in the soil. The chemical fractionation technique provides useful details on the amount and distribution of the element in the soil.

Evaluation of phosphorus & potassium status of soils is necessary to make sound fertilizer recommendations for optimizing the productivity of field crops. Soil P fraction gives an idea about the soil phosphorus supplying capacity to plants. Under Submerged rice it is necessary to evaluate the effect of different nutrient management practices on depth-wise distribution of soil P and K fraction.

In view of the above, a study entitled “Effect of organic and inorganic fertilization on depth wise distribution of different forms of soil phosphorus and potassium in Vertisol” with the following objectives:

1) To study the depth-wise distribution of different form of soil phosphorus and potassium in Vertisol under different fertilization practices.
2) Effect of fertilization (both organic and inorganic) on soil Physical properties.
3) To study the percentage distribution of different form of P and K under various depth.

Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

This chapter deals with the review of research work carried out by different researchers on the topic **"Effect of organic and inorganic fertilization on depth wise distribution of different forms of phosphorus and potassium in *Vertisol*"**. A brief review of work done presented in this chapter under the following heads:

2.1 Depth-wise distribution of different form of soil phosphorus and potassium in Vertisol under different fertilization practices.

2.1.1 Phosphorus fraction

2.1.2 Potassium fraction

2.1.3 Depth-wise distribution of different form of soil potassium.

2.1.4 Depth-wise distribution of different form of soil phosphorus.

2.2 Effect of fertilization (both organic and inorganic) on soil physico-chemical properties.

2.3. Percentage distribution of different form of P and K.

2.3.1 Percentage distribution of different forms of K.

2.3.2 Percentage distribution of different forms of P.

2.1. Depth-wise distribution of different form of soil phosphorus and potassium in *Vertisol* under different fertilization practices.

Combined use of fertilizers with manures influences the form and availability of soil Phosphorus and Potassium in many ways. The proportion of forms of phosphorus such as Ca-p , Al-P , Fe-P , reductant soluble-P , organic P governs the response to applied P (Singh *et al*. 2003) .Therefore, the present study was carried out to determine the forms of phosphorus. The conversion of applied P into specific inorganic forms is important, as the fertilizer reaction product is the source of phosphorus from soil.

The different forms of inorganic K exist in sort of dynamic equilibrium (Mortland, 1960). Use of chemical fertilizers in conjunction with organic manures has been reported to influence the dynamics of inorganic K fractions. Therefore, soil P and K fractionation studies serve as a valuable tool to provide insight into the mechanism of integrated nutrient management in regulating P and K availability.

2.1.1 Phosphorus fractions

Jaggi (1991) reported that plants mainly depend upon inorganic forms for their phosphorus requirements. It has now been established that saloid-P, Al-P, Fe-P, Reductant-P and Ca-P are the major soil inorganic P fractions and their relative proportion depeds upon various factors.

Pavan and Androcioli (1995) studied the effects of NPK + Green manure + compost and NPK + green manure + compost + grass staw mulch on P fractions in a latosol using a sequential extraction procedure. Moderately labile P (NaOH-Po, NaOH-Pi) and non labile P (HCl-Pi, residual P) were significantly increased by the application of compost and mulch. $NaHCO_3$–Pi and resin-Pi accounted for the largest proportion of inorganic and organic P, respectively. The residual P fraction was the single largest fraction of total P; it was not affected by any of the treatments and increased with soil depth. Exclusive application of inorganic fertilizers increased both non-labile and poorly labile fractions

Bahl and Singh (1997) conducted laboratory and green house experiments in ten soils (eight alkaline and two acid soils) to study the effect of added P, green manuring and cropping on Olsen’s P and inorganic soil P fractions. P-fertilization resulted in increase in all the estimated P-fractions. Due to green manure addition, Saloid-P increased at the expense of other P fractions.

Vasuki *et al.* (1998) analyzed surface sample (0-20cm) of Alfisols collected from 5 tobacco-growing areas of Karnataka, India and revealed that the Saloid-P fraction was the smallest (2.1-8.9 ppm), while Al-P and Fe-P were the dominant fractions. The concentration and contribution of each fraction to total P was in the order: Saloid-P < occluded-P < Ca-P < reductant –P < Al-P < Fe-P. Among the properties, pH, organic carbon and free iron oxides were found to have the greatest influence on the inorganic P fractions.

Two field experiments were conducted in Poland to determine the effects of applied farmyard manure (FYM), cattle slurry (CS),pig slurry (PS) and mineral fertilizer (MF) on the content of total, organic and mineral P in soil lessive and brown soil. The influence of fertilizer application on the uptake and utililization of P by cultivated plants was also determined. Long term fertilizer application contributed to a significant increase in the content of total, organic and mineral P in the soil. P utilization from fertilizers applied to soil lessive was higher than from those applied to brown soil. (Sadej, 2000)

Lee *et al.* (2004) Found that continuous fertilizer application and rice cultivation led to a continuous decrease in ratio of organic P to total P in the plough layer with the lapse of years. In conclusion, the combined application of chemical fertilizers and compost could be an effective method to increase the plant availability of P in soils by promoting microbial activity.

Sheeba and Kumaraswamy (2005) revealed that amongst manures, urban compost applied at 12.5 t per ha improved the maximum status of total P (895 ppm) and organic (143 ppm) and inorganic P (743 ppm) followed by FYM at 12.5 t per ha.

However, available P was the highest (78 kg/ha) in the plots receiving FYM followed by urban compost (72 kg/ha). Amongst fertilizers, the maximum values of total P (874 ppm), inorganic P (709 ppm) and available P (85 kg/ha) were found in NPK at 120:60:60 with almost at par value in the fertilizer treatments receiving 60 kg P per ha, organic P content was also almost similar in all the P receiving fertilizer treatments.

A study was undertaken to evaluate the effect of chemical fertilizers and organic manures on the amount and distribution of P fractions in soil after two cycles of rice-wheat cropping system. There was a significant increase in saloid-P, Al-P and Ca-P as result of inorganic fertilization and organic amendments which could be attributed to the transformation of applied P at faster rate into saloid-P, Al-P and Ca-P in the first instance and then to Fe-P with time (Sihag *et al*., 2005).

Guppy *et al.* (2005) reported that the incorporation of organic matter in soils that are able to rapidly absorb applied phosphorus fertilizers reportedly increased phosphorus availability to plants.

Joshi (2006) reported that under Long-term fertilizer management in Vertisol , maximum portion of applied P was transformed in Ca-P followed by Red-P,Fe-P and Al-P. In case of potassium, maximum portion of applied K was transformed into non-exchangeble K and minimum into water soluble K, whereas exchangeable K and available K were intermediate.

Bhakare *et al*. (2006) revealed that there was highly significant positive relationship between yield and all the fraction of P in *Inceptisol* of Maharastra. The significant positive correlation was also observed between all the forms of P, P uptake and available P. Total P had highest relationship with P uptake and available P (0.939** and 0.971 respectively).

Dutta *et al*. (2007) studied the physico-chemical properties of the soils and showed that the soils were acidic (pH: 4.21 to 5.67) in nature with moderate to high in organic carbon content. Avid variation was observed in extractable P, extractable Al, amorphous Al and exchangeable cations. The different inorganic forms of soil P, were in decreased in the order of Al-P > Fe-P > reductant soluble P > Ca-P > occluded P > saloid P.

Majumdar *et al*. (2007) reported that among inorganic fractions, significantly increase in saloid-P, Al-P, Fe-P and Ca-P but depletion in reductant-P soluble and occluded-P was observed. The P use efficiency was higher at lower doses of applied P with the maximum value (21.3%) recorded with SSP @ 30 kg P_2O_5 ha^{-1} +FYM treatment. Application of 60 kg P2O5 ha-1 through SSP alone or with FYM was most efficient dose for production of high quality soyabean and forms of P build up followed by 60 kg P_2O_5 ha^{-1} as SSP + RP (1:1) with or without FYM in acid Alfisol of Meghalaya.

Jatav *et al.* (2010) revealed significant variation in different fractions of phosphorus and potassium and soil chemical properties in a field experiments conducted during 2004-05 to 2006-07 at central potato research institute's farm on brown soils in mid hills of Shimla. Fractionation studies revealed significant increase in saloid-P, Al-P, Ca-P and various forms of K under integrated use of inorganic fertilizers and FYM.

In acid soils of Meghalaya, Laxminarayana, (2011) reported that Fe-P was the major P fraction contributing to the available P pool as extracted by different extraction methods as well as P nutrition of rice.

Tiwari *et al*. (2012) studied different fractions of P under three cropping systems. In rice based cropping system values of Fe-P was the lowest, while Al-P was low in okra based cropping and Ca-P is low in pea based cropping cropping pattern. Available P was relatively higher in potato based cropping patterns.

Lungmuana *et al*. (2012) observed the dominance of reductant soluble phosphate and iron phosphate and less amount of saloid bound phosphate and calcium phosphate in red and laterite zone of West Bengal were observed.

2.1.2 Potassium fraction

Singh *et al*. (2000) examined the impact of integrated use of FYM and fertilizer nitrogen in soybean-wheat cropping system on soil potassium status. The application of fertilizer nitrogen and FYM increased the potassium uptake by the crop. A declining trend in small quantity was noted in non-exchangeable potassium on application of FYM and fertilizer nitrogen.

Thippeswamy *et al.* (2000) studied the influence of different doses of K applied at various growth stages of rice. They observed that water-soluble K, available K, 1N HNO_3 extracted and 0.1N HNO_3 extracted K increased with increase in potassium doses up to 80 kg K_2O ha. but decreased with growth stages of crops from tillering to harvest. Split application of K i.e. half as basal, one fourth at tilling and one fourth at panicle initiation also influenced different K fractions in soil.

Benipal *et al*. (2001) studied Alluvial soils of Punjab for fractional distribution of potassium and reported that water soluble K, available K, exchangeable K and non-exchangeable K were high in Southwestern zone as compared to other zones. However, all forms of K were found to decrease in absence of K fertilizer or manure.

Pannu *et al*. (2001) reported that long-term application of organic materials (exept green manure) on different K fractions in two soils under rice-wheat cropping system improved all the K fraction over unammended control.

Sharma and Sharma (2001) summarized that water soluble, exchangeable, available, non-exchangeable and 1N HNO_3 extractable K ranged from 11.5 to 65.0, 26 to 265, 45 to 310, 705 to 1762 and 775 to 2000 ppm while studying different forms of K in potato growing soils of Punjab. The different forms of K except water soluble K were significantly correlated with sand.

Singh *et al.* (2001) studied the distribution of different forms of potassium in eight soil profiles of Firozabad district of U.P. and revealed that total, lattice, HCl soluble, fixed, exchangeable and water soluble K in different soil profiles ranged from 0.75 to 2.12 per cent, 0.29 to 1.34 per cent, 3125 to 6050 mg kg^{-1}, 1150 to 1900 mg kg^{-1}, 39 to 100 mg kg^{-1} and 6 to 25 mg kg^{-1} respectively. Water soluble and exchangeable K was maximum in surface horizons and in general decreases with depth. Total, lattice, HCl soluble and fixed K were found to be increased with depth.

Contribution of water soluble, exchangeable, available, non-exchangeable and lattice K was 0.04, 1.39, 1.43, 3.95 and 94.61 per cent towards total soil K in Inceptisols of West coast of Maharastra as reported by Kaskar *et al*. (2001)

Pannu *et al.* (2002) conducted an experiment to know the effect of long term application of organic materials on different K fractions in soil under rice-wheat cropping system in an Alfisol and reported that incorporation of organic materials to the soil improved the exchangeable K fraction over unamended control.

In Meghalaya, a field experiment was conducted to evaluate the effect of potassium levels and FYM on yield and uptake of nutrient by sweet potato and different forms of K in an acid Alfisol of Meghalaya. Available K (sum of water soluble and exchangeable K) increased significantly. The interaction between K and FYM was also significant. The buildup in available K with FYM application was also noticed in *an* acid Alfisol. (Majumdar *et al*., 2002)

Srinivasan *et al.* (2002) conducted an experiment to know the effect of different organic fertilizers on different forms of K. It was found that non-exchangeable K was significantly the lowest in the lower depth and release of non-exchangeable K for crop uptake was the highest in (control) and NPK and it was minimum in organic sources added plots.

Panwar *et al*. (2002) studied the distribution of different forms of K in twenty surface soil samples in the village Kumawanton-ka-gudan of Udaipur (Rajsthan) and reported that the water soluble K, exchangeable K, HNO_3-K, Morgan K, reserve K and total K of these soils ranged from 4 to 16.8, 30 to 200, 320 to 2080, 19 to 55, 265 to 2020 and 644 to 4166 mg kg^{-1} respectively. The per cent potassium saturation varied from 0.4 to 2.8 with a mean value of 1.1 indicating that most of the soils in this area are poorly saturated with ion. Exchangeable K had high correlation with K saturation per cent, Morgan K and organic carbon where as water soluble K was found to have negative correlation with organic carbon and pH of soils. HNO_3 extractable K had high correlation with total K and reserve K and also with soil properties like CEC, silt and clay.

Mythili and Natarajan (2003) conducted an experiment at Tamil Nadu Agriculture University, Coimbatore and found that uptake and available potassium content increased significantly with the application of green manure along with improvement in soil fertility.

Kaur and Benipal (2006) conducted an experiment at Punjab Agriculture University Research farm to study the effect of crop residue and FYM on potassium forms. Rice straw contains higher amounts of available and water soluble potassium where as FYM contains considerable amount of all the forms of potassium. The soils showed increase in available potassium status.

Joshi (2006) reported that under long-term fertilizer management in Vertisol .The all P and K fractions were higher in chemical fertilizer or with FYM.

Singh *et al*. (2006) investigated forms of potassium and their relationship with physical and chemical properties of soils belonging to thermic and hyper thermic thermal regimes in state of Manipur. The water soluble, exchangeable, available, $HN0_3$ acid soluble and fixed potassium in the thermic and hyper thermic regimes constituted 0.05, 1.00, 1.05, 3.97 and 2.72% and 0.07, 1.62, 1.69, 2.69 and 3.24%, respectively of the total potassium fraction.

Yaduvanshi and Swarup (2006) studied the effect of NPK fertilizers alone and in combination with green manuring (*Sesbania aculeata*) or FYM on K balance and release properties in rice-wheat cropping sequence on Aquic Natrustalfs. It was observed that in plots receiving fertilizer K, the contribution of non-exchangeable K to plant uptake was lower as compared to without K fertilization. The results suggested that sub-soil layers being also stressed for K and continuous mining of soil reserve K may affect crop yields adversely in long-term.

Sood *et al.* (2008) conducted an experiment in CSK H.P. Agriculture University Palampur (Himachal Pradesh) to study different forms of potassium. Continuous application of chemical fertilizers and amendments improved the entire potassium fraction in soil over control.

Patra *et al*. (2008) conducted an incubation study on potassium fixation and availability in six rice soils of West Bengal with varying levels of added K. Maximum per cent K fixation was observed at 15 mg kg^{-1} of added K in all the soils, the more so in *Entisols* than in I*nceptisols* and *Alfisol*. Fertilizer K requirement per unit increase in available K in soil was relatively higher in *Entisols* and *Inceptisols* (1.15 to 1.19) than in *Alfisol* (1.06).

Yadav *et al*. (2009) studied the forms of potassium, their distribution and relationship with soil properties in four soil profiles representing eastern plain of Rajasthan. The mean value of water soluble, exchangeable, available, non-exchangeable, nitric acid soluble, lattice and total potassium were 10.29, 242.22, 254.58, 1464.87, 1707.28, 1927.76 and 3634.84 mg kg^{-1} of soil, respectively.

Jatav *et al*. (2010) performed fractionation studies and revealed significant increase in saloid-P, Al-P, Ca-P and various forms of K under integrated use of inorganic fertilizers and FYM.

Athokpam *et al*. (2010) studied the forms of potassium and their relationship with physico-chemical properties of acidic soils in Manipur State. A highly significant correlation was observed with pH, EC, CEC, organic carbon, available N and clay, negatively correlated with sand. Nitric acid extractable K varied from 250.0 to 562.5 mg kg^{-1} and it was 2.9 and 2.9% of lattice K and total K, respectively.

Gurumurthy and Prakasha (2011) conducted a field experiment in soils of Navile, Shivamogga in Karnataka. Among the five different land use system studied, the soils under silvi-system and current fallow land use systems recorded higher potassium fixation capacity than the soils under cultivated land use systems.

2.1.3. Depth- wise distribution of different form of soil potassium.

Although a major portion of K is absorbed by crop plants from the surface soil, subsoil contribution to K nutrition is often substantial. The amount of K taken up from lower soil horizons depends on K concentration in soil and rooting characteristics of plant. Part of the plant nutrients applied on surface soil may leach down and accumulate in sub soil horizons that are often exploited by deep rooted crops in a crop rotation. (Srinivasarao *et al.*, 2001)

In a long-term field experiment conducted since 1972 over a period of 26 years in a medium black calcareous soil drastically reduced the soil available as well as reserved K status. Skipping of K in control and 100 percent NP treatment resulted the highest depletion of 38.2 per cent and 36.7 per cent, respectively. Non-exchangeable K showed a declining trend and was least in 100 percent NP treatment (Santhy *et al*., 2003). Similar results were obtained by Singh *et al*., (2002) where continuous cropping of fifteen years depleted available K in soil from initial level of 77.5 mg kg^{-1} to 38.60 mg kg^{-1}.

Arora and Chahal (2003) reported available K content varied from 41.5 to 314.0 mg kg^{-1} in the surface and 32.0 to 243.0 mg kg^{-1} in the subsurface soils with an average value of 76.0 mg kg^{-1} in the sandy loam soils of Punjab. The available K content was positively and significantly correlated with silt, clay and CEC while negatively and significantly correlated with sand content.

Dhaliwal *et al*. (2004) studied distribution of different forms of potassium in major benchmark series under rice-wheat cropping system in Punjab and found that available potassium contents decreased with increasing soil depth in all the soil series.

Bachkaiya (2005) conducted an experiment in Vertisol to asses depth wise distribution of different forms of K. The amount of all fractions was higher in surface layer (0-15 cm) than that in sub-surface layer (15-30cm) .The order of dominance of different forms of potassium in the soil were non-exchangeable K > exchangeable K > Available K > water soluble K. Similar results were also reported by Sahu(2006) and Baghel (2007).

Yaduvanshi and Swarup (2006) studied the effect of NPK fertilizers alone and in combination with green manuring (Sesbania aculeata) or farmyard manure (FYM) on potassium (K) balance and release properties in rice-wheat cropping sequence on

Aquic Natrustalfs under long- term fertilizer experiment. It was observed that in plots receiving fertilizer K, the contribution of non-exchangeable K to plant uptake was lower as compared to without K fertilization (control, 100% N and 100% NP). The results suggest that sub-soil layers are also stressed for K and the continuous mining of soil reserve K may affect crop yields adversely in long-term.

Sen and Ghosh (2011) Reported that the fertilization increased cumulative crop yield and potassium uptake in Alfisol followed by Inceptisol and Vertisol. The quantity of water soluble, exchangeable, non exchangeable K decreased during the crop growing cycle both in the fertilized and unfertilized treatments in all the soils. Exchangeable K in the Inceptisol and non exchangeable K in the Vertisol decreased more significantly in the fertilized plots as compared to control. Thus intensive cropping without K fertilization will lead to all forms of potassium depletion and subsequent degradation of clay and silt minerals that may constraint profitable crop production in the post green revolution era.

Jatav and Devangan (2012) studied the potassium status of Inceptisol of Baloda block at Janjgir district of Chhattisgarh State. Significant and positive correlations were observed among different soil K fraction. The order of dominance of different forms of soil potassium was non-exchangeable K > exchangeable K > available K > water-soluble K. Potassium fixation study reveals that K fixation decreased beyond 20 ppm K addition level in the soil under study.

Ajiboye and Ogunwale (2013) evaluated the potassium status of soils developed over talc overburden in a southern Guinea savanna of Nigeria was evaluated using exchangeable, acid extractable, total and residual potassium values in particle-size fractions. Exchangeable K, acid-extractable K, total K and residual K were determined in these fractions. Reserved K values were similar to those of mobile

K, but lower than total and residual K, whereas exchangeable K showed the lowest values. Total K was >25 cmol kg^{-1} in all the profiles; reserved K ranged from 9.26 to 24.45 cmol kg^{-1} and mobile K ranged from 5.12 to 29.57 cmol kg^{-1}.

2.1.4. Depth-wise distribution of different form of soil phosphorus.

Saleque *et al*. (2004) reported that long-term effects of rice (Oryza sativa L.) cultivation with varying nutrient management on soil P fraction are important to understand from soil nutrition. The P fractionation study was conducted over the treatments and soil depth. The depletion of $NaHCO_3$–P and NaOH-Pi at the 0 to 15 cm depth under control and T_2 (one-third of recommended fertilizer doses) suggests that the rice plant depends upon these fractions of P. The P depletion profile in wetland rice appears to be confined within the first 15 cm depth. The mean P uptake by rice showed a polynomial relationship with $NaHCO_3$–P and NaOH-Pi (average of 0–15 cm) and it was linearly correlated with acid P (0–15 cm).

Maximum build up in soil P fractions were observed with the application of 150 per cent chemical fertilizer followed by 100 per cent fertilizer application alone or with FYM .It was noted that the integration of chemical fertilizer with BGA and green manure resulted in a higher build up of all soil P fractions. The buildup of P fraction can be attributed to its lower uptake both by rice and wheat crops than its application that resulted in its accumulation as phosphorus is an immobile element and therefore is not likely to be lost by leaching. This trend of P build up as a result of long term INM practice has also been reported by Rokima and Prasad, (1991) and Sihag *et al*. (2005).

Majumdar *et al*. (2007) reported that among inorganic fractions, significantly increase in saloid-P, Al-P, Fe-P and Ca-P but depletion in reductant-P soluble and occluded-P was observed. The P use efficiency was higher at lower doses of applied P with the maximum value (21.3%) recorded with SSP @ 30 kg P_2O_5 ha^{-1} +FYM treatment. Application of 60 kg P_2O_5 ha^{-1} through SSP alone or with FYM was most efficient dose for production of high quality soybean and forms of P build up followed by 60 kg P_2O_5 ha^{-1} as SSP + RP (1:1) with or without FYM in acid Alfisol of Meghalaya.

Barancikova *et al. (*2007) reported that soil phosphorus (P) can exist in various inorganic (Pi) and organic forms (Po). Specific determination of Pi can be obtained by fractionation methods. In this paper, the determination of various phosphorus forms (available P, total P, Pi and Po fractions) in arable and mountain soils is presented. Besides, the detailed characterization of P compounds in humic acids (HA) is also shown. The results obtained show that the highest content of the available P can be found in arable soils with a high input of fertilizers, and that the predominant part of Pi is included in hardly soluble fractions, mainly in the soil types with neutral soil reaction. Our data also show the correlation between total P and Po, the dominant form of P in the topsoil of mountain soils.

Thakur *et al.* (2010) The results of the continuous use of N alone or NP had deleterious effect on long term fertility and sustainability. The availability N and P content decreased in the soil depth, whereas available K decreased up to half meter and then gradually increased.

Trivedi, *et al*. (2010) revealed that the Olsen-P, Al-P, Fe-P, Red-P and Total-P decreased with increase in the depth of soil. Similar findings were also reported by Tiwari, *et al*. (2012).

2.2 Effect of fertilization (both organic and inorganic) on soil physico-chemical properties.

2.2.1 Soil pH

Pothare, *et al*. (2007) reported that all the soil properties such as pH were favorably influenced with the conjuctive use of organics and inorganics. Highest values were observed in the treatment of 100% NPK + 10 t FYM ha^{-1}. In general among all the treatments 100% NPK+FYM showed better result and control gave poorest results. Similar results were reported by Agrawal, *et al*. (2010).

Rajeswar *et al.* (2009) reported that all the pedons were neutral (7.4) to moderately alkaline (8.7) in reaction (pH) in soils of Garikapadu of Krishna (A.P.). Lower pH values were recorded in the surface as compared to subsurface horizons.

2.2.2 Electrical conductivity

Pothare, *et al*. (2007) reported that all the soil properties such as EC were favorably influenced with the conjuctive use of organics and inorganics. Highest values were observed in the treatment of 100% NPK + 10 t FYM ha^{-1}. Similar results were finding in Agrawal, *et al*. (2010).

Rajeswar *et al.* (2009) reported that the EC values varied from 0.10 to 0.32 dSm^{-1} in the soils of Garikapadu, Krishna (A.P.).

Jatav (2010), Vaishnav (2010) and Shukla (2011) observed that the Electrical conductivity of soil water suspension are less than $1dSm^{-1}$ of *Inceptisol* of Baloda block, *Inceptisol, Alfisol* and *Vertisol* of Pamgarh block in Janjgir-Champa district (C.G.) and *Vertisols of* Dhamtari(C.G.).

2.2.3 Organic Carbon

Pothare, *et al*. (2007) reported that all the soil properties such as organic carbon were favorably influenced with the conjunctive use of organic and inorganics. Highest values were observed in the treatment of 100% NPK + 10 t FYM ha^{-1}. Similar results were finding in Agrawal *et al*. 2010.

Jatav (2010) reported that the variation in organic C content in sampled soils was from 0.23 to 0.83 with the mean value 0.44 % of *Inceptisol* group of Baloda block of Janjgir-Champa district of Chhattisgarh. Vaishnav (2010) observed that the organic carbon content of *Vertisols* of Dhamtari block of Dhamtari district of Chhattisgarh varied from 0.15 to 0.91 per cent.

Shukla (2011) found that the variation in organic carbon of the soils varied from 0.09 to 1.1 percent (mean-0.57%), samples representing the *Inceptisol, Alfisol* and *Vertisol* of Pamgarh block in Janjgir-Champa district (C.G.).

2.2.4 Available Nitrogen, Phosphorus and Potassium

Gupta (2000) reported the available N, P, and K status in soil also improved with the individual application of fertilizer nutrients but still higher build-up of available N, P, and K was noted in FYM/Compost treated plots.

Usman (2000) reported the effects of organic sources alone on the growth of rice plant and its growth parameters were not significant due to their slow supply of nutrients. These growth parameters were improved when supplemented with mineral fertilizers at the rate of 100-75-60 kg N, P_2O_5 and K_2O ha^{-1} along with organic materials.

Pothare, *et al*. (2007) reported that all the soil properties such as available NPK were favorably influenced with the conjuctive use of organics and inorganics. Highest values were observed in the treatment of 100% NPK + 10 t FYM ha^{-1}. Similar results were finding to Agrawal, *et al*., 2010.

2.2.5 Bulk density

Bharambe *et al.* (2002) revealed that crop residue incorporation considerably improved the soil properties such as decreased bulk density in soybean-sorghum sequence.

Selvi *et al*. (2005) reported that bulk density decreased significantly in NPK fertilizer along with organics (1.30 Mg m^{-3}) but did not vary significantly with NPK. Similar results were reported by Seeba and Kumaraswamy (2001).

Bajpai *et al*. (2006) analysed the soil after twelve years of long term manuring and fertilizer under a rice-wheat cropping system at Raipur (C.G.). Use of only fertilizers increased the bulk density, which might be due to deterioration of soil by inorganic fertilizer.

Hati *et al.*,(2007) The results showed that the bulk density was reduced significantly with the 100% NPK + FYM treatment over all other treatments.

Bandyopadhyay *et al.* (2010) reported that the results indicated that conjunctive use of recommended dose of fertilizer and farmyard manure (NPK + FYM) resulted in significant decrease of bulk density.

2.2.6 Partical density

Laghate *et al.* (1990) investigated different forms of potassium in two typical salt affected soil of Gujarat and found that the available potassium was only 0.8- 3.4 per cent of the total potassium. The sand contributed most of potassium to the soil followed by silt and clay. The mica increased while K-feldspar decreased with decrease in particle size.

Ram *et al*. (2010) revealed that the particle density of these soils varied from 2.36 to 2.64 Mg m^{-3}. It slightly decreased in horizons just below the upper layer then increased with depth in all the profiles which could be attributed to decreased organic matter content in flood prone soils of eastern plains of Rajsthan.

Shivanna *et al*. (2012) studied the potassium forms like water soluble-K, exchangeable-K, non-exchangeable-K, lattice-K and total-K were measured in some hilly zone paddy soils of Shivamogga district of Karnataka. Correlation coefficients were calculated. Results show that maximum amount of K content in soils is in the non-exchangeable form. The variation in the distribution of potassium depends upon the mineral present, particle size and degree of weathering.

2.2.7 Infiltration rate

More (1994) on sodic vertisol under rice-wheat rotation observed that application of FYM; organic waste and manures decreased soil pH but increased the infiltration rate.

Bellaki and Badanner (1997) found that the improvement in infiltration rate of Vertisol in 50% RDF + 50% N applied either through green manure or FYM in Sorghum-Safflower crop rotation over 10 year under dry land condition. Sesbania GM and Mungbean residue incorporation resulted in reduction of bulk density and increase in soil aggregation which in turn increased the infiltration rate and percolation rate in rice-wheat cropping system (Mandal *et al*., 1999).

Marathe amd Bharambe (2005) noted that application of recommended dose of fertilizer had higher infiltration rate (1.27 cm hr^{-1}) and cumulative infiltration (108 mm) over control (0.80 cm hr^{-1} and 63 mm).

Bajpai *et al*. (2006) observed that integrated nutrient management in rice wheat system had markedly influence on infiltration rate. However, the infiltration rate was significantly higher (1.30 cm hr^{-1}) in 100% recommended NPK through fertilizer in rice and wheat, over the control plot (0.85 cm hr^{-1}).

2.2.8 Soil Texture

Rao *et al.* (2002) studied the distribution pattern of different forms of K in pulse growing regions of Alfisol. They reported that exchangeable K showed significantly positive correlation with clay content in Bangalore.

Athokpam *et al*. (2010) reported that a highly significant correlation was observed with pH, EC, CEC, organic carbon, available N and clay, negatively correlated with sand. Nitric acid extractable K varied from 250.0 to 562.5 mg kg^{-1} and it was 2.9 and 2.9% of lattice K and total K, respectively.

2.3 The percentage distribution of different form of P and K under various depths.

2.3.1 Percentage distribution of different forms of K

Das *et al*. (2000) reported that the distribution of different forms of potassium in some typical soil profiles occurring on various land forms under red and laterite ecosystem of West Bengal. The content of water soluble, exchangeable, HNO_3 extractable, non-exchangeable and total-P varied from 0.004 to 0.047, 0.11 to 0.5%, 0.18 to 0.98, 0.03 to 2.78 and 1.92 to 90.8 Cmol/kg^{-1}, respectively. The surface soils contained the less amount of all forms of K than subsurface soils except water soluble. Significant positive correlations were observed amongst different forms.

Contribution of water soluble, exchangeable, available, non- exchangeable and lattice K was 0.04, 1.39, 1.43, 3.95 and 94.61 per cent towards total soil K in Inceptisols of West coast of Maharashtra as reported by Kaskar *et al.*,(2001).

Singh *et al.* (2001) studies the distribution of different forms of potassium in eight soil profiles of Firozabad district of U.P. and revealed that total, lattice, HCl soluble, fixed, exchangeable and water soluble K in different soil profiles ranged from 0.75 to 2.12 per cent, 0.29 to 1.34 per cent, 3125 to 6050 mg kg^{-1}, 1150 to 1900 mg kg^{-1}, 39 to 100 mg kg^{-1} and 6 to 25 mg kg^{-1} respectively. Water soluble and exchangeable K was maximum in surface horizons and in general decreased with depth. Total, lattice, HCl soluble and fixed K were found to be increased with depth.

Singh *et al*. (2006) investigated different forms of potassium in soils belonging to thermic and hyperthermic thermal regimes in state of Manipur. The water soluble, available and exchangeable potassium ranged 0.05 to 0.07 per cent, 1.05 to 1.69 per cent and 1.00 to 1.62 per cent of total potassium fraction, respectively.

Babar *et al*. (2007) reported that fourteen profile from five districts of Central and Eastern Vidarbha region of Maharastra were studied for the potassium fraction distribution and their interrelationship between forms of potassium. The available, water soluble, exchangeable, non-exchangeable and lattice K contributed 1.97, 0.12, 1.88, 11.25 and 86.76 per cent towards total K. The increase in available K significantly correlated with exchangeable K (r = 0.9964**) in Central Vidarbha where as total and lattice K was highly significant and positively correlated with each other in Vidarbha (r = 0.9954**) and Eastern Vidarbha (r = 0.9946**).

2.3.2 Percentage distribution of different foms of P

Sharma and Tripathi (1992) studied phosphorus fractions of surface layer of some acid hill soils of north-west India and revealed that these soils were fairly rich in total P reserve (average 493 ppm). The average contribution of four fraction (S-P: Al-P, Fe-P, Ca-P and Reductant-P) was 0.8, 5.9, 15.6, 5.8 and 21.5 per cent, respectively.

Patgiri and Datta (1993) studied the forms and distribution of phosphorus in some tea growing acid soils and reported that the total P content varied from 810 to 1162 ppm. The contribution of different fractions towards inorganic P was as follows. Al-P (49.5%) > Fe-P (35.9%) > RS-P (7.9%) > Ca-P (6.6%).

Materials and Methods

CHAPTER-III

MATERIALS AND METHODS

The present study entitled **"Effect of organic and inorganic fertilization on depth wise distribution of different forms of phosphorus and potassium in *Vertisol*"** under rice crop. It was carried out during *Kharif* season of the year, 2012-2013. The details of experiment, prevailing weather conditions, material used and techniques adopted during the course of investigation are briefly presented in this chapter.

3.1 Experiment Site

A field experiment was conducted on Vertisol of Instractional Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidhyalaya, Raipur, Chhattisgarh.

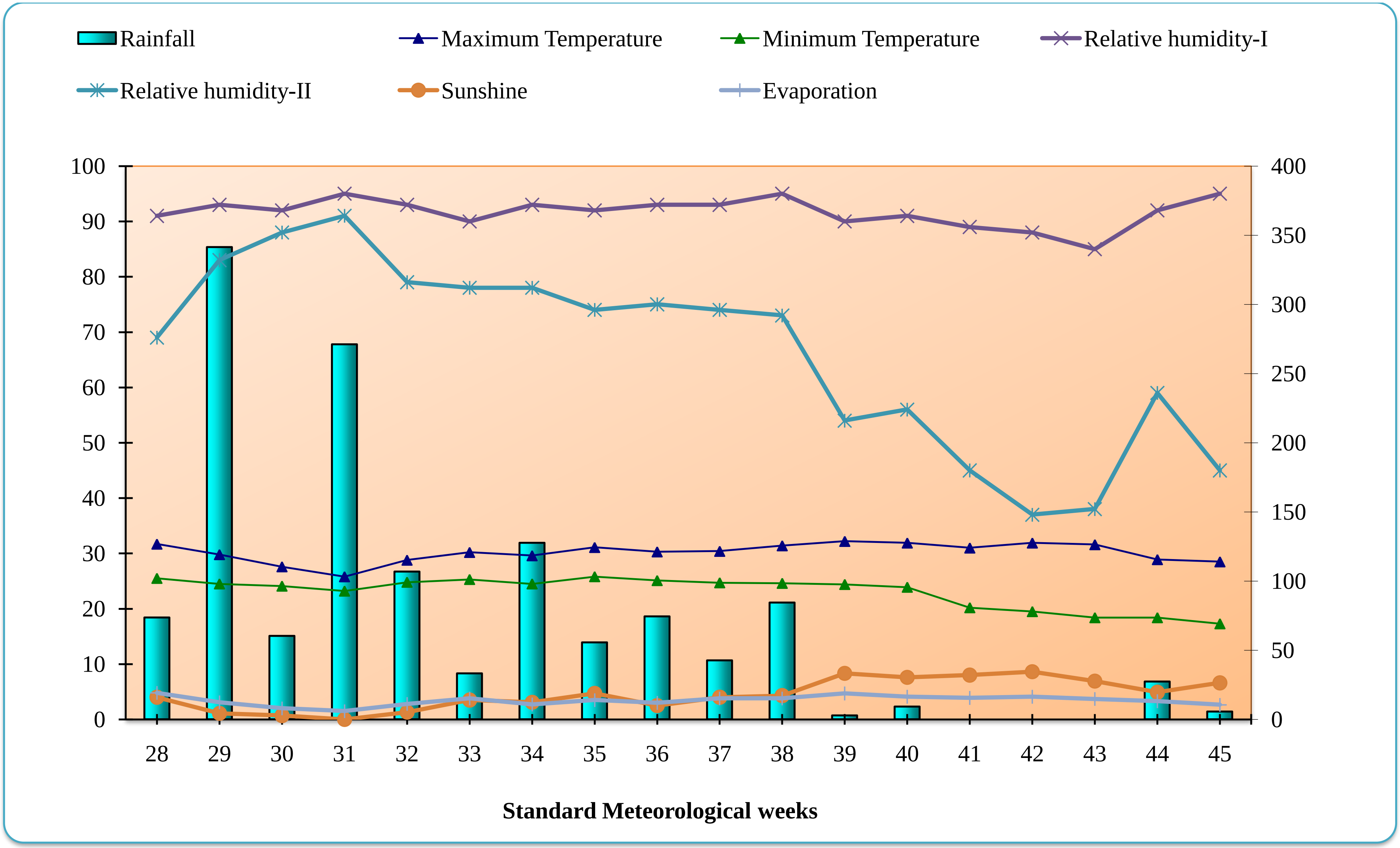
3.2 Geographical situation

Raipur is situated at 21^0 4 North Latitude and 81^0 4 East Longitude with the altitude of 293 meter above mean sea level.

3.3 Climate and weather conditions

The region comes under sub-humid climate .The average annual rainfall of the area is 1317.77 mm. Major amount of precipitation occurs between June and September (about 3-4 months) which is the main rice growing seasons. Weekly temperature (Maximum and Minimum), open pan evaporation and rainfall of 2012-2013 were recorded from the meteorological observatory of Agrometerology Department, I.G.K.V. Raipur.

Fig. 3.1:Weekly Meteorological data during crop growth period (from 11 July, 2012 to November 20, 2012)



3.4 Soil Characteristics

The experimental soil (Vertisol) is fine montmorillonite, hyperthermic, udic chromustert, locally called as *Kanhar* and is identified as Arang II series. It is usually deep, heavy clayey (50 %), dark brown to black in colour and neutral to alkaline in reaction due to presence of lime concentrations. The soil was analyzed for its initial characteristics as per the methods mentioned below and some important physico-chemical properties of the soil are given in Table 3.1

Table 3.1: Some important initial physico-chemical properties of the soil under study.

S.NO.	Properties	Value
1.	pH	7.7
2.	EC (dSm^{-1})	0.20
3.	organic carbon ($g\ kg^{-1}$)	6.10
4.	Available Nitrogen ($kg\ ha^{-1}$)	236
5.	Available Phosphorus ($kg\ ha^{-1}$)	16.0
6.	Available Potassium ($kg\ ha^{-1}$)	474
7.	Bulk density ($Mg\ m^{-3}$)	1.37
8.	Infiltration rate ($cm\ hr^{-1}$)	0.5
9.	Soil Texture (%)	
	Sand	20
	Silt	30
	Clay	50
10.	Texture class	Clay

3.5 Experimental details and Layout

Location	**:**	**Instractional Farm, I.G.K.V. Raipur (C.G.)**
Season	**:**	***Kharif-2012***
Crop	**:**	**Rice**
Plot Size	**:**	**20m x10m**
Spacing	**:**	**Row x Plant (20cm x 10 cm)**
Replication	**:**	**Four**
Design	**:**	**Split plot design**

Main plot:

TREATMENTS

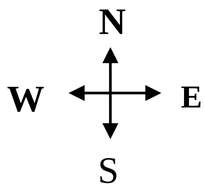
Treatments	Fertilizer application
T_1	Control
T_2	50% of the recommended optimum NPK fertilizer schedule (50:30:20::N:P_2O_5:K_2O)
T_3	100% of the recommended optimum NPK dose (100:60:40::N:P_2O_5:K_2O)
T_4	150% of the recommended optimum NPK dose (150:90:60::N:P_2O_5:K_2O)
T_5	100% of recommended optimum NPK + $ZnSO_4$ @10kg /ha in *Rabi crops* only (100:60:40::N:P_2O_5:K_2O +$ZnSO_4$)
T_6	100% N and P of recommended N dose of fertilizer (100:60:0::N:P_2O_5:K_2O)
T_7	100% N of recommended optimum N dose (100:0:0::N: P_2O_5:K_2O)
T_8	100%NPK + FYM (5 t /ha in *kharif crop* only)
T_9	50% NPK +BGA (10 Kg/ha dry culture in *kharif* crop only)
T_{10}	50% NPK+GM (Sown in site cut and mixed in soil in *kharif* season only)

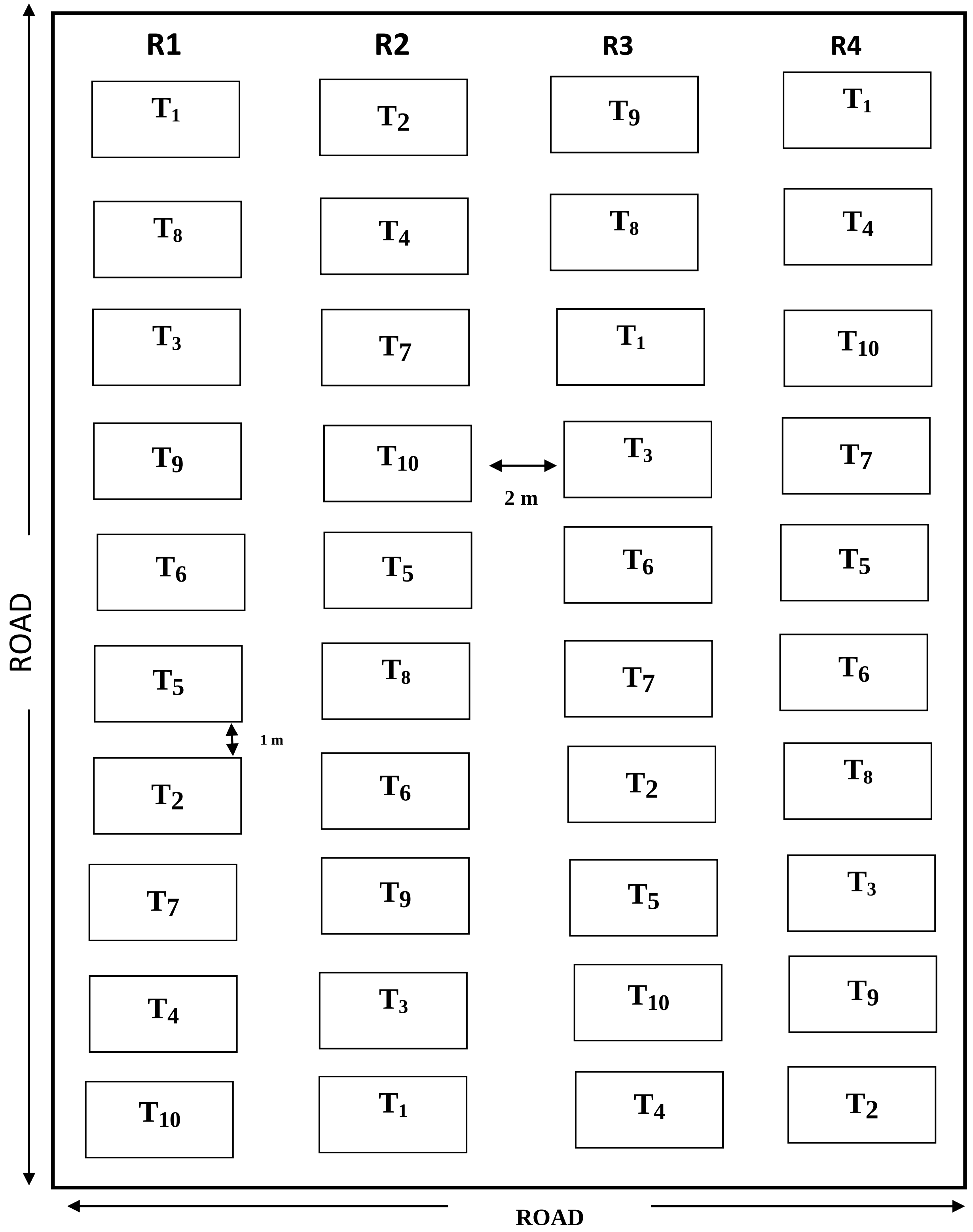
Sub plot: Soil depth- D1: 0-15 cm

D2: 15-30 cm

D3: 30-60 cm

Lay out plan for Experimental Field





3.6 Soil Analysis

Soil samples were collected from each plot at three soil depths (0-15 cm, 15-30 cm and 30-60 cm) from the experimental field. Soil samples from each plot at three soil depths were also collected for split plot design except P fraction for which sample were pooled on one sample due constraint of flexibility. Initial soil samples pooled (four replications) was prepared for site characterization. For analysis of P fractions under different treatments replicated soil samples were mixed and only one sample was prepared. Similarly total K was also analyzed. Average data is shown in results parts. The following standard methods were used for analysis of the soil sample.

3.6.1 Soil pH

Soil pH was determined by glass electrode pH meter in 1:2.5 soil water suspensions as described by Piper (1967).

3.6.2 Electrical Conductivity

The soil sample used for pH determination was allowed to settle down for 24 hours. The electrical conductivity of the supernatant liquid was determined by conductivity meter as described by Black (1965).

3.6.3 Organic carbon

Organic carbon was determined by Walkley and Black's rapid titration method (1934) as determined by Black (1965).

3.6.4 Available N

The available nitrogen in soil was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1965).

3.6.5 Available P

Soil available phosphorus was determined by using 0.5M $NaHCO_3$ (pH 8.5) solution (Olsen extractant) as suggested by Olsen *et al.* (1965).

3.6.6 Available K

Soil available potassium was extracted by shaking with neutral normal ammonium acetate for 5 minute (Hanway and Heidel, 1952) and potassium in the extract was estimated by flame photometer.

3.6.7 Bulk density

Bulk density was determined by removing natural undisturbed core sample from soil depth 0-15 cm, 15-30cm and 30-60 cm by core sampler. The samples were oven dried at 105^0C to a constant weight. Bulk density was calculated by the following formula.

$$\text{Bulk density (Mg m}^{-3}\text{)} = \frac{\text{Wt. of oven dry soil in 0.08 m ring (Mg)}}{\text{Volume of 0.08 m ring (m}^3\text{)}}$$

3.6.8 Particle density

Particle density of a soil sample is calculated from two measured quantities namely mass of the soil solid and its volume. As pycnometer is used to determine the particle density, the method is known as "Pycnometer method". Particle density was calculated by the following formula.

$$\text{Particle density (Mg m}^{-3}\text{)} = \frac{\text{Mass of soil solid (Mg)}}{\text{Volume of solids (m}^3\text{)}}$$

3.6.9 Infiltration rate

Double ring infiltrometer method used for Infiltration rate.

3.6.10 Soil Texture

Soil Texture of the soil was done by International pipette method as described by Piper (1967).

3.6.11 Scheme of Phosphorus fractionation

This method was described by Chang and Jackson (1957) modified by Peterson and Corey (1966).

Saloid bound phosphorus

Extraction by ammonium chloride (NH_4Cl): 25 mL of 1N NH_4Cl was added to 50 ml centrifuge tube containing 0.5 gram soil and shaken for 30 minutes to remove easily soluble loosely bound P which is referred to as Saloid bound P. The suspension was then centrifuged at 2000 rpm for 10 minutes followed by decantation.

Estimation of P: 5 mL aliquot was taken from the supernatant solution and transferred into 25 mL volumetric flask. To this 4mL reagent B (this was prepared fresh for each estimation) was added and the volume was made to 25 mL. After allowing standing for 30 minutes the color intensity was measured by a Spectrophotometer.

Aluminium Phosphate

Extraction by ammonium fluoride (NH_4F): 25 mL of 0.5 N NH_4F was added to the soil saved in the centrifuge tube after the extraction of Saloid–bound P and was shaken for 1 hour followed by centrifuging at 2000 rpm for 10 minutes and decantation. P was estimated in the supernatant solution after decolorizing with charcoal.

Estimation of P: 5 mL aliquot was taken from the supernatant solution and transferred into 25 mL volumetric flask and 4 ml of 0.8 M Boric acid was added to eliminate the interference of fluoride ions (Jackson, 1958). To this 4 mL reagent B (this was prepared fresh for each estimation) was added and the volume was made to 25 mL. After allowing standing for 30 minutes the color intensity was measured by Spectrophotometer.

Iron phosphate

Extraction by NaOH: Soil samples saved after extraction of Al-P was washed twice with 25 mL of saturated NaCl followed by centrifuging at 2000 rpm for 5 minutes and decantation. After this 25 mL of 0.1 N NaOH was added and the solution was shaken for 17 hours. The suspension was then centrifuged for 15 minutes at 2400 rpm followed by decantation. P was estimated in the supernatant solution after decolorizing with charcoal.

Estimation of P: 5 mL aliquot was taken from the supernatant solution and transferred into 25 mL volumetric flask and 0.5 mL of 5 N H_2SO_4 was added. The flask was shaken gently till the effervescences ceased to evolve. This was followed by addition of 4 mL reagent B. and the volume was made to 25 mL. After allowing standing for 30 minutes the color intensity was measured by a Spectrophotometer.

Reductant phosphorus

Extraction by Citrate Dithionite: Soil in the centrifuge tube was washed twice with 25 mL of satured NaCl solution and then suspended in 25 mL of trisodium citrate to which 0.5 g of solid sodium dithionite was added. After shaking the tube for 5 minutes, the suspension in the centrifuge was heated on a water bath at 75-80^{0}C for 15 minutes with continuous stirring by a glass rod and then the loss in volume was made up to25 mL by distilled water. Shaking for 5 minutes followed this and then it was centrifuged at 2000 rpm for 10 minutes followed by decantation. Citrate dithionite was oxidized by $KMnO_4$ before estimation of P.

Estimation of P: 5 mL of aliquot was transferred in a separating funnel and 4 mL of 0.25 M $KMnO_4$ was added and allowed to stand for 2 minutes. After this 5 mL of molybdate -sulphuric acid solution. The funnel was then shaken 25 times by turning upside down to thoroughly disperse the alcohol through the aqueous phase. After the two phases separate, the aqueous phase was discarded and 4 mL of reagent B was added to the suspension. The funnel was shaken for 1 minutes and the aqueous layer was discarded. The blue color alcohol was transferred into a 25 mL volumetric flask by thoroughly washing the funnel with ethyl alcohol and the volume was made to 25 mL with ethyl alcohol. The solution was allowed to stand for 10 minutes and the color intensity was measured by a colorimeter.

Calcium phosphate

Extraction by Sulphuric acid (H_2SO_4): Soil saved in the centrifuged was washed twice with saturated NaCl as described earlier and 25 mL of 0.5 N H_2SO_4 was added and shaken for 1 hour. This was followed by centrifuging at 2000 rpm for 10 minutes and decantation.

Estimation of P: 5 mL aliquot was taken from the supernatant solution and transferred into 25 mL volumetric flask. To this 4 mL reagent B was added and the volume was made to 25mL.After allowing standing for 10 minutes the color intensity was measured by a Spectrophotometer.

Total P

Extraction by Perchloric acid ($HClO_4$): 2g of soil + 30 mL of 60% $HClO_4$ in a 250mL volumetric flask. Digest the mixture at a temperature a few degree below the boiling point on a hot plate in a hood until the dark color due to organic matter disappears.

Then continue heating at the boiling temperature 20 min longer. At this stage, heavy white fumes as $HClO_4$ appear, and the insoluble material becomes like white sand. The total digestion with usually requires about 40 minutes and cool the mixture. Add distilled water to obtain a volume of 250 mL, and mix the contents.

Estimation of P: Pipette an aliquot that contains 5 mL of the solution into a 50 mL volumetric flask. Add 10 mL of the vanadomolybdate reagent, and dilute the solution to 50 mL with distilled water. After allowing standing for 30 minutes the color intensity was measured by a Spectrophotometer.

3.6.12 Scheme of Potassium fractionation

Available K

Soil potassium was extracted by shaking with neutral normal ammonium acetate for 5 minutes (Hanway and Heidel, 1952) and potassium in the extract was estimated by flame photometer.

Exchangeable K

This was determined by centrifugation and decantation procedure as described by Black (1965).Ten gram of soil sample was placed in 50 mL centrifuge tube and 25 mL ammonium acetate was added. Thereafter the content was shaken for 10 minutes. The supernatant was decanted into 100 mL volumetric flask. Three additional extractions were made in the same manner. These combined extracts were diluted to 100 mL with ammonium acetate, the solution was mixed thoroughly and potassium was determined by flame photometer.

Water-soluble K

Water soluble potassium was estimated in 1:5 soil water suspensions after shaking it for 1 hour and K was estimated in the filtrate by flame photometer (Black, 1965).

Non-exchangeable K

Two gram of soil was placed in digestion tube and 20 mL of 1 N HNO_3 was added. The content was boiled for 10 minutes and suspensions were then filtrated through Whatman filter paper No. 1 and potassium was estimated in the filtrate by flame photometer (Black, 1965).

Total K

Place a 0.1 g soil sample of finely ground soil in a 30 mL Pt Crucible, add few drops of water, and 5 mL of HF and 0.5 mL of $HClO_4$. With organic soils, add 3 mL of HNO_3 and 1 mL of $HClO_4$ to the crucible. Heat the soil-acid mixture on a hot plate until fumes of $HClO_4$ appear cool the crucible .Heat the crucible to 200 to 225^0C, and evaporate the contents to dryness. Remove the crucible, and when it is cool, add 5 mL of 6N HCl and about 5 mL of water. When the residue completely dissolves in HCl, transfer the sample to a 100 mL volumetric flask, and dilute the contents and measure to flame photometer.

3.7 Statistical analysis

The experiment was laid out in a split plot design (SPD). The data obtained from the various characters under study were analyzed by the method of analysis of variance as described by Gomez and Gomez (1984). The critical difference (CD) at 5 per cent was calculated where difference among the treatment were found significant in "F" test, otherwise only standard error of mean was calculated. Analysis of variance (ANOVA) table was prepared in the following way each character.

1. Standard error of mean SEm±
    a. Comparison of two main plot = $\sqrt{EaMS/r \times s}$
    b. Comparison of two subplot = $\sqrt{EbMS/r \times m}$
    c. Comparison of two sub plot at same level of main plot = $\frac{\sqrt{EbMS}}{r}$

d. Comparison of two main plot at same or different level of sub plot = $\sqrt{EaMS + (s-1)EbMS/r \times s}$

In order to compute the mean value of treatments, standard error and critical values were calculated as follow:

Table 3.2: The skeleton of ANOVA

Source of variance	D.F.	Sum of squares	Mean sum of squares	F cal	F tab
Replication	r-1				
Main plot(m)	m-1				
Error (a)	(r - 1) (m-1)				
Sub plot (s)	(s-1)				
m×s	(m-1)(s-1)				
Error(b)	m(r-1)(s-1)				
Total	rms-1				

2. Standard error of difference SEd

a. Comparison of two main plot = $\sqrt{2EaMS/r \times s}$

b. Comparison of two subplot = $\sqrt{2EbMS/r \times m}$

c. Comparison of two sub plot at same level of main plot = $\frac{\sqrt{EbMS}}{r}$

d. Comparison of two main plot at same or different level of sub plot = $\sqrt{2EaMS + (s-1)EbMS/r \times s}$

3. Critical difference (CD)

$$\text{CD} = SE\ (d) \times t\ value(5\%)\ at\ error\ (edf)$$

Results and Discussion

CHAPTER - IV

RESULTS AND DISCUSSION

This chapter deals with the findings of the fractionation study conducted to investigate the changes in soil P and K fractions in Vertisol under rice crop.

Evaluation of phosphorus & potassium status of soils is necessary to make sound fertilizer recommendations for optimizing the productivity of field crops. Soil P and K fractions gives an idea about the soil phosphorus and potassium supplying capacity to plants. Under Submerged rice it is necessary to evaluate the effect of different nutrient management practices on depth-wise distribution of soil P and K fraction.

4.1 Depth-wise distribution of different form of soil phosphorus and potassium in Vertisol under different fertilization practices.

4.1.1. Status of different forms of soil K in Vertisol.

The status of different K fractions were studied water soluble, available, exchangeable and non-exchangeable K at three soil depths. The potassium fractions were found in the order of non-exchangeable, exchangeable, available and water soluble K. The levels of different K fractions with respect to soil depth indicated that all K fractions were higher in surface layer as compared to sub surface layer. However, available K status in three soil depths was almost same. Non-exchangeable K values were more than double of the exchangeable K fraction.

The transport of routinely applied fertilizer which dissolves completely or partially in the soil solution, through the soil profile is significant process for plant uptake of nutrients and their leaching from the soil profile. Major parameters that influence transport of potassium are soil solution, exchangeable, non-exchangeable and mineral lattice potassium.

Table 4.1:Effect of organic and inorganic fertilization and soil depth on water soluble K(kgha^{-1}).

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	16.43^{a}	13.03^{a}	12.50^{a}	13.99^{a}
50% NPK	21.64^{c}	19.63^{c}	17.18^{c}	19.48^{c}
100% NPK	24.90^{e}	21.05^{cd}	18.53^{cd}	21.49^{d}
150% NPK	26.88^{f}	23.13^{de}	22.32^{ef}	24.11^{e}
100% NPK + Zn	23.19^{d}	21.73^{d}	18.85^{d}	21.25^{d}
100% NP	19.01^{b}	15.81^{b}	13.68^{ab}	16.17^{b}
100% N	18.79^{b}	15.72^{b}	14.89^{b}	16.47^{b}
100% NPK + FYM	25.56^{ef}	23.08^{de}	21.39^{e}	23.34^{e}
50% NPK + BGA	19.89^{b}	16.95^{bc}	16.12^{bc}	17.65^{bc}
50% NPK + GM	21.06^{c}	18.19^{c}	18.14^{cd}	19.13^{c}
D-mean	21.73^{c}	18.83b	17.36^{a}	19.31
CD at 5%	T=1.64	D=0.75	TXD=NS	
SEM	0.56	0.26		

Data presented in Table 4.1 and represented graphically in fig.4.1 showed that the water soluble K differed significantly by application of fertilizer K with respect to three soil depths. Interaction of fertilizer K levels with soil depth (D) was found to be not-significant.

In surface soil the highest value of water soluble K was recorded in 150% NPK (26.88 kg ha^{-1}) followed by 100% NPK+FYM (25.56 kg ha^{-1}) and 100%NPK (24.90 kg ha^{-1}) and lowest value in control (16.43 kg ha^{-1}). Similar trend was found in deeper layer. WS-K significantly increased with increased in fertilizer dose i.e. from control to 150% similarly application of FYM. Also has significant affect of WS-K over 50%, 100% NPK fertilizer doses and was at par with 150% fertilizer dose. Water soluble K (WS-K) ranged from 16.43 to 26.88 kg ha^{-1} in 0-15 cm soil depth, which contributes only 0.05 to 0.09 per cent of total K. Similar results was found by

Mandal *et al*.,(2011) in Inceptisol of Tripura. Soil solution K is the immediate source of potassium used by plants. Levels of soil solution K are generally low unless recent amendments of K have been made to the soil. Levels of solution K are affected by the equilibrium and kinetic reactions that occurs amongst the different forms of soil K, the soil moisture content and the concentration of bivalent cations in the solution and on the exchange phase (Sparks, 2002) . The increasing trend in water-soluble potassium is natural phenomenon due to continuous use of soluble potassium fertilizer as reported by Majumdar *et al*., 2002, Chakravarti (1992) and Bhandarkar (2004).

Surface soils contain more WS-K than subsurface soil which may be due to application of potassic fertilizers. The values of WS-K was highest at 0-15 cm (21.73 kg ha^{-1}) followed by 15-30 cm (18.83 kg ha^{-1}) and 30-60 cm (17.36 kg ha^{-1}) in soil profiles. WS-K significantly decreased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). Dhaliwal *et al*. (2004) estimated that distribution of different forms of potassium in major benchmark series under rice-wheat cropping system and found that water soluble potassium contents decreases with increasing soil depth in all the soil series. Continuous application of chemical fertilizers and amendments improved the entire potassium fraction in soil over control. As reported by Sood *et al*., (2008).

Table 4.2: Effect of organic and inorganic fertilization and soil depth on available K (kg ha^{-1}).

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	455^{a}	425^{a}	400^{a}	427^{a}
50% NPK	561^{e}	523^{c}	498^{c}	527^{d}
100% NPK	567^{ef}	550^{d}	535^{e}	551^{e}
150% NPK	589^{g}	569^{e}	555^{f}	571^{f}
100% NPK + Zn	569^{f}	547^{d}	533^{e}	550^{e}
100% NP	493^{b}	465^{b}	445^{b}	468^{c}
100% N	462^{a}	461^{b}	450^{b}	458^{b}
100% NPK + FYM	589^{g}	569^{e}	556^{f}	572^{f}
50% NPK + BGA	544^{d}	525^{c}	496^{c}	522^{d}
50% NPK + GM	555^{e}	529^{c}	505^{d}	529^{d}
D-mean	538^{c}	516^{b}	497^{a}	517
CD at 5%	T=7.46	D=4.45	TXD=14.08	DXT=4.03
SEM	2.57	1.54	4.97	1.39

Results presented in Table 4.2. and fig.4.2. revealed that in rice crop, available K status influenced significantly with different levels of fertilizer K application with soil depth. Application of higher levels of fertilizer K (150% NPK and 100% NPK+FYM) exhibited significantly higher value (589 kg ha^{-1}) and of available K and lowest value (455 kg ha^{-1}) of available K was recorded under control. Significantly higher available K was observed at surface layers (0-15) than that at subsurface layer (15-30 cm) and (30-60 cm).Treatment (T) and soil depth (D) interaction showed significant effect.

The available K at different depths of soil profile as influenced by imposition of different treatments is given in table 4.2. AV-K significantly increased with increasing dose of fertilizer i.e. from control to 150 % similarly application of FYM.

Highest value was 100% NPK+FYM (572 kg ha^{-1}) however it was at par with 150% NPK (571 kg ha^{-1}). In general values of soil available K were highest in 150% NPK and 100% NPK+FYM (589 kg ha^{-1}), control (455 kg ha^{-1}), Similar results were found by Thakare *et al*., (2010) and Thakur *et al*., (2010). The highest value of available K in 100% NPK+FYM from all soil layer was attributed to better conservation and use efficiency of this nutrient in the presence of organic manures.

AV-K significantly decreased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). The values of available K was highest at 0-15 cm (538 kg ha^{-1}) followed by 15-30 cm (516 kg ha^{-1}) and 30-60 cm (497 kg ha^{-1}). The difference in the values of indicating decreasing trend with increase in soil depth. Available K content among different treatments for the given soil depths were attributed to differences in the soil environment created by the nutrient applied through fertilizer. Based on the result of a long-term fertilizer experiment, Sharma *et al.* (1998) concluded that there could be mining of native reserve of K even under its optimum application rates, and it may affect the productivity of land. The available K gradually decreased in soil up to 60 cm depth. A typical behavior of K distribution within the soil profile, irrespective of the treatments applied was attributed to the movement of K in the profile, from the applied pool, luxury consumption of K by the growing crops as per its availability and the prevailing soil moisture situations of the profiles (Kauraw 1982; Sahu 2004 and Thakur *et al*., 2010).

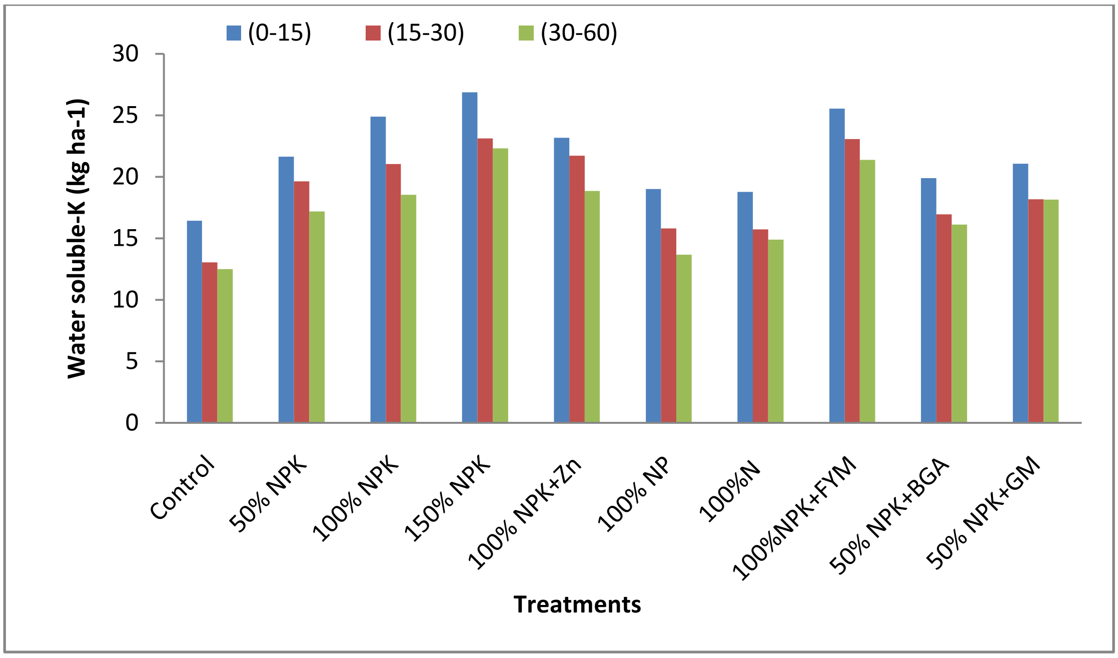


Fig.4.1 Effect of organic and inorganic fertilization on water soluble K (kg ha^{-1}) at three soil depths.

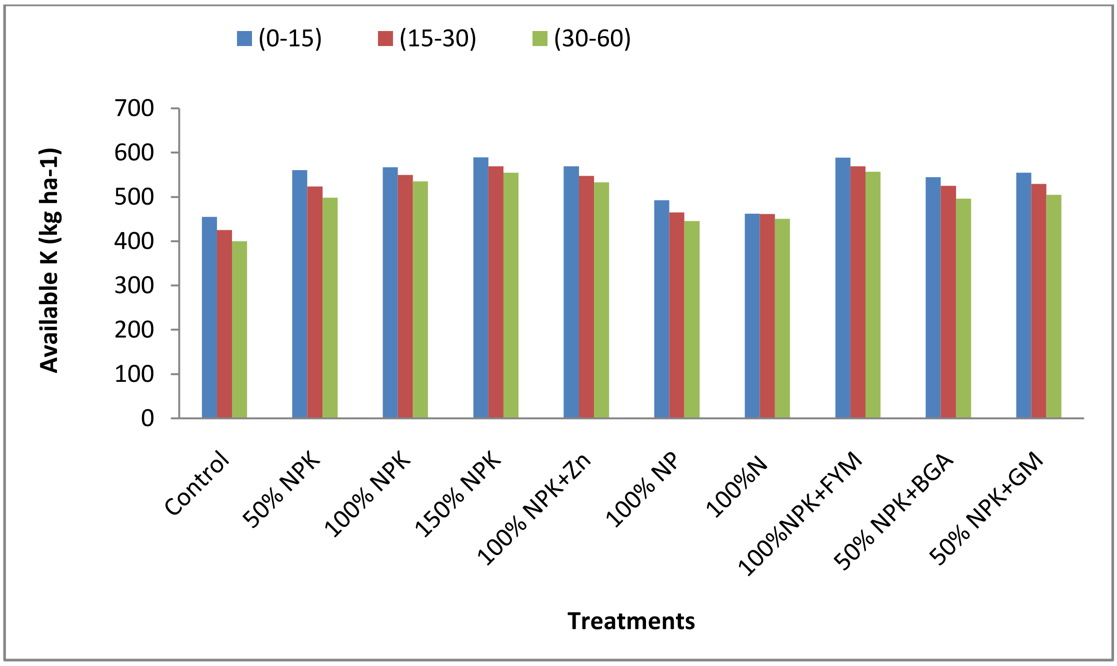


Fig.4.2. Effect of organic and inorganic fertilization on available K (kg ha^{1}) at three soil depths.

Table 4.3: Effect of organic and inorganic fertilization and soil depth on Exchangeable K (kg ha^{-1}).

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	652^{a}	618^{a}	606^{a}	625^{a}
50% NPK	683^{b}	676^{b}	667^{b}	675^{b}
100% NPK	685^{b}	676^{b}	669^{b}	677^{b}
150% NPK	705^{c}	695^{c}	690^{c}	697^{c}
100% NPK + Zn	697^{b}	690^{bc}	685^{c}	691^{c}
100% NP	655^{a}	619^{a}	609^{a}	628^{a}
100% N	662^{a}	607^{a}	603^{a}	624^{a}
100% NPK + FYM	708^{c}	700^{c}	690^{c}	699^{c}
50% NPK + BGA	681^{b}	672^{b}	658^{b}	670^{b}
50% NPK + GM	684^{b}	673^{b}	660^{b}	672^{b}
D-mean	681^{b}	662^{a}	654^{a}	666
CD at 5%	T=19.61	D=12.44	TXD=NS	
SEM	6.76	4.39		

The exchangeable K fraction under different fertilizer K levels and soil depth are presented in table 4.3 and fig.4.3. Significantly higher value of this form was recorded at application of 100%NPK+ FYM. Interaction effect between treatment (T) and soil depth (D) was not- significant.

Ex-K significantly increased with increasing dose of fertilizer i.e from control to 150% similarly application of FYM. The highest value of exchangeable K was recorded in 100% NPK + FYM (708 kg ha^{-1}) followed by 150% NPK (705 kg ha^{-1}) and lowest value in control (652 kg ha^{-1}). Similar trend was recorded in lower surface. Highest value was 100% NPK+FYM (699 kg ha^{-1}) however it was at par with 150% NPK (697 kg ha^{-1}). Ex-K significantly decreased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm).The exchangeable K was higher in surface layer (681 kg ha^{-1}) and low in subsurface (654 kg ha^{-1}). Exchangeable K was found higher in surface soils than subsurface soils which could be attributed due to more intensive weathering. Variation in ex-K was more in surface soil than that of subsurface soil; similar finding was reported by Mandal *et al*., (2011).

Exchangeable K is the portion of the soil K that is electro-statically bound as an outer-sphere complex to the surfaces of clay minerals and humic substances. It is readily exchanged with other cations and also is readily available to plants. It is continuosly replenished by the non-exchangeable fraction and in turn it replenishes the K in soil solution.

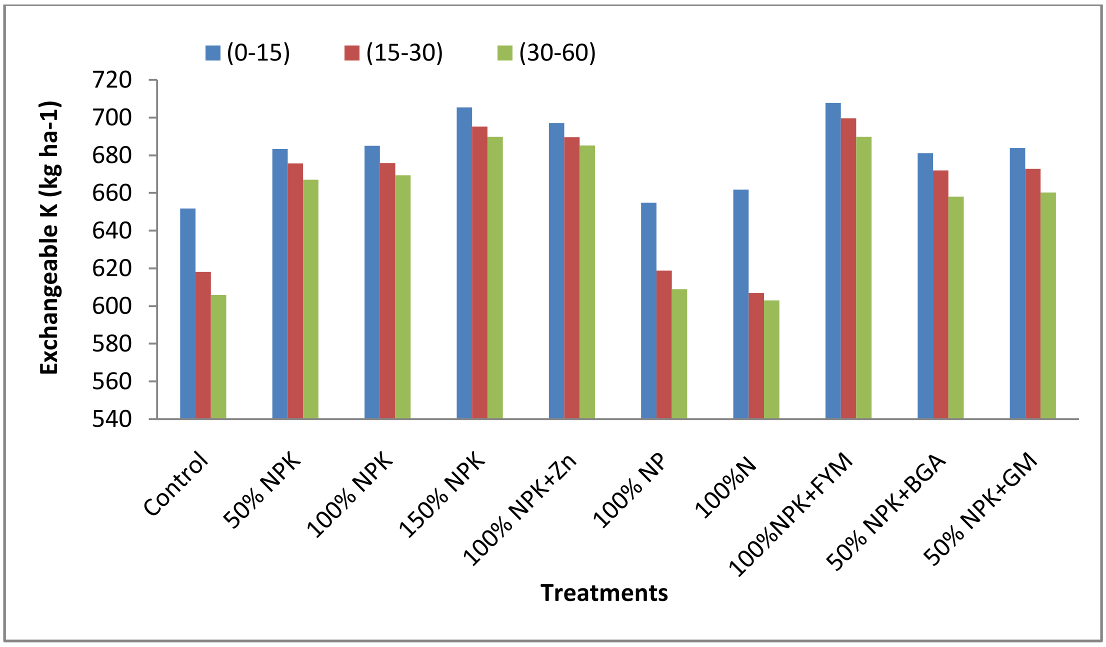


Fig. 4.3. Effect of organic and inorganic fertilization on exchangeable K (kg ha^{-1}) at three soil depths.

Table 4.4: Effect of organic and inorganic fertilization and soil depth on non-exchangeable K (kg ha^{-1}).

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	1520^{a}	1365^{a}	1299^{a}	1395^{a}
50% NPK	2028^{c}	1995^{c}	1722^{b}	1915^{c}
100% NPK	2164^{d}	2069^{d}	1688^{b}	1974^{c}
150% NPK	2278^{d}	2135^{d}	1861^{c}	2091^{d}
100% NPK + Zn	2181^{d}	1920^{c}	1660^{b}	1920^{c}
100% NP	1724^{b}	1580^{b}	1568^{b}	1624^{b}
100% N	1538^{a}	1491^{ab}	1398^{a}	1476^{a}
100% NPK + FYM	2267^{d}	2082^{d}	1773^{c}	2040^{d}
50% NPK + BGA	2048^{c}	1855^{c}	1693^{b}	1865^{c}
50% NPK + GM	2004^{c}	1958^{c}	1705^{b}	1889^{c}
D-mean	1975^{c}	1845^{b}	1637^{a}	1819
CD at 5%	T=164.49	D=78.79	TXD=NS	
SEM	56.69	27.85		

Data given in Table 4.4 and fig. 4.4 indicate that in rice crop, non-exchangeable K significantly affected to due to application of different fertilizer K levels. Non-exchangeable K significantly increased with increasing dose of fertilizer i.e. from control to 150% similarly application of FYM. The higher value was observed in the treatment 150% NPK then followed by 100% NPK + FYM and lowest value in control. However, significantly higher non-exchangeable K fraction was observed at surface layer (0-15 cm) than at sub-surface layer (15-30 cm). Non-exchangeable-K significantly decreased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). Interaction between treatment levels (T) and depth (D) was not-significant.

Non-exchangeable K or fixed K differs from mineral K in that it is not bonded within the crystal structures of soil mineral particles. It is held between adjacent tetrahedral layers of di-octahedral and tri-octahedral micas, vermiculites and intergraded clay minerals. Release of non- exchangeable K to the exchangeable from occurs when levels of exchangeable and soil solution K declined after crop removal and/ or leaching and perhaps by large increase in microbial activity (Sparks 2002).

Table 4.5: Average of Total K (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	29987	28789	28567	29114
50% NPK	30812	30789	30545	30715
100% NPK	30899	30780	30630	30770
150% NPK	31378	30998	30875	31084
100% NPK + Zn	31267	30997	30979	31081
100% NP	29981	28976	28965	29307
100% N	30102	28998	28978	29359
100% NPK + FYM	31398	31345	31199	31314
50% NPK + BGA	30845	30568	30512	30642
50% NPK + GM	30985	30578	30556	30706
D-mean	30765	30282	30181	30409

The total K content in profiles of Vertisol ranged from 28567 to 31398 kg ha^{-1} (Table 4.5 and Fig. 4.5). The highest value of total K recorded under 100% NPK+FYM followed by 150% NPK. The total K increased with increase in K doses up to fertilizers but split application also influenced the different K fractions along with total K. Similar results were found by Thippeswamy *et al.* (2000).

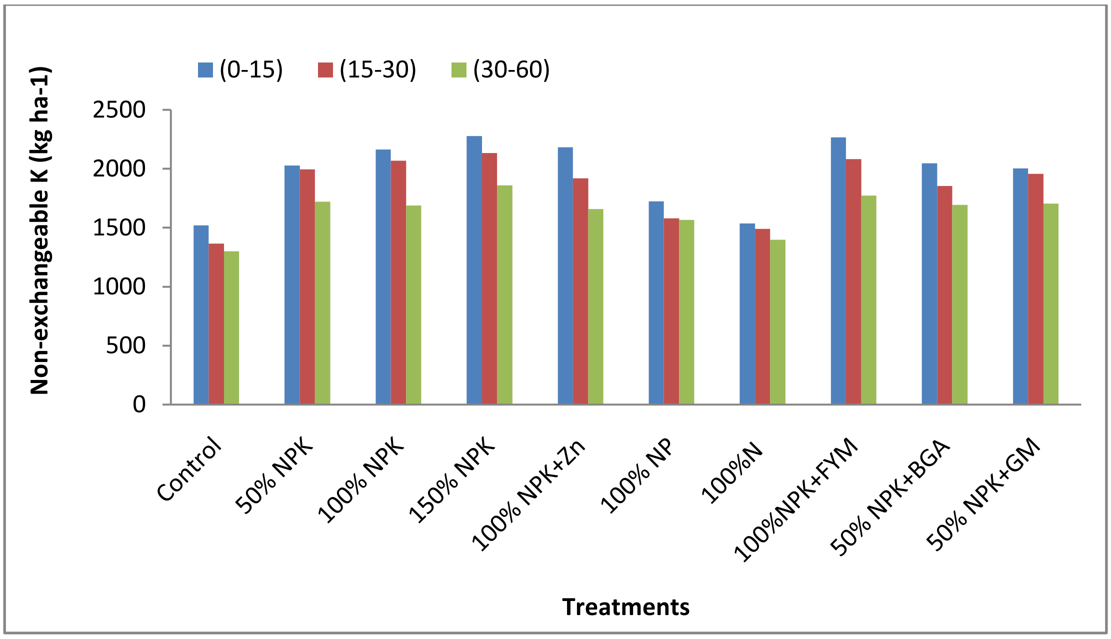


Fig.4.4 Effect of organic and inorganic fertilization on non-exchangeable K (kg ha^{-1}) at three soil depths.

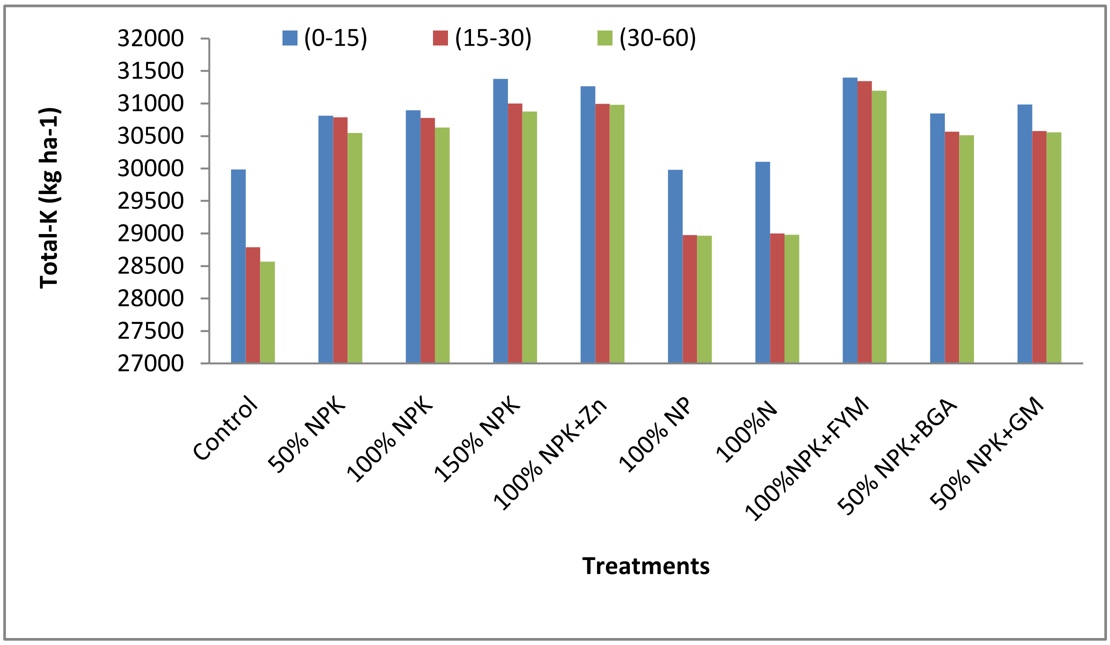


Fig. 4.5 Average of Total K (kg ha^{-1}) under different fertilizer practices at three soil depths.

4.1.2. Status of different forms of soil phosphorus (kg ha^{-1}) in Vertisol.

Phosphorus, like any other plant nutrient is present in soil in two major components i.e. organic and inorganic. Organic P, which is mainly confined to the surface layer, is mineralized into inorganic forms. But the plants mainly depend on inorganic P forms for their P requirements. saloid-P, Al-P, Fe-P and Ca-P fractions are the main source of P supply to the plants. The proportion of forms of phosphorus such as Ca-P, Al-P, Fe-P, Occluded and Organic-P governs the response to applied P (Singh *et al*., 2003)

The amount of P recovered under various fractions varied considerably depending upon the treatments given to rice crop. All P fractions *viz*. saloid-P, Al-P, Fe-P, Red-P and Ca-P increased over control, only when chemical fertilizers were applied at higher levels (100 and 150 per cent) either alone or in combination with organics during the rice crop. The application without P fertilization did not influence soil P fractions, as under 100% N treatment. The continuous addition of organics with chemical fertilizers may stimulate mineralizaion and immobilization of plant nutrients, thereby affecting their amounts in different organic and inorganic forms in soil (Sihag *et al*., 2005).

In general, the integration of inorganic sources with FYM increased Al-P and Fe-P fraction of P whereas application of super imposed dose through over chemicals alone. Further, integration with BGA and GM increase soil-P fraction over control.

Inorganic source (150% NPK) recorded higher saloid-P, Red-P and Ca-P. Interconversions of P fractions, greater accumulation of a particular fraction due to use of different organics, crop preference for a particular P fraction, chelation of Fe-P and Al-P by organic compounds, time period and soil types and its conditions in influenced the relative amount of P fractions in soil as has been reported by different researchers (Jain and Sarkar, 1979; Hedley *et al*., 1982; Mandal and Mandal 1973; Mandal and Chatterjee, 1972; Velayutham *et al*., 1970).

All the P fractions were recorded higher values at 150 per cent chemical fertilizer followed by 100 per cent fertilizer application alone or with FYM. Comparatively higher value of Red-P and Ca-P was recorded in 150% NPK followed by 100% NPK + FYM.

Table 4.6: Average of saloid-P (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	3.48	2.99	2.49	2.99
50% NPK	5.56	4.66	3.91	4.71
100% NPK	7.24	7.06	6.69	7.00
150% NPK	8.98	7.97	7.35	8.10
100% NPK + Zn	6.99	5.69	5.15	5.94
100% NP	7.79	6.89	5.46	6.72
100% N	3.13	2.85	2.36	2.78
100% NPK + FYM	8.88	8.25	7.53	8.22
50% NPK + BGA	5.65	4.95	3.78	4.79
50% NPK + GM	5.84	4.98	3.90	4.91
D-mean	6.35	5.63	4.86	5.62

The data on saloid-P is presented in table 4.6 and figure 4.6. Maximum concentration of saloid-P was recorded in 150% NPK (8.98 kg ha^{-1}) followed by 100% NPK + FYM (8.88 kg ha^{-1}) treatments. The treatment receiving fertilizer N alone (100% N) and control) resulted in the lowest value of saloid-P (3.13 and 3.48 kg ha^{-1}) respectively. The result indicates that as fertilizer dose increased, the status of saloid-P also increased corresponding at three soil depths. Similar results were reported by Singh *et al*., (2010)

Among all the P fractions lowest was saloid-P. Its content in surface samples (0-15 cm) varied from 3.13 to 8.98 kg ha^{-1}, sub surface (15-30 cm) 2.85 to 8.25 kg ha^{-1} and subsurface (30-60 cm) 2.36 to 7.53 kg ha^{-1}. Surface layer showed highest saloid bound phosphorus 6.35 kg ha^{-1} followed by subsurface 5.63 kg ha^{-1} and low amount in deep layer 4.86 kg ha^{-1}. The amount of P recovered in saloid –P, Al-P and Ca-P form was found to increase significantly with the application of inorganic fertililizers and their combined use with organic material over control in soil.

Similar findings were also reported by Rajeswar *et al*., (2009) found that available P decreased gradually from surface to subsurface layer and its content was higher at surface layer.

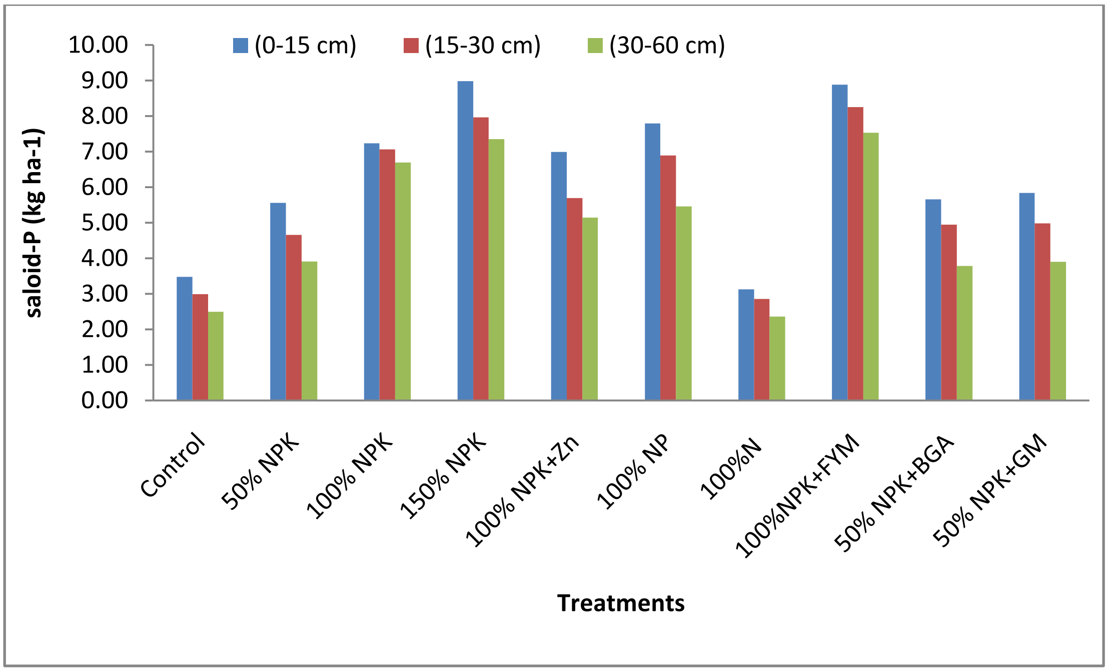


Fig.4.6 Average of saloid-P (kg ha^{-1}) under different fertilization practices at three soil depths.

Table 4.7:Average of Al-P (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	32.79	28.45	23.47	28.24
50% NPK	52.20	43.35	35.48	43.68
100% NPK	57.15	53.09	45.17	51.80
150% NPK	61.36	57.92	53.93	57.74
100% NPK + Zn	54.51	51.84	49.91	52.09
100% NP	55.78	52.45	48.97	52.40
100% N	38.20	27.09	22.04	29.11
100% NPK + FYM	61.63	58.39	54.38	58.13
50% NPK + BGA	49.74	45.86	33.99	43.19
50% NPK + GM	48.58	45.35	36.92	43.62
D-mean	51.20	46.38	40.43	46.00

The data presented in Table 4.7 and depicted in figure 4.7 showed that Al-P was significantly influenced by different fertilization practices. The lowest value was recorded in control and 100% N. The highest value was recorded in 100% NPK+FYM (61.63 kg ha^{-1}) followed by 150% NPK (61.36 kg ha^{-1}). Higher value of Al-P content in FYM treatment as compared to control may be due to the solubilization effect of certain organic acids which are released during the FYM decomposition as reported by Patel *et al*., 1991. The Al-P content in soil changed widely with continuous use of various combinations of inorganic fertilizer. The Al-P concentration ranged from 32.79 to 61.63 kg ha^{-1} in 0-15 cm, 28.45 kg ha^{-1} to 58.39 kg ha^{-1} in 15-30 cm and 23.47 to 54.38 kg ha^{-1} in 30-60 cm soil depths, respectively. It's content declined sharply with soil depth from 51.20 kg ha^{-1} in surface soil to 40.43 kg ha^{-1} present in soil depth of 30-60 cm. These findings corroborate with those of Singh *et al*., 2010, Trivedi *et al*., 2010 and Tiwari *et al*.,(2012).

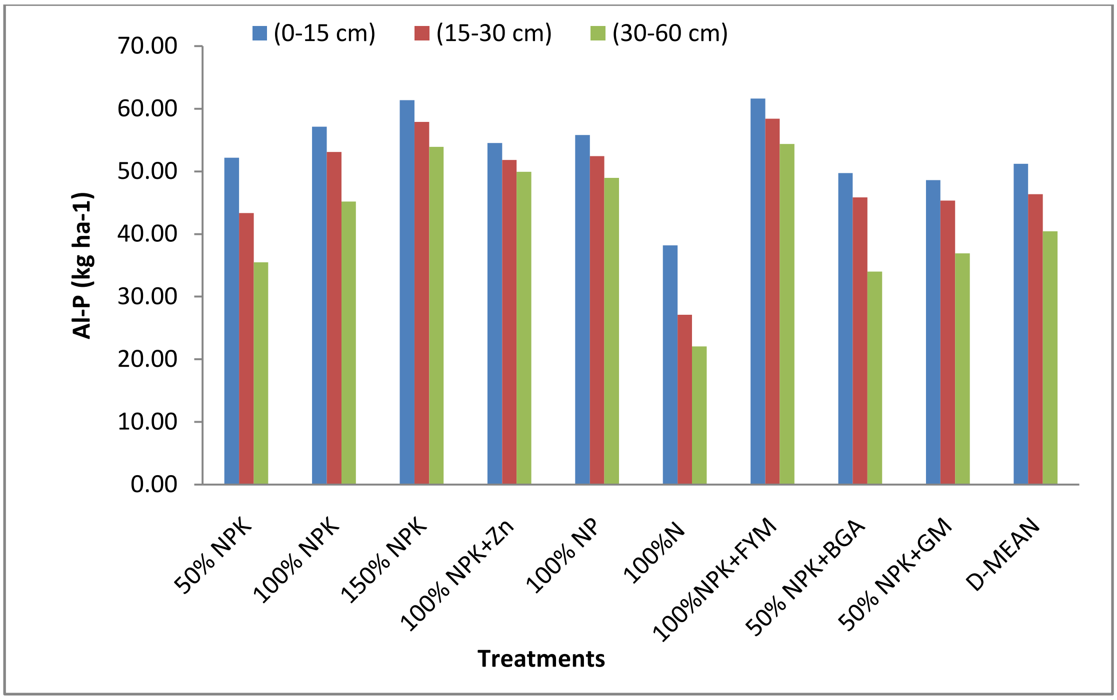


Fig. 4.7 Average of Al-P (kg ha^{-1}) under different fertilization practices at three soil depths.

Table 4.8: Average of Fe-P (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	52.34	47.87	40.69	46.97
50% NPK	67.66	62.92	48.16	59.58
100% NPK	81.57	72.28	56.92	70.26
150% NPK	84.56	78.71	65.49	76.25
100% NPK + Zn	79.15	72.01	60.77	70.64
100% NP	73.68	62.79	57.12	64.53
100% N	55.58	46.87	38.02	46.82
100% NPK + FYM	85.40	80.96	65.38	77.25
50% NPK + BGA	66.89	60.04	45.88	57.60
50% NPK + GM	65.24	58.73	50.37	58.11
D-mean	71.21	64.32	52.88	62.80

The data presented in Table 4.8 and represented graphically in figure 4.8 revealed that each addition of NPK (100% NPK, 150% NPK and 100% NPK+FYM) increased the magnitude of decrease in Fe-P content as compared to control. The Fe-P was found to be highest in the treatment 100% NPK + FYM (85.40 kg ha^{-1}) followed by 150% NPK (84.56 kg ha^{-1}) which were found to be significantly superior to all other treatments. Similar trends found in lower depths.

The results further indicated that Fe-P ranged from 71.21 kg ha^{-1}, 64.32 kg ha^{-1} and 52.88 kg ha^{-1} soil in 0-15 cm, 15-30 cm and 30-60 cm soil depth, respectively. Similar results were reported by Bhakare and Tuwar 2006.

Table 4.9: Average of Red- P (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	90.67	82.41	77.11	83.40
50% NPK	119.45	99.84	87.76	102.35
100% NPK	129.90	112.79	98.47	113.72
150% NPK	134.01	115.97	112.07	120.68
100% NPK + Zn	127.09	116.57	105.34	116.33
100% NP	107.22	106.64	103.55	105.80
100% N	94.33	89.97	79.58	87.96
100% NPK + FYM	132.22	123.05	110.58	121.95
50% NPK + BGA	118.34	92.78	84.65	98.59
50% NPK + GM	121.01	95.98	85.90	100.96
D-mean	117.42	103.60	94.50	105.17

The data presented in Table 4.9 and graphically depicted in figure 4.9 showed that highest value of R-P was recorded in 150% NPK (134.01 kg ha-^{1}) followed by 100% NPK + FYM (132.22 01 kg ha^{-1}) and lowest value in control (90.67 kg ha^{-1}). Similar trends were found in lower depths. Graded dose of NPK fertilizers caused an increase in R-P as compared to control. Higher value of R-P in 100% NPK + FYM and 150% NPK may be attributed to the fact that the integration of chemicals with FYM increased all P fractions over chemicals alone. The values of R-P were lower than of Ca-P but higher than the Al-P and Fe-P. Which may be attributed to the low sesquioxides. These findings followed the results reported by Kolambe (1992), Nale (1996), Bhakare and Tuwar (2006).

Reductant soluble P content in the soil profiles ranged from 117.42 kg ha^{-1} in surface soil and decreases in lower depth103.60 to 94.50 kg ha^{-1}. R-P fairly rich as compared to Al-P and Fe-P. Reductant soluble P was higher in surface horizons and the same decreased down the depth. Similar trend in profile was also reported by Singh and Omanwar (1987), Dongale (1993) and Trivedi *et al*., (2010).

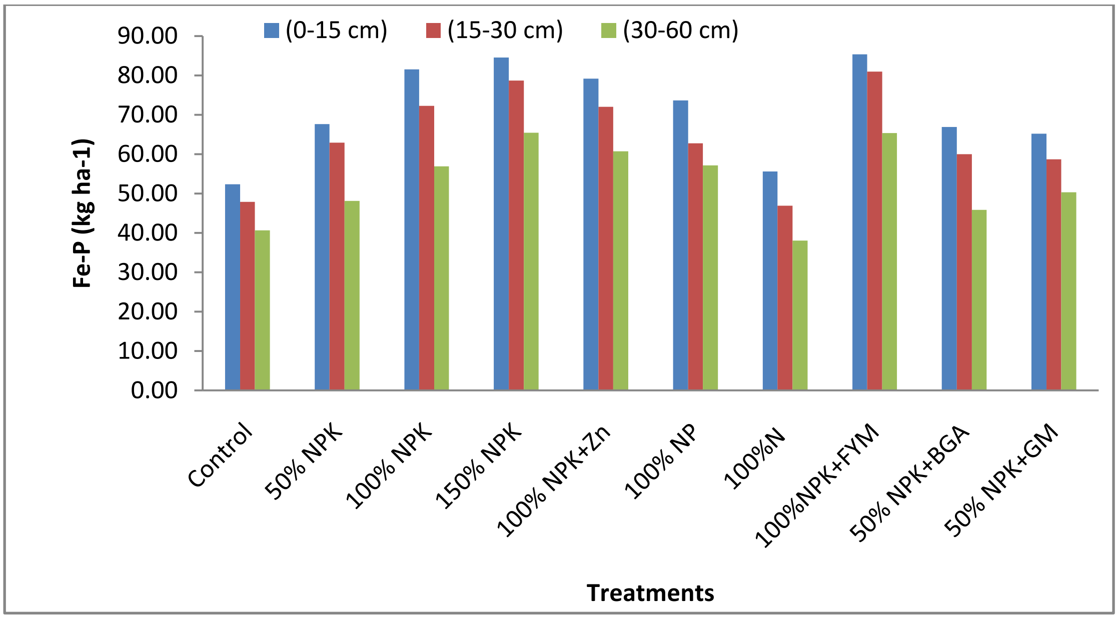


Fig .4.8 Average of Fe-P (kg ha^{-1}) under different fertilization practices at three soil depths.

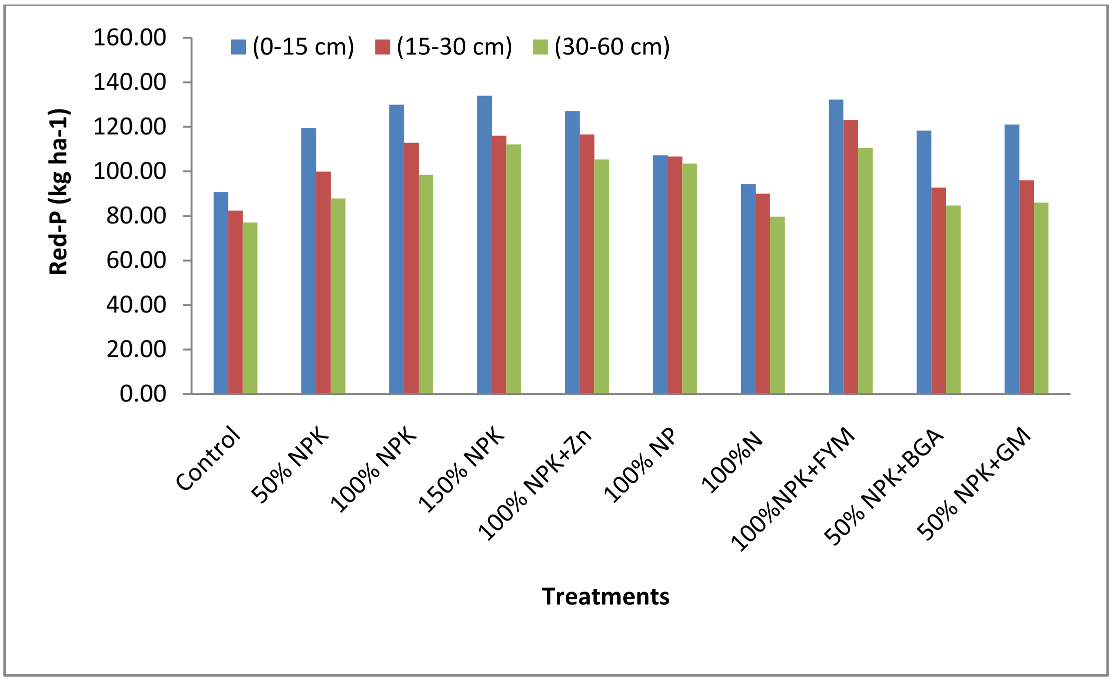


Fig.4.9 Average of Red-P (kg ha^{-1}) under different fertilization practices at three soil depths.

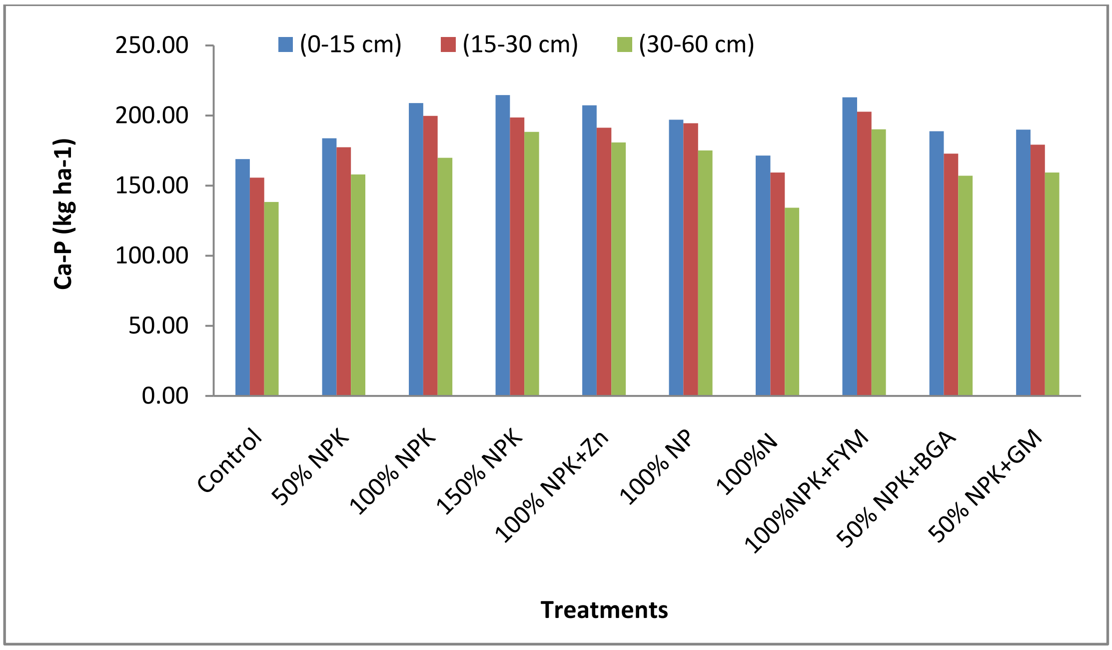


Fig.4.10 Average of Ca-P (kg ha^{-1}) under different fertilization practices at three soil depths.

Table 4.10:Average of Ca-P (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	168.99	155.73	138.38	154.37
50% NPK	183.88	177.43	158.00	173.11
100% NPK	208.87	199.87	169.95	192.90
150% NPK	214.62	198.57	188.24	200.48
100% NPK + Zn	207.32	191.39	180.79	193.17
100% NP	196.98	194.62	175.11	188.91
100% N	171.54	159.41	134.29	155.08
100% NPK + FYM	213.00	202.82	190.27	202.03
50% NPK + BGA	188.77	172.88	156.99	172.88
50% NPK + GM	189.98	179.32	159.44	176.25
D-mean	194.39	183.20	165.15	180.92

Table 4.10 and fig. 4.10 showed that maximum concentration of Ca-P was recorded in 150% NPK (214.62 kg ha^{-1}) followed by 100% NPK + FYM (213.00 kg ha^{-1}) minimum concentration in control (168.99 kg ha^{-1}). On the other hand, plots receiving P application along with N or N and K (50% NPK, 100% NPK, 150% NPK, 100% NPK + Zn, 100% NP, 100% NPK + FYM, 50% NPK + BGA and 50% NPK + GM) recorded substantially higher Ca-P content over control. The results indicates clearly that as the P fertilizer dose increased, the status of Ca-P also increased correspondingly at three soil depths. Similar trends found in lower depths. Calcium-P was found to be the dominant P fraction among various inorganic P forms present in these soil. The Ca-P concentration ranged from 194.39 kg ha^{-1} in 0-15 cm, 183.20 kg ha^{-1} in 15-30 cm to 165.15 kg ha^{-1} in 30-60 cm in soil depth, respectively. The Ca-P declined sharply with soil depth. Successive addition of inorganic P fertilizer tended to improve Ca-P concentration in soil from 154.37 kg ha^{-1} in control to 202.03 kg ha^{-1}

in 100% NPK + FYM. The use of P fertilizer in combination with N and K raised the soil P content in all the fractions; the increase being more at higher rates of P addition. The continuous use of phosphatic fertilizers in cropping system resulted in buildup of phosphate in soil and it got transformed into different inorganic P fractions. Similar results were also reported by Singh *et al*., 2010.

The Ca-P was the major inorganic P fraction in all the treatment plot because calcareous soils are reported to have large amounts of P as Ca-P, irrespective of nature and kind of added fertilizer due to the more stabilized nature of calcium system under high pH (Jaggi 1991). The Ca-P and R-P was dominated in Vertisol.

Combined use of fertilizers with manures influences the form and availability of soil Phosphorus in many ways. The proportion of forms of phosphorus such as Ca-P, Al-P, Fe-P, R-P, organic P governs the response to applied P (Singh *et al*., 2003).

Table 4.11:Average of Available P (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	**Soil depth**			**T-mean**
	(0-15 cm)	**(15-30 cm)**	**(30-60 cm)**	
Control	9.6	7.6	5.9	7.7
50% NPK	20.3	18.5	16.2	18.3
100% NPK	29.0	26.8	23.0	26.3
150% NPK	31.1	28.4	26.8	28.8
100% NPK + Zn	28.7	26.7	23.7	26.4
100% NP	28.0	24.6	25.5	26.0
100% N	8.6	7.9	5.9	7.5
100% NPK + FYM	30.1	29.2	27.5	28.9
50% NPK + BGA	18.7	17.3	16.0	17.3
50% NPK + GM	20.7	18.7	17.7	19.1
D-mean	22.5	20.6	18.8	20.6

CD at 5% T=1.06 D=0.62 TXD=NS

The available phosphorus contents in different soil layers of the profile as influenced by imposition of different treatments are given in table 4.11 and presented graphically fig.4.11. The higher value (22.5 kg ha^{-1}) of soil available P content recorded in surface layer (0-15 cm). It was found that in general, the difference in P content got reduced significantly with increasing soil depth. The P content of surface soil layer ranged between 8.6 to 31.1 kg ha^{-1}. The values of available P declined with increasing soil depth and got reduced to 5.9 to 27.5 kg ha^{-1} at about 60 cm soil depths. It indicates that the P content decreased significantly with increasing soil depth. Similar finding were reported by Thakur *et al*., (2010).

The highest value of available P was recorded in treatment 150% NPK (31.1 kg ha^{-1}) followed by 100% NPK (30.1 kg ha^{-1}). Swarup and Yaduvanshi (2000) found that exclusion of P in the fertilizer schedule had resulted in lowering the available P content in the surface soil. The results also support that increasing levels of fertilizer application had resulted in substaintially enhancing the available P content and so was the case with use of FYM along with balanced dose of fertilizer. They also reported the beneficial effects of organic matter on available P in soils.

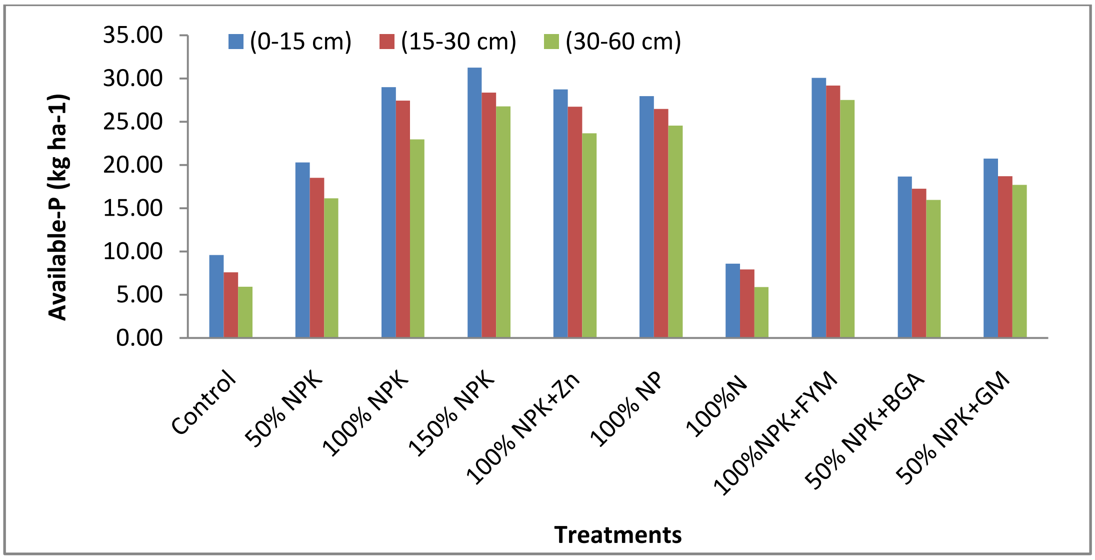


Fig.4.11 Average of available P (kg ha^{-1}) under different fertilization practices at three soil depths.

Table 4.12: Average of Total- P (kg ha^{-1}) under different fertilization practices at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	4998	4695	4321	4671
50% NPK	5231	5111	4659	5000
100% NPK	5679	5565	4897	5380
150% NPK	5789	5468	5342	5533
100% NPK + Zn	5698	5552	5439	5563
100% NP	5399	5389	5231	5340
100% N	4993	4987	4467	4816
100% NPK + FYM	5698	5623	5437	5586
50% NPK + BGA	5378	4998	4643	5006
50% NPK + GM	5322	5121	4656	5033
D-mean	5418.5	5250.9	4909.2	5193

Higher concentration of Total-P was recorded in 150% NPK (5789 kg ha^{-1}) followed by 100% NPK+FYM (5698 kg ha^{-1}) and 100% NPK (5679 kg ha^{-1}) treatments (Table 4.12 and fig. 4.12). Plots, which have received fertilizer N alone (control and 100% N) resulted in the lowest value of total-P as compared to other fertilizer treatments. On the other hand, plots receiving P application along with N or N and K (50% NPK, 100% NPK, 150% NPK, 100% NPK + Zn, 100% NP, 100% NPK+FYM, 50% NPK+BGA and 50% NPK+GM) recorded substantially higher total-P content. The results indicates clearly that as the P fertilizer dose increased, the status of total-P also increased correspondingly to three soil depths. Similar results found were by Dhillon and Dev (1990), Dikshit *et al.,* (1994) and Singh *et al.,* (2010).

The total-P in all the horizons within the soil profiles varied from 4000 to 6000 kg ha^{-1} (Table 4.12). Verisols and associated soils have high content of total P (Tamboli, 1996 and Bhakare et al., 2006). It generally decreased with depth in all the profiles. The decrease in total-P content may be due decrease in organic matter content down the profiles. Similar results were also reported by Viswantha and Doddamani (1991) and Dongale (1993). The highest content of total-P in surface layers may be attributed to continuous addition of manure and fertilizer in this layer. Similar results were found by Trivedi *et al.*,(2010). All the forms of P increased due to application of P fertilizer in sequence cropping, hence the total P content also increased.

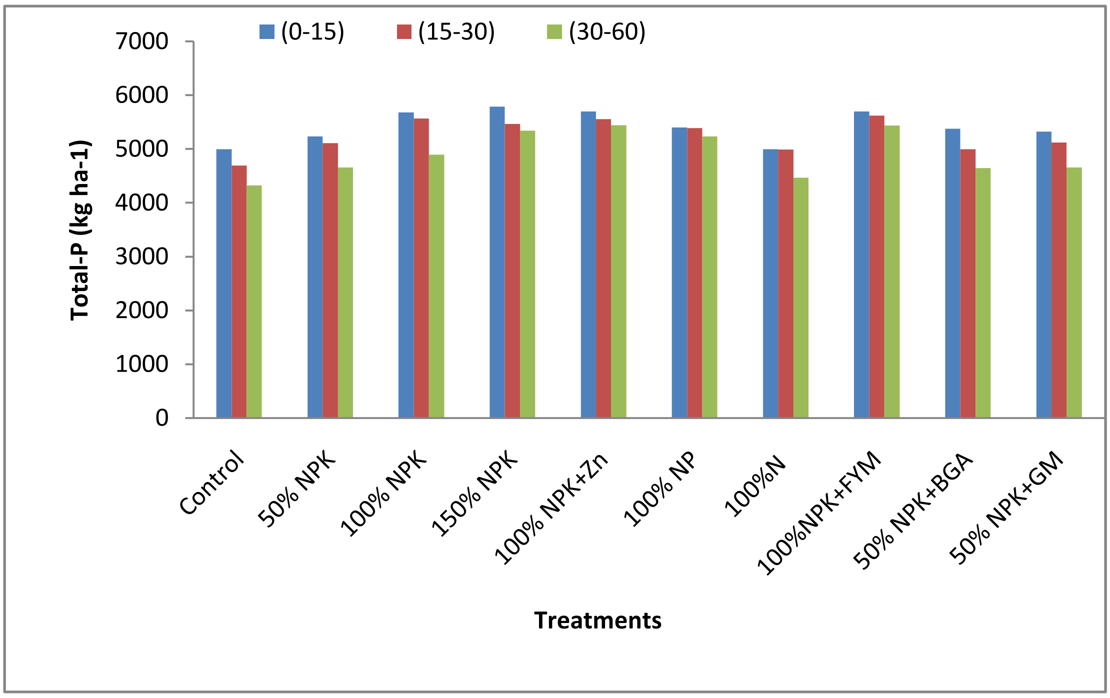


Fig.4.12 Average of Total P (kg ha^{-1}) under different fertilization practices at three soil depths.

4.2 Effect of fertilization (both organic and inorganic) on soil physical properties.

4.2.1 Soil pH

pH was determined in soil sample of different treatments in rice crop in the year 2012 and presented in table 4.13.

The application of different levels of chemical fertilizer supplemented with FYM, BGA and Green manuring in some of the treatments not affected pH significantly.

The basic soil properties of the profile are presented in table 4.13. pH values significantly increased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). The pH value low in surface layer (7.4) and increase in subsurface layer (7.7). The soil pH values (7.3 to 7.8) showed considerable variation with depth at different treatments levels. Similar results were reported by Thakur et al.,(2010). Depth wise variation in soil pH indicate slight increase with the increase in depth. Thakare and Ingle (2010) stated that soil pH depends on the amount of soluble salt present in soil.

Table 4.13: Effect of organic and inorganic fertilization on soil pH at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	7.4^{a}	7.5^{a}	7.8^{a}	7.6^{a}
50% NPK	7.3^{a}	7.4^{a}	7.6^{a}	7.5^{a}
100% NPK	7.4^{a}	7.6^{a}	7.7^{a}	7.6^{a}
150% NPK	7.4^{a}	7.7^{ab}	7.8^{a}	7.6^{a}
100% NPK + Zn	7.5^{a}	7.8^{a}	7.9^{ab}	7.7^{a}
100% NP	7.5^{a}	7.7^{ab}	7.8^{a}	7.7^{a}
100% N	7.3^{a}	7.5^{a}	7.6^{a}	7.4^{a}
100% NPK + FYM	7.5^{a}	7.7^{ab}	7.8^{a}	7.6^{a}
50% NPK + BGA	7.6^{ab}	7.7^{ab}	7.8^{a}	7.7^{a}
50% NPK + GM	7.5^{a}	7.7^{ab}	7.7^{a}	7.6^{a}
D-mean	7.4^{a}	7.6^{b}	7.7^{c}	7.6
CD at 5%	T= NS	D= 0.07	TXD=NS	
SEM	0.09	0.03		

4.2.2 Electrical conductivity (dSm^{-1})

Data presented in table 4.14 showed that the electrical conductivity differed significantly by application of fertilizer with respect to three soil depths. Interaction of electrical conductivity with soil depth was found to be not significant.

Electrical conductivity significantly affected the all treatments. Electrical conductivity increased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). Electrical conductivity (0.17 to 0.26 dSm^{-1}) increased with soil depth, which indicates these soils have high clay content (50%), the dominant clay minerals are of smectite group and also titeniferous magnetite minerals present. The existing clays have the properties of churning within the pedon and the process of churning causes vertical mixing and leads to development of wide and deep cracks, and closely intersecting slickensides. The churning also results in non development of diagnostic horizons. Similar results was found by Thakur *et al*.,(2010).

Table 4.14: Effect of organic and inorganic fertilization on EC (dSm^{-1}) at three soil depths.

Treatment	**Soil depth**			**T-mean**
	(0-15 cm)	**(15-30 cm)**	**(30-60 cm)**	
Control	0.17^{a}	0.20^{b}	0.22^{ab}	0.20^{b}
50% NPK	0.19^{b}	0.21^{b}	0.23^{b}	0.21^{bc}
100% NPK	0.22^{bc}	0.23^{cd}	0.24^{bc}	0.23^{c}
150% NPK	0.21^{bc}	0.22^{c}	0.23^{b}	0.22^{bc}
100% NPK + Zn	0.21^{bc}	0.22^{c}	0.24^{bc}	0.22^{bc}
100% NP	0.20^{b}	0.22^{c}	0.24^{bc}	0.22^{bc}
100% N	0.22^{bc}	0.24^{d}	0.26^{c}	0.24^{c}
100% NPK + FYM	0.19^{b}	0.20^{b}	0.21^{ab}	0.20^{b}
50% NPK + BGA	0.16^{a}	0.18^{a}	0.20^{a}	0.18^{a}
50% NPK + GM	0.19^{b}	0.20^{b}	0.20^{a}	0.20^{b}
D-mean	0.19^{a}	0.21^{b}	0.23^{c}	0.21
CD at 5%	T=0.02	D=0.01	TXD=NS	
SEM	0.009	0.004		

4.2.3 Organic carbon (g kg^{-1})

Data presented in table 4.15 showed that the organic carbon differed significantly by application of fertilizer with respect to three soil depths. Interaction of organic carbon with soil depth was found to be not-significant.

The organic carbon (g kg^{-1}) determined in soil sample in Vertisol under rice crop in the year 2012. Organic carbon significantly increased with increasing dose of fertilizer i.e. from control to 150% similarly application of FYM. The organic carbon was recorded highest 100%NPK+FYM (7.63 g kg^{-1}) followed by 150%NPK (7.48 g kg^{-1}) with non-significant difference between the treatment. The organic carbon content of the soil (5.53 to 7.63 g kg^{-1}) has registered a decreasing trend with increasing soil depth. There results corroborate the findings of Thakur *et at*., (2010). Organic carbon Significantly decreased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). The surface soil 0-15 cm content in 6.80 g kg^{-1}, 15-30 cm content in 6.48 g kg^{-1} and 30-60 cm content in 6.04 g kg^{-1}.

The fertility of soil is intimately linked with its organic matter which has an influence on physical, chemical and biological properties of the soil. It is well known that under continuous agricultural practice with imbalanced fertilization the organic matter content in the top soil will decrease.

Table 4.15: Effect of organic and inorganic fertilization on Organic carbon (g kg^{-1}) at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	5.53^{a}	5.20^{a}	4.93^{a}	5.22^{a}
50% NPK	7.03^{d}	6.35^{d}	5.85^{b}	6.41^{c}
100% NPK	7.23^{e}	6.93^{f}	6.45^{e}	6.87^{d}
150% NPK	7.48^{f}	7.18^{g}	6.78^{f}	7.14^{e}
100% NPK + Zn	6.50^{c}	6.33^{c}	6.03^{c}	6.28^{c}
100% NP	6.58^{c}	6.13^{b}	5.73^{b}	6.14^{b}
100% N	5.70b	5.38^{a}	5.13^{a}	5.40^{a}
100% NPK + FYM	7.63^{fg}	7.43^{h}	6.90^{f}	7.32^{f}
50% NPK + BGA	7.05^{d}	6.70^{e}	6.20^{d}	6.65^{d}
50% NPK + GM	7.28^{ef}	7.23^{g}	6.38^{e}	7.01^{e}
D-mean	6.80^{c}	6.48^{b}	6.04^{a}	6.4
CD at 5%	T=0.26	D=0.10	TXD=NS	
SEM	0.09	0.04		

4.2.4 Available Nitrogen

Data presented in Table 4.16. showed that the available N different significantly by application of fertilizer N with respect to three soil depths. Interaction of available N levels with soil depth (D) was found to be not significant.

Table 4.16: Effect of organic and inorganic fertilization on available nitrogen (kg ha^{-1}) at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	216.56^{a}	187.17^{a}	146.36^{a}	183.36^{a}
50% NPK	256.17^{b}	252.45^{b}	250.72^{b}	253.11^{b}
100% NPK	263.52^{b}	261.45^{b}	259.02^{b}	261.33^{b}
150% NPK	267.61^{b}	265.80^{c}	261.69^{b}	265.03^{b}
100% NPK + Zn	263.05^{b}	260.23^{b}	256.13^{b}	259.80^{b}
100% NP	259.97^{b}	257.95^{b}	255.41^{b}	257.78^{b}
100% N	261.23^{b}	258.14^{b}	254.38^{b}	257.91^{b}
100% NPK + FYM	268.95^{b}	266.32^{c}	264.71^{c}	266.66^{b}
50% NPK + BGA	257.87^{b}	255.86^{b}	253.59^{b}	255.77^{b}
50% NPK + GM	258.96^{b}	256.40^{b}	254.01^{b}	256.46^{b}
D-mean	257.39^{b}	252.17^{a}	245.60^{a}	251.72
CD at 5%	T=13.98	D=8.57	TXD=NS	
SEM	4.82	3.03		

The available N values of different soil layers as influenced by continuous application of different treatments are presented in table 4.16. Available nitrogen significantly decreased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). In general, the nitrogen content recorded from various soil layers were the highest in the surface layer (257.39 kg ha^{-1}) and decreased (245.60 kg ha^{-1}) with increasing soil depth. Thus, the minimum value was recorded from the lowest layer of each treatment. Available nitrogen significantly increased with increasing dose of fertilizer i.e. from control to 150% similarly application of FYM. Further, the highest value in any soil layer was registered in 100% NPK+FYM followed by 150% NPK treatments. A comparison of different treatments (Table 4.16) for the same soil layer indicated that the highest values of available N were found associated with treatments where recommended fertilizer + FYM was applied. Similar results were found in Thakur *et al.,(*2010). The highest available N content was recorded in surface and sub surface layer with application of 100% NPK + FYM as compared to control and then progressively declined with increasing soil depth. Similarly, Nand Ram (1998) mentioned that the original status of organic carbon (available N) was maintained only by integrating NPK fertilizer and FYM.

4.2.5. Available Phosphorus

Data presented in Table 4.17 showed that the rice crop available P different significantly by application of fertilizer P with respect to three soil depths. Interaction of available P levels with soil depth (D) was found to be not-significant.

The available P was significantly increased by the treatments 50% NPK, 100% NPK, 150% NPK, 100% NPK + Zn, 100% NP, 100% NPK + FYM, 50% NPK + BGA and 50% NPK + GM and decrease value in Control and 100% NPK. The available P was recorded highest in 150% NPK (31.1 kg ha^{-1}) followed by 100% NPK + FYM (30.1 kg ha^{-1}) the response of different treatments were significant.

The available phosphorus were found significant in soil depth. The available phosphorus contents in different soil layers of the profile as influenced by imposition of are given in table 4.17. The illustration representing different treatments indicated that, in general, the differences in P content got reduced significantly with increasing soil depth. The P content of surface soil layer ranged between 9.60 to 31.1 kg ha^{-1}. The values of available P declined with increasing soil depth and got reduced to 5.9 to 27.5 kg ha^{-1} at about 60 cm soil depth. It was indicated that the P content decreased significantly with increasing soil depth. Similar results were found in Thakur *et al*.,(2010).

Continuous use of balanced fertilizer is conducive for maintaining the soil available P. The results of the present study also revealed that in surface soil, maximum available P content was present as compared to that at lower depth in all the treatments. It was also observed that successive significant increase had occurred due to increasing levels of fertilizer application in surface soil. Similar results have also been reported by Thakur *et al*.,(2010). These auther found that exclusion of P in the fertilizer schedule had resulted in lowering the available P content in the surface soil. The results also support that increasing levels of fertilizer application had resulted in substantially enhancing the available P content and so was the case with use of FYM along with balanced dose of fertilizer . Swarup and Yaduvanshi (2000), Thakur *et al*.,(2010) have also reported the beneficial effects of organic matter on available P in soils.

Table 4.17: Effect of organic and inorganic fertilization on available phosphorus ($kg\ ha^{-1}$) at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	9.6^{a}	7.6^{a}	5.9^{a}	7.7^{a}
50% NPK	20.3^{c}	18.5^{c}	16.2^{b}	18.3^{b}
100% NPK	29.0^{d}	26.8^{f}	23.0^{d}	26.3^{d}
150% NPK	31.1^{e}	28.4^{g}	26.8^{f}	28.8^{e}
100% NPK + Zn	28.7^{d}	26.7^{e}	23.7^{d}	26.4^{d}
100% NP	28.0^{d}	24.6^{d}	25.5^{e}	26.0^{d}
100% N	8.6^{a}	7.9^{a}	5.9^{a}	7.5^{a}
100% NPK + FYM	30.1^{e}	29.2^{g}	27.5^{f}	28.9^{e}
50% NPK + BGA	18.7^{b}	17.3^{b}	16.0^{b}	17.3^{b}
50% NPK + GM	20.7^{c}	18.7^{c}	17.7^{c}	19.1^{c}
D-mean	22.5^{c}	20.6^{b}	18.8^{a}	20.6
CD at 5%	T=1.06	D=0.62	TXD=NS	
SEM	0.369	0.220		

4.2.6. Available Potassium

The available K was significantly increased by the treatments 50% NPK, 100% NPK,150% NPK,100% NPK+Zn,100% NPK+FYM, 50% NPK+BGA and 50% NPK+GM but decrease in Control,100% N and 100%NP. The available K was recorded highest 150% NPK and 100% NPK+FYM (589 kg ha^{-1}), the response of different treatments were significant. AV-K significantly decreased with increasing soil depths (0-15 cm, 15-30 cm and 30-60 cm). The surface soil 0-15 cm content in 538 kg ha^{-1}, low in sub surface 15-30 cm content in 516 kg ha^{-1} and 30-60 cm content in 497 kg ha^{-1}. Interaction of Treatments (T) and soil depth (D) was found to be significant. (Table 4.18)

Table 4.18:Effect of organic and inorganic fertilization on available K (kg ha^{-1}) at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	455^{a}	425^{a}	400^{a}	427^{a}
50% NPK	561^{e}	523^{c}	498^{c}	527^{d}
100% NPK	567^{ef}	550^{d}	535^{e}	551^{e}
150% NPK	589^{g}	569^{e}	555^{f}	571^{f}
100% NPK + Zn	569^{f}	547^{d}	533^{e}	550^{e}
100% NP	493^{b}	465^{b}	445^{b}	468^{c}
100% N	462^{a}	461^{b}	450^{b}	458^{b}
100% NPK + FYM	589^{g}	569^{e}	556^{f}	572^{f}
50% NPK + BGA	544^{d}	525^{c}	496^{c}	522^{d}
50% NPK + GM	555^{e}	529^{c}	505^{d}	529^{d}
D-mean	538^{c}	516^{b}	497^{a}	517
CD at 5%	T=7.46	D=4.45	TXD=14.08	DXT=4.03
SEM	2.57	1.54	4.97	1.39

4.2.7. Bulk Density (Mgm^{-3})

The bulk density is important soil characteristics and it was determined up to the depth of 0-15 cm, 15-30 cm and 30-60 cm interval in rice crop in the year 2012 are presented in Table 4.19. Interaction of bulk density levels with soil depth (D) was found to be not- significant. (Table 4.19)

Bulk density was significantly by different treatment at 0-15 cm, 15-30 cm and 30-60 cm depth of the soil. Bulk density significantly increased with increasing fertilizer dose i.e. from control to 150% not similarly application of FYM. It was (1.35 Mgm^{-3}) in the value had increased in the treatments control , 50% NPK, 100% NPK, 150% NPK, 100% NPK + Zn, 100% NP and 100% N, Whereas it decreased in 100% NPK + FYM (1.33), 50% NPK +BGA (1.34) and 50% NPK +GM (1.33) was significantly lower as compared to all the treatment. Bulk density significantly increased with increasing soil depths. The bulk density of soil depth (0-15 cm) 1.35 Mgm^{-3}, (15-30 cm) 1.40 Mgm^{-3} and (30-60 cm) 1.64 Mgm^{-3}. The bulk density is increased with increasing soil depth.

Bulk density (Mgm^{-3}) worked out in the depth of (0-15 cm), (15-30 cm) and (30-60 cm) in rice crop in the year (2012) was increased from the except in treatment 100%NPK+FYM, 50%NPK+BGA and 50%NPK+GM. The higher bulk density was recorded in those treatments where only chemical fertilizers applied and in those treatments where chemical fertilizer were supplemented particularly with FYM high values were recorded. The response between the treatments was significant. Hati (2007), Bandyopadhyay (2010) and Nandapure (2011) similar result to the bulk density was reduced significantly with the 100% NPK + FYM treatment over all other treatments. Melero *et al.*,(2011) The result showed that an increase with soil depth in both tillage systems and in all crop rotations, which could be related to the increase of soil bulk density and soil mass with depth.

Bulk density of the soils ranged from 1.35 to 1.66 Mg m^{-3}. It slightly decreased in horizons just below the upper layer and then increased with depth in all the profiles which could be attributed to decreased organic matter content and secondary accumulation of illuviated clays but further orientation of clay in pore space increased the bulk density value in 15-30 cm and 30-60 cm. Similar results were finding in Walia and Rao 1996, Ram et al., (2010).

Table 4.19: Effect of organic and inorganic fertilization on bulk density (Mgm^{-3}) at three soil depths.

Treatment	**Soil depth**			**T-mean**
	(0-15 cm)	**(15-30 cm)**	**(30-60 cm)**	
Control	1.35^{c}	1.40^{c}	1.64^{c}	1.46^{c}
50% NPK	1.35^{c}	1.42^{e}	1.65^{d}	1.47^{d}
100% NPK	1.36^{c}	1.41^{d}	1.64^{c}	1.47^{d}
150% NPK	1.36^{d}	1.42^{e}	1.66^{e}	1.48^{e}
100% NPK + Zn	1.36^{d}	1.42^{e}	1.65^{d}	1.48^{e}
100% NP	1.36^{d}	1.41^{d}	1.66^{e}	1.48e
100% N	1.36^{d}	1.42^{e}	1.65^{d}	1.48^{e}
100% NPK + FYM	1.33^{a}	1.38^{a}	1.62^{a}	1.44^{a}
50% NPK + BGA	1.34^{b}	1.39^{b}	1.63^{b}	1.45^{b}
50% NPK + GM	1.33^{a}	1.38^{a}	1.62^{a}	1.44^{a}
D-mean	1.35^{a}	1.40^{b}	1.64^{c}	1.47
CD at 5%	T=0.010	D=0.004	TXD=NS	
SEM	0.004	0.001		

4.2.8. Particle density ($Mg\ m^{-3}$)

Particle density were determined in soil sample of different treatments in Vertisol under rice crop in the year 2012 are presented in Table 4.20. The particle density was recorded highest in 50%NPK, 150% NPK, 50% NPK+GM (2.59 Mgm^{-3}) followed by control (2.58 Mgm^{-3}) although the difference between the treatment were not-significant. Interaction of particle density levels with soil depth (D) was found to be non-significant. The particle density was recorded low in surface layer (0-15 cm) and highest in subsurface layer (15-30 cm and 30-60 cm) although the difference between the soil depth were significant.

Particle density of the soils ranged from 2.53 to 2.64 Mgm^{-3}. Particle density significantly increased with increasing soil depths. The particle density was low in surface layer (0-15 cm = 2.54 $Mg\ m^{-3}$) and low in subsurface layer (15-30 cm=2.56 Mgm^{-3}, 30-60 cm=2.62 Mgm^{-3}). It slightly decreased in horizons just below the upper layer and then increased with depth in all the profiles which could be attributed to decreased organic matter content and secondary accumulation of illuviated clays but further orientation of clay in pore space increased the particle density value in 15-30 cm and 30-60 cm. Similar results were finding in Walia and Rao 1996, Ram et al., (2010).

Table 4.20: Effect of organic and inorganic fertilization on particle density (Mgm^{-3}) at three soil depths.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	2.56^{a}	2.58^{ab}	2.61^{a}	2.58^{a}
50% NPK	2.57^{b}	2.58^{ab}	2.61^{a}	2.58^{a}
100% NPK	2.54^{a}	2.55^{a}	2.63^{ab}	2.57^{a}
150% NPK	2.55^{a}	2.58^{ab}	2.63^{ab}	2.58^{a}
100% NPK + Zn	2.54^{a}	2.55^{a}	2.60^{a}	2.56^{a}
100% NP	2.53^{a}	2.55^{a}	2.60^{a}	2.56^{a}
100% N	2.53^{a}	2.55^{a}	2.62^{a}	2.56^{a}
100% NPK + FYM	2.55^{a}	2.56^{a}	2.64^{b}	2.58^{a}
50% NPK + BGA	2.55^{a}	2.56^{a}	2.63^{ab}	2.58^{a}
50% NPK + GM	2.55^{a}	2.57^{a}	2.64^{b}	2.59^{ab}
D-mean	2.54^{a}	2.56^{b}	2.62^{c}	2.57
CD at 5%	T=NS	D=0.01	TXD=NS	
SEM		0.007		

4.2.9. Soil Texture

The important physical properties of the soils have been summarized in table 4.21. Sand content of the soils ranged from 20 per cent, Silt content varied from 30 per cent and Clay content varied from 50 per cent.(Table 4.21)

Table 4.21: Soil Texture (per cent)

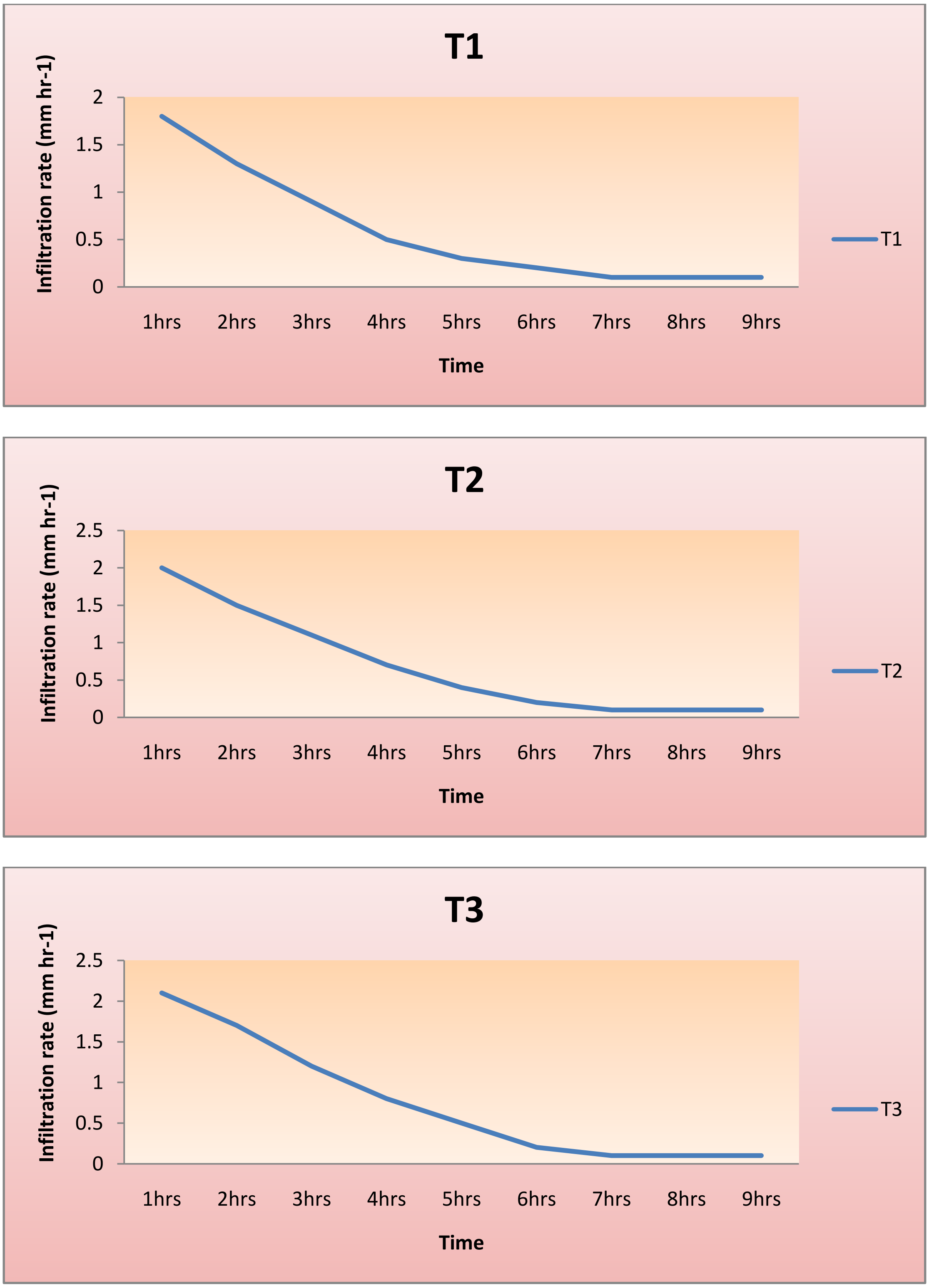
Treatment	Soil Texture		
	Sand	Silt	Clay
Control	22	31	47
50% NPK	21	34	45
100% NPK	23	30	47
150% NPK	22	32	46
100% NPK + Zn	21	32	48
100% NP	23	31	46
100% N	20	30	50
100% NPK + FYM	21	33	46
50% NPK + BGA	22	31	47
50% NPK + GM	22	30	48
Mean	20	30	50

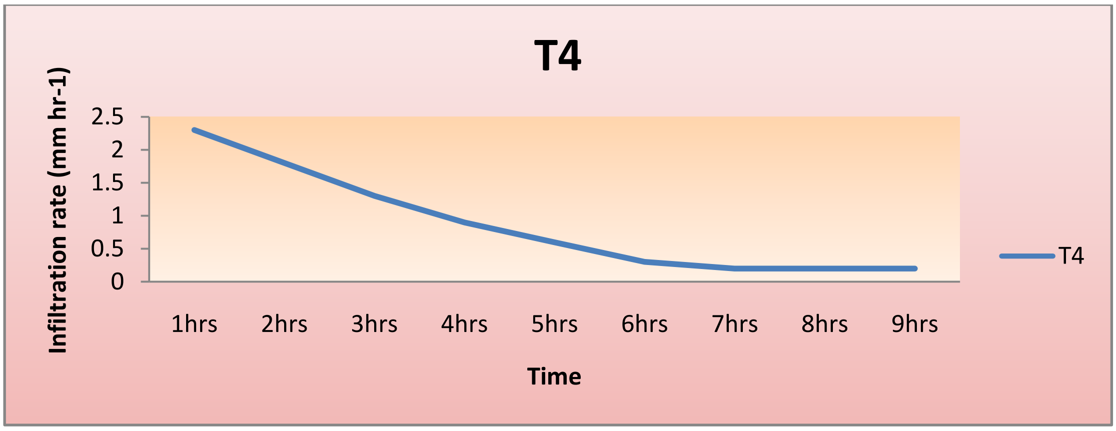
4.2.10. Infiltration rate

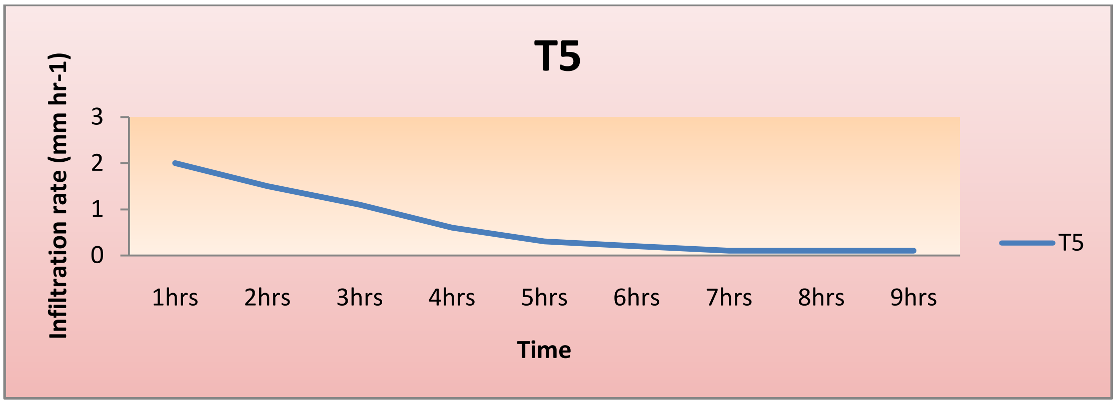
Infitration rate was determined in different treatments in Vertisol under rice crop. The term infiltration is downward entry of water from the surface of soil. The soil texture plays predominant role in infiltration characteristic of soils with high clay content has low infiltration rate, while the soil with high sand content has high infiltration rate, beside texture, organic matter, bulk density, presence of water table, moisture percentage, tillage practices and surface vegetation were also side factor affecting the infiltration characteristic.

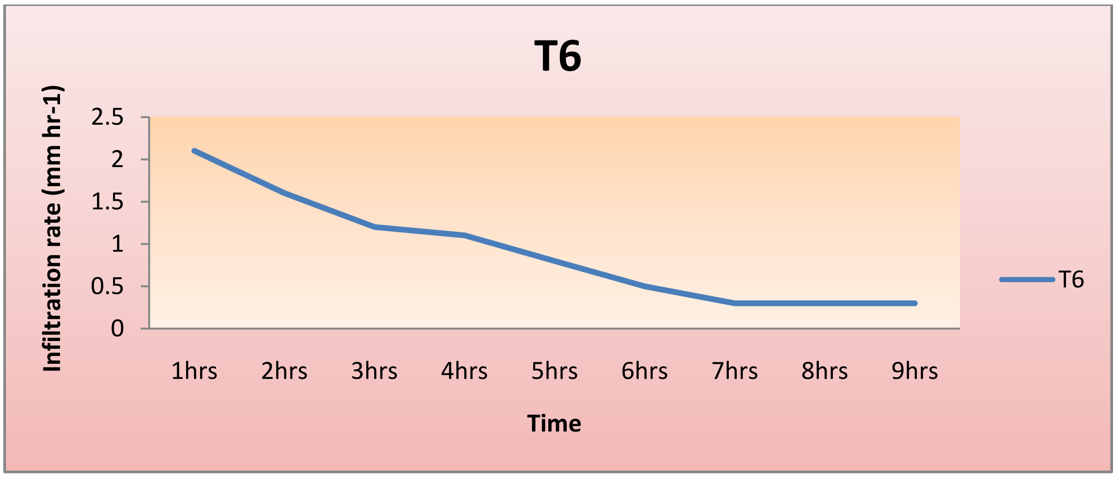
The higher infiltration rate in treatment 100%NPK+FYM and 50%+NPK+GM as compared to other treatment. More in (1994), on sodic Vertisol under rice-wheat rotation observed that application of FYM; organic waste and manures decreased soil pH but increased the infiltration rate. (Appendix VI)

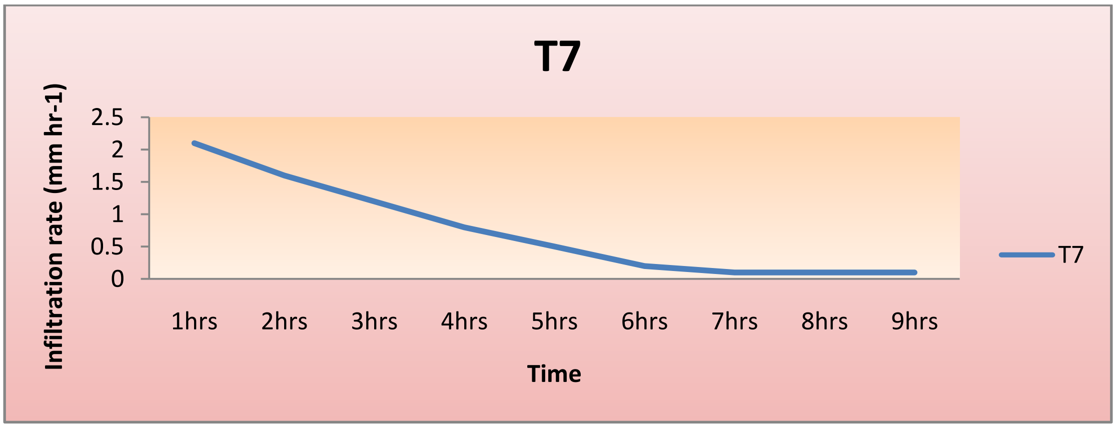
Fig. 4.13: Effect of fertilization on (both organic and inorganic) infiltration rate (mm hr^{-1}) in different treatments.

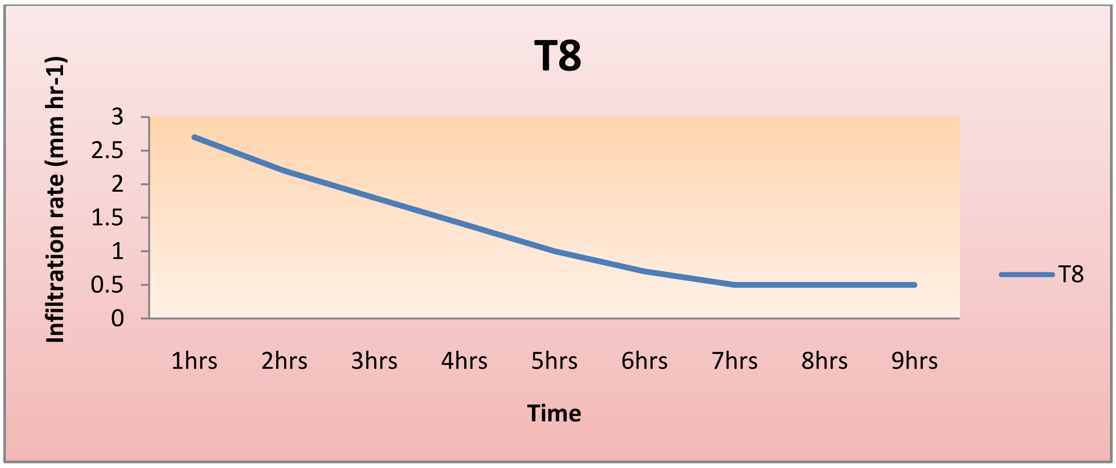


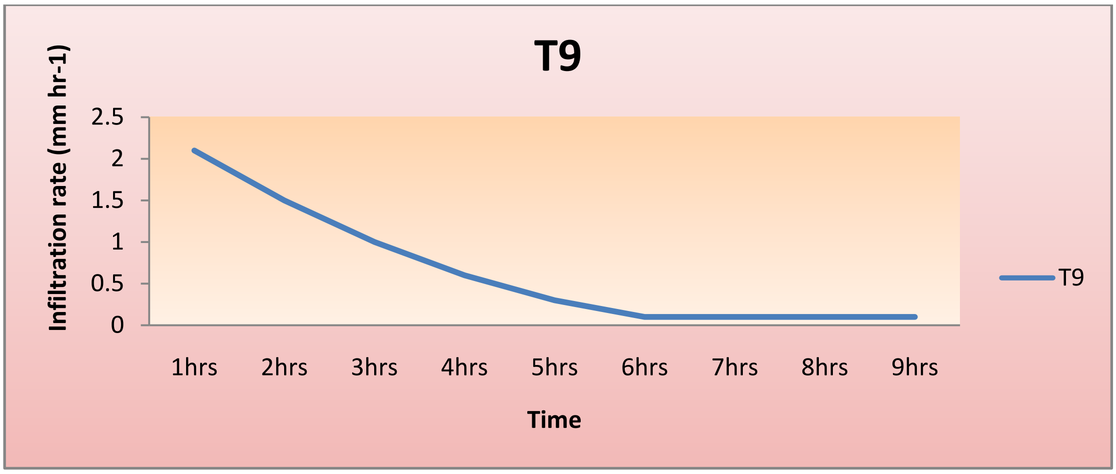

T4
Infiltration rate (mm hr-1)
2.5
2
1.5
1
0.5
0
1hrs 2hrs 3hrs 4hrs 5hrs 6hrs 7hrs 8hrs 9hrs
Time
T4

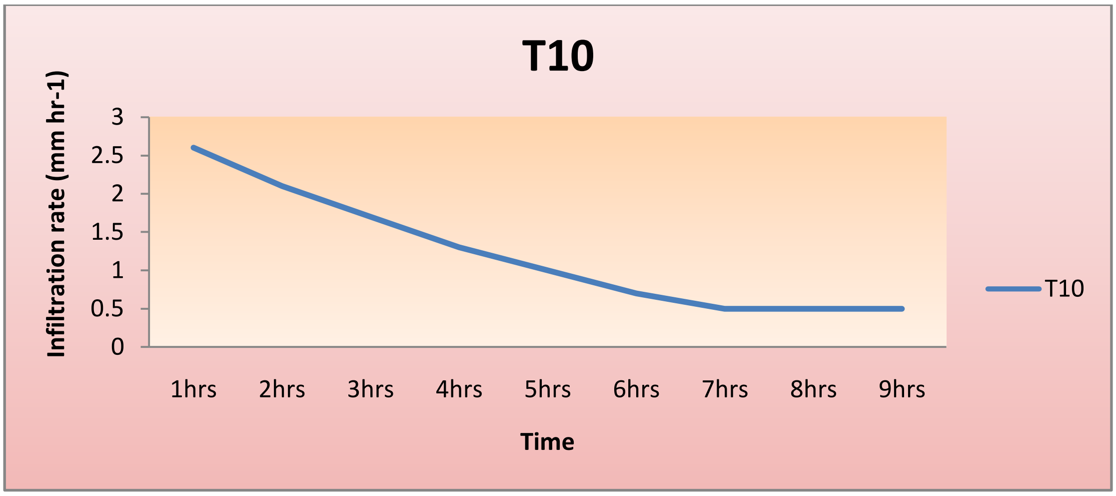

T5
Infiltration rate (mm hr-1)
3
2
1
0
1hrs 2hrs 3hrs 4hrs 5hrs 6hrs 7hrs 8hrs 9hrs
Time
T5


T6
Infiltration rate (mm hr-1)
2.5
2
1.5
1
0.5
0
1hrs 2hrs 3hrs 4hrs 5hrs 6hrs 7hrs 8hrs 9hrs
Time
T6


T7
Infiltration rate (mm hr-1)
2.5
2
1.5
1
0.5
0
1hrs 2hrs 3hrs 4hrs 5hrs 6hrs 7hrs 8hrs 9hrs
Time
T7


T8
Infiltration rate (mm hr-1)
3
2.5
2
1.5
1
0.5
0
1hrs
2hrs
3hrs
4hrs
5hrs
6hrs
7hrs
8hrs
9hrs
Time
T8


T9
Infiltration rate (mm hr-1)
2.5
2
1.5
1
0.5
0
1hrs
2hrs
3hrs
4hrs
5hrs
6hrs
7hrs
8hrs
9hrs
Time
T9


T10
Infiltration rate (mm hr-1)
3
2.5
2
1.5
1
0.5
0
1hrs
2hrs
3hrs
4hrs
5hrs
6hrs
7hrs
8hrs
9hrs
Time
T10

4.3 Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of different forms of K and P.

4.3.1. Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of different forms of K.

Table 4.22: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of water soluble K .

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	0.05	0.05	0.04	0.05
50% NPK	0.07	0.06	0.06	0.06
100% NPK	0.08	0.07	0.06	0.07
150% NPK	0.09	0.07	0.07	0.08
100% NPK + Zn	0.07	0.07	0.06	0.07
100% NP	0.06	0.05	0.05	0.06
100% N	0.06	0.05	0.05	0.06
100% NPK + FYM	0.08	0.07	0.07	0.07
50% NPK + BGA	0.06	0.06	0.05	0.06
50% NPK + GM	0.07	0.06	0.06	0.06
D-mean	0.07	0.06	0.06	0.06

The percent distribution of water soluble K content of the top (0-15 cm) soil in the treatments receiving K fertilizer (150% NPK, 100% NPK and 100% NPK + FYM) was higher as compared with 100% N , 100% NP and control treatments (Table 4.22). Similar results were observed at 15-30 cm and 30-60 cm soil depth. Similar results were found in Yaduvanshi and Swarup (2006). The highest value of water soluble K was recorded in 150% NPK (0.09 percent) followed by 100% NPK + FYM (0.08 per cent). The water soluble K ranged in surface layer 0.05 to 0.09 per cent (0-15 cm) and subsurface 0.04 to 0.07 per cent (15-30 cm and 30-60 cm). Singh *et al*. (2006) reporteded that the water soluble potassium ranged 0.05 to 0.07 percent respectively of the total potassium fraction.

Table 4.23: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Available K.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	1.52	1.48	1.40	1.46
50% NPK	1.82	1.70	1.63	1.72
100% NPK	1.84	1.78	1.74	1.79
150% NPK	1.88	1.81	1.79	1.83
100% NPK + Zn	1.82	1.76	1.72	1.77
100% NP	1.64	1.60	1.54	1.59
100% N	1.60	1.59	1.55	1.58
100% NPK + FYM	1.87	1.82	1.78	1.82
50% NPK + BGA	1.76	1.71	1.63	1.70
50% NPK + GM	1.79	1.73	1.65	1.72
D-mean	1.75	1.70	1.64	1.70

The available K content at different depths of soil profile as influenced by imposition of different treatments is given in table 4.23. In general, the values of soil available K were the highest in 150% NPK, significantly superior to that of 100%

NPK + FYM**.** However, the values of available K in the surface soil layer ranged between 1.52 to 1.88 per cent and the values continued to drop in all treatments with increasing depth, thus the values of 30-60 cm soil layer approached the lowest values, which ranged between 1.40 to 1.79 per cent. Similar results were found in Thakur *et al*.,(2010).

Table 4.24. Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Exchangeable K.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	2.17	2.15	2.12	2.15
50% NPK	2.22	2.19	2.18	2.20
100% NPK	2.22	2.20	2.19	2.20
150% NPK	2.25	2.24	2.23	2.24
100% NPK + Zn	2.23	2.22	2.21	2.22
100% NP	2.18	2.14	2.10	2.14
100% N	2.20	2.09	2.08	2.12
100% NPK + FYM	2.25	2.23	2.21	2.23
50% NPK + BGA	2.21	2.20	2.16	2.19
50% NPK + GM	2.21	2.20	2.16	2.19
D-mean	2.21	2.19	2.16	2.19

Data presented in table 4.24 showed that the exchangeable K in general range from 2.21 per cent in surface layer and 2.16 per cent in 30-60 cm. soil profile and which is 2.16 to 2.25 per cent of total K. Similar results were found in Babar et al.,(2010). The highest values was recorded in 150% NPK and 100% NPK + FYM

(2.25 per cent). Similar trends was reported by Majumdar *et al.* (2002) and Pannu *et al.* (2002).

Table 4.25: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Non-Exchangeable K.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	5.07	4.74	4.55	4.79
50% NPK	6.58	6.48	5.64	6.23
100% NPK	7.00	6.72	5.51	6.41
150% NPK	7.26	6.89	6.03	6.72
100% NPK + Zn	6.98	6.19	5.36	6.18
100% NP	5.75	5.45	5.41	5.54
100% N	5.11	5.14	4.82	5.02
100% NPK + FYM	7.22	6.64	5.68	6.51
50% NPK + BGA	6.64	6.07	5.55	6.09
50% NPK + GM	6.47	6.40	5.58	6.15
D-mean	6.41	6.07	5.41	5.96

Table 4.25 showed that the highest and lowest value of non-exchangeable K being in surface and subsurface layer. The highest value of non-exchangeable K was recoreded in the treatments 150% NPK (7.26 per cent) followed by 100% NPK + FYM (7. 22 per cent) and lowest value in Control (5.07 per cent). While the range of non–exchangeable K was quit higher in surface sample (6.41 per cent) and sub surface (5.41 per cent) in profile sample. This form of K also exhibit trend with depth. The variation in depth wise distribution pattern of non-exchangeable K might be due to changes in particle size distribution in various layers (Brar and Sekhon, 1987 and Babar *et al*., 2007). This highest content of non-exchangeable K in surface horizon

was related to clay content, which could fix the K in soils, due to the presence of illitic and other 2:1 type clay minerls.

4.3.2 Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of different forms of phosphorus.

Table 4.26: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of saloid-P.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	0.07	0.06	0.06	0.06
50% NPK	0.11	0.09	0.08	0.09
100% NPK	0.13	0.13	0.14	0.13
150% NPK	0.16	0.15	0.14	0.15
100% NPK + Zn	0.12	0.10	0.09	0.11
100% NP	0.14	0.13	0.10	0.13
100% N	0.06	0.06	0.05	0.06
100% NPK + FYM	0.16	0.15	0.14	0.15
50% NPK + BGA	0.11	0.10	0.08	0.10
50% NPK + GM	0.11	0.10	0.08	0.10
D-mean	0.12	0.11	0.10	0.11

The saloid-P was also observed that the highest value in 150% NPK and 100% NPK + FYM (0.16 per cent) and lowest value in control (0.7 per cent) and 100% N (0.6 per cent) table 4.26. Similar trends were founding in lower depths. On the other hand, plots receiving P application along with N or N and K (50% NPK, 100% NPK, 150% NPK, 100% NPK + Zn, 100% NP, 100% NPK + FYM, 50% NPK

+ BGA and 50% NPK + GM) recorded substantially higher saloid-P content. The results indicate clearly that as the P fertilizer dose increased, the status of saloid-P also increased correspondingly at three soil depths. Similar results were found in Sihag *et al*.,(2005), Jatav et al.,(2010) and Singh et al.,(2010). Fractionation studies revealed significantly increased in saloid-P under integrated use of inorganic fertilizer and FYM. The results on changes in different fractions of P due to continuous use of inorganic fertilizers indicated that saloid-P ranged between 0.06 to 0.16 per cent soil in 0-15 cm depth, 0.06 to 0.15 per cent in 15-30 cm and 0.06 to 0.14 per cent in 30-60 cm soil depth (Table 4.26). Thangaswamy *et al.* (2005) and Rajeswar *et al.* (2009) similar results were reported by the highest P was observed in the surface horizons and decreased regularly with depth.

Table 4.27: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Al-P.

Treatment	**Soil depth**			**T-mean**
	(0-15 cm)	**(15-30 cm)**	**(30-60 cm)**	
Control	0.66	0.61	0.54	0.60
50% NPK	1.00	0.85	0.76	0.87
100% NPK	1.01	0.95	0.92	0.96
150% NPK	1.06	1.06	1.01	1.04
100% NPK + Zn	0.96	0.93	0.92	0.94
100% NP	1.03	0.97	0.94	0.98
100% N	0.77	0.54	0.49	0.60
100% NPK + FYM	1.08	1.04	1.00	1.04
50% NPK + BGA	0.92	0.92	0.73	0.86
50% NPK + GM	0.91	0.89	0.79	0.86
D-mean	0.94	0.88	0.81	0.88

Maximum concentration of Al-P was recorded in 100% NPK + FYM (1.08 per cent) followed by 150% NPK (1.06 per cent). Plots, which have received fertilizer N alone (100% N and control) resulted in the lowest value of Al-P (0.66 and 0.77 per cent) as compared to other fertilizer treatments. The Al-P content in soil changed widely with continuous use of various combinations of inorganic fertilizers. (Table 4.27). The Al-P concentration ranged from 0.66 to 1.08 per cent soil in 0-15 cm depth, 0.61 to 1.06 per cent in 15-30 cm and 0.54 to 1.01 per cent in 30-60 cm soil depth. The average percentage mean of Al-P was higher in surface layer (0.94 per cent) and low in sub surface (0.88 and 0.81 per cent). Similar results were reported by Singh *et al*., (2010) and Tiwari *et al*.,(2012).

Table 4.28: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Fe-P.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	1.05	1.02	0.94	1.00
50% NPK	1.29	1.23	1.03	1.19
100% NPK	1.44	1.30	1.16	1.30
150% NPK	1.46	1.44	1.23	1.38
100% NPK + Zn	1.39	1.30	1.12	1.27
100% NP	1.36	1.17	1.09	1.21
100% N	1.11	0.94	0.85	0.97
100% NPK + FYM	1.50	1.44	1.20	1.38
50% NPK + BGA	1.24	1.20	0.99	1.14
50% NPK + GM	1.23	1.15	1.08	1.15
D-mean	1.31	1.22	1.07	1.20

Table 4.28 showed that the results further indicated that Fe-P ranged from 1.31 per cent in 0-15 cm, 1.22 per cent in 15-30 cm and 1.07 per cent in 30-60 cm soil depths. The higher Fe-P was recorded in 100% NPK + FYM (1.50 per cent) followed by 150% NPK (1.46 per cent) and the lower value in control (1.05 per cent).

Table 4.29: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Red-P.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	1.81	1.76	1.78	1.78
50% NPK	2.28	1.95	1.88	2.04
100% NPK	2.29	2.03	2.01	2.11
150% NPK	2.31	2.12	2.10	2.18
100% NPK + Zn	2.23	2.10	1.94	2.09
100% NP	1.99	1.98	1.98	1.98
100% N	1.89	1.80	1.78	1.82
100% NPK + FYM	2.32	2.19	2.03	2.18
50% NPK + BGA	2.20	1.86	1.82	1.96
50% NPK + GM	2.27	1.87	1.84	2.00
D-mean	2.16	1.97	1.92	2.01

Reductant soluble P is fairly rich as compared to Al-P and Fe-P. This content in the soil profiles ranged from 0-15 cm (2.16 per cent), 15-30 cm (1.97 per cent) and (1.92 per cent) in 30-60 cm soil depth (table 4.29). In all the profiles, reductant soluble-P was higher in surface horizons and the same decreased down the depth. Similar trend was found in soil profile also reported by Singh and Omanwar (1987), Dongale (1993) and Trivedi *et al.*,(2010). Dry environment at surface is conducive for its accumulation instead of prolonged moist condition prevailing in deeper layer.

Table 4.30: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Ca-P.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	3.38	3.32	3.20	3.30
50% NPK	3.52	3.47	3.39	3.46
100% NPK	3.68	3.59	3.47	3.58
150% NPK	3.71	3.63	3.52	3.62
100% NPK + Zn	3.64	3.45	3.32	3.47
100% NP	3.65	3.61	3.35	3.54
100% N	3.44	3.20	3.01	3.21
100% NPK + FYM	3.74	3.61	3.50	3.61
50% NPK + BGA	3.51	3.46	3.38	3.45
50% NPK + GM	3.57	3.50	3.42	3.50
D-mean	3.58	3.48	3.36	3.47

Calcium-P was found to the dominant P fraction among various inorganic P forms present in these soils. The Ca-P concentration ranged from 3.58 per cent in 0-15 cm surface layer, 3.48 per cent in 15-30 cm and 3.36 per cent in 30-60 cm soil depths, respectively. The Ca-P declined sharply with soil depth.(Table 4.30)

The highest value of Ca-P was recorded in 100% NPK + FYM (3.74 per cent) followed by 150% NPK (3.71 per cent) and lower value in Control (3.38 per cent) and 100% N (3.44 per cent). Similar trends was found in deeper layer. Successive additions of inorganic P fertilizer tended to improve Ca-P concentration in soil. These results elucidate that amongst different inorganic fractions of P, maximum accumulation occurred in Ca-P fraction both in surface as well as subsurface soil, whereas the minimum concentration was noticed in case of saloid-P in all the fertilizer-treated plots. Similar results were reported by Singh *et al.*, (2010).

Table 4.31: Effect of organic and inorganic fertilization and soil depth on percent (%) distribution of Available-P.

Treatment	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	0.19	0.16	0.14	0.16
50% NPK	0.39	0.36	0.35	0.37
100% NPK	0.51	0.49	0.47	0.49
150% NPK	0.54	0.52	0.50	0.52
100% NPK + Zn	0.50	0.48	0.44	0.47
100% NP	0.52	0.49	0.47	0.49
100% N	0.17	0.16	0.13	0.15
100% NPK + FYM	0.53	0.52	0.51	0.52
50% NPK + BGA	0.35	0.35	0.34	0.35
50% NPK + GM	0.39	0.37	0.38	0.38
D-mean	0.41	0.39	0.37	0.39

Maximum of 0.54 per cent available P fraction (31.1 kg ha^{-1}) was obtained in 150% NPK treatment and the lowest of 0.17 and 0.19 per cent in 100% N and Control. This might be probably because of higher rate of application in 150% NPK (Table 4.31). These results suggested that all inorganic fractions of P have a combined effect on the availability of soil P, phosphorus uptake and crop yield by different crops. Dhillon and Dev (1990) and Dikshit *et al.*, (1994) had made similar observation.

Summary, Conclusion & Suggestions for Future Research Work

CHAPTER-V

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

A study based on **"Effect of organic and inorganic fertilization on depth wise distribution of different forms of phosphorus and potassium in *Vertisol*"** was performed on Vertisol under rice crop on soil samples obtained from the ongoing Long Term Fertilizer Experiment (LTFE) project. The experimental soil (Vertisol) locally called as *Kanhar* is fine montmorillonite, hyperthermic, udic chromustert, deep, clayey and neutral to alkaline in reaction.

There were ten treatment combinations which consisted of control (no fertilizer application) and graded levels of NPK. During rainy season, chemical fertilizer were integrated with Farm yard manure (FYM+100 per cent NPK), Green Manure (GM-Sesbania aculeata+50 per cent NPK) and Blue Green Algae (BGA+50 per cent NPK) before transplanting rice. The treatment combinations for rice were T1 (Control),T2(50%NPK),T3(100%NPK),T4(150%NPK),T5(100%NPK+Zn),T6(100% NP),T7(100%N),T8(100%NPK+FYM),T9(50%NPK+BGA)andT10(50%NPK+GM). The soil samples were collected from three soil depth 0-15 cm, 15-30 cm and 30-60 cm. For analysis split plot design was used and fertilizer levels were considered in main plot and soil depth in sub plot. The soil was analyzed for soil P and K fractions and depth wise distribution of different form of P and K, percentage distribution of P and K under soil depths.

The P and K status of the different soil P fractions (saloid-P, Al-P, Fe-P, Red-P and Ca-P) and K fractions (water soluble, exchangeable, non-exchangeable and available K) were analyzed from 0-15 cm, 15-30 cm and 30-60 cm soil depths. All P fractions and K fractions were higher in 150% NPK and 100% NPK+FYM. Fertilizer was added at the rate of 0,50,100 and 150 percent of recommended dose (100:60:40) in rice crop, integrated with FYM at 100 per cent level and with green manure and BGA at 50 per cent level in rice. The integration with FYM showed pronounced effect on P fractions and K fractions. The effect of integration with FYM was observed, which resulted in higher accumulation of all K fractions except non-exchangeable K. Maximum portion of applied P was transformed in Ca-P followed by Red-P, Fe-P and Al-P. In case of potassium, applied K was transformed into non-exchangeable K and minimum into water soluble K, whereas exchangeable K and available K were intermediate.

The soil physico-chemical properties were affected by organic and inorganic fertilization in present experiment. Soil quality is related with nutrients status, physical and chemical properties of soils. The effect of NPK fertilizers alone and in combination with green manuring (GM), Farm yard manure (FYM) and BGA invertigation have influences the distribution of different form of P and K in soil.

All P Fractions and K fractions were higher in surface layer than that sub surface layer. The sequential order of dominance of different forms of P were Ca-P > Red-P > Fe-P > Al-P > saloid-P and form of K were non-exchangeable > exchangeable > available > water soluble.

The continuous use of balanced fertilizer is conducive for maintaining the all P fractions in soil. The present study also revealed that in surface soil (0-15 cm), maximum P content was present as compared to that at lower depth (15-30 cm and 30-60 cm) in all treatments. It was also observed that successive significant increase had occurred due to increasing levels of fertilizer application in surface soil. Application of fertilizer K did not influence all K fractions. Significant effect of fertilizer K application was observed on available and exchangeable K, whereas, there was no effect of fertilizer K application on water soluble and non-exchangeable K.

Surface soil (015 cm) showed higher soil K fractions than that sub surface soil (15-30 cm) and low in deep layer (30-60 cm).

Percentage distribution was also studied of different forms of P and K at 0-15 cm, 15-30 cm and 30-60 cm soil depths. The higher amount of all P and K fractions were recorded in surface layer (0-15 cm) than at sub surface (15-30 cm) and low in deep layer (30-60 cm). However, higher P and K availability was observed at surface layer than that at sub surface layer. Keeping above things in mind it can be concluded:

1. Maximum portion of P and K fractions were higher with chemical fertilizer.
2. The integration of chemical fertilizer with FYM, GM and BGA resulted in higher amount of all soil P fraction and K fraction in surface layer.
3. The amount of all P fractions and K fractions was higher in surface layer (0-15 cm) than that sub surface (15-30 cm) and low in deep layer. The phosphorus and potassium availability decrease with increasing soil depths under Vertisol.
4. Continuous monitoring of physical and chemical properties should be carried out for maintaining soil health and enhancing the crop production.
5. There is significant relationship in percentage distribution of different forms of P and K under soil depths. The higher amount of P and K (per cent) fractions was recorded in surface layer than that sub surface layer.

Suggestions for future work

1. K dynamics characteristics need to be evaluated under different cropping system as well as under different soil types.
2. Some more experiment should be carried out for understanding of Phosphorus dynamics in Vertisol under rice based cropping system for its effective utilization.

Abstract

"EFFECT OF ORGANIC AND INORGANIC FERTILIZATION ON DEPTH WISE DISTRIBUTION OF DIFFERENT FORMS OF PHOSPHORUS AND POTASSIUM IN *VERTISOL*"

by

Ku. Tripti Nayak

ABSTRACT

A study based on "Effect of organic and inorganic fertilization on depth wise distribution of different forms of phosphorus and potassium in *Vertisol*" was performed on Vertisol under rice crop on soil samples obtained from the ongoing Long Term Fertilizer Experiment (LTFE) project. The P and K status of the different soil P fractions (saloid-P, Al-P, Fe-P, Red-P and Ca-P) and K fractions (waster soluble, exchangeable, non-exchangeable and available K) were analyzed from 0-15 cm, 15-30 cm and 30-60 cm in soil depths. All P fractions and K fractions were higher in surface layer than that subsurface layer. The sequential order of dominance of different forms of P were Ca-P > Red-P > Fe-P > Al-P > saloid-P and K were non-exchangeable > exchangeable > available > water soluble in Vertisol. The highest value of P fractions and K fractions were recorded in the treatments 150% NPK and 100% NPK+FYM. Fertilizer was added rate of 0, 50, 100 and 150 percent of recommended dose (100:60:40) in rice integrated with FYM at 100 per cent level and with green manure and BGA at 50 per cent level in rice. The integration with FYM showed pronounced effect on P fractions and K fractions. Continuous monitoring of physical and chemical properties should be carried out for maintaining soil health and enhancing the crop production. The effect of integration with FYM was observed, which resulted in higher accumulation of all K fractions except non-exchangeable K. Maximum portion of applied P was transformed in Ca-P followed by Red-P, Fe-P and Al-P and in case of potassium, Applied K was transformed into non-exchangeable K and minimum into water soluble K, whereas exchangeable K and available K were intermediate.

Percentage distribution of different forms of P and K at 0-15 cm, 15-30 cm and 30-60 cm soil depths was also studied the higher amount of all P and K fractions (per cent) were recorded in surface layer (0-15 cm) than at sub surface (15-30 cm) and low in deep layer (30-60 cm). However, higher P and K availability was observed at surface layer than that at sub surface layer.

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Appendices

Appendix-I : Weekly meteorological data during crop growth period (from 11 July, 2012 to November 20, 2012)

Week No	Month	Date	Temp (°C)		Rainfall (mm)	Relative humidity (%)		Vapour pressure		Wind velocity (Kmph)	Evaporation (mm)	Sun shine (Hrs)
			Max	Min		I	II	I	II			
28	July	09-15	31.7	25.5	73.6	91	69	23.4	23.7	06.0	04.8	04.0
29		16-22	29.8	24.5	341.4	93	83	22.7	24.1	05.9	03.1	01.1
30		23-29	27.6	24.1	60.3	92	88	21.6	23.1	09.3	02.0	00.7
31		30-05	25.8	23.2	271.1	95	91	21.1	22.5	11.1	01.5	00.0
Average			28.73	24.33	746.4*	92.75	82.75	22.20	23.35	08.08	02.85	01.45
32	August	06-12	28.8	24.8	106.8	93	79	22.6	22.6	08.7	02.8	01.3
33		13-19	30.2	25.3	33.2	90	78	22.7	22.4	06.4	03.8	03.5
34		20-26	29.6	24.5	127.6	93	78	22.6	23.0	05.6	02.7	03.1
35		27-02	31.1	25.8	55.6	92	74	24.1	24.3	02.9	03.5	04.7
Average			29.92	25.1	323.2*	90	77.25	23	23.07	05.9	03.2	03.15
36	Sep	03-09	30.3	25.1	74.4	93	75	23.9	23.4	03.4	03.0	02.5
37		10-16	30.4	24.7	42.6	93	74	22.8	22.8	06.8	03.8	04.0
38		17-23	31.4	24.6	84.4	95	73	23.0	23.0	03.3	03.8	04.3
39		24-30	32.2	24.4	02.8	90	54	22.4	19.0	01.9	04.7	08.3
Average			31.07	24.7	204.2*	92.75	69	23.02	22.05	03.85	03.82	04.77
40	Oct	01-07	31.9	23.9	09.2	91	56	21.8	19.1	02.3	04.1	07.6
41		08-14	31.0	20.2	00.0	89	45	17.6	14.4	01.3	03.9	08.0
42		15-21	31.9	19.5	00.0	88	37	16.9	12.6	01.4	04.1	08.6
43		22-28	31.6	18.4	00.0	85	38	15.4	12.8	02.3	03.7	06.9
44		29-04	28.9	18.4	27.3	92	59	16.2	15.8	02.3	03.3	04.9
Average			31.06	20.08	36.5*	89	47	17.58	14.94	01.92	12.28	72.00
45	Nov	05-11	28.5	17.3	05.6	95	45	15.2	21.5	00.8	02.6	06.6
46		12-18	28.4	12.7	00.0	90	33	11.1	09.2	01.4	03.6	09.1
47		19-25	29.6	16.4	00.0	84	43	12.9	13.0	01.6	03.2	07.3
Average			28.83	15.47	5.6* 1317.77**	89.67	40.33	13.07	14.57	01.27	03.15	07.67

* Total of the month, ** Cumulative rainfall during the season

Appendix II: Data of distribution of different forms of K (kg ha^{-1}) at three soil depths.

Treatment	1. Water soluble K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	16.43	13.03	12.50
50% NPK	21.64	19.63	17.18
100% NPK	24.90	21.05	18.53
150% NPK	26.88	23.13	22.32
100% NPK + Zn	23.19	21.73	18.85
100% NP	19.01	15.81	13.68
100% N	18.79	15.72	14.89
100% NPK + FYM	25.56	23.08	21.39
50% NPK + BGA	19.89	16.95	16.12
50% NPK + GM	21.06	18.19	18.14

Treatment	2. Available K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	455	425	400
50% NPK	561	523	498
100% NPK	567	550	535
150% NPK	589	569	555
100% NPK + Zn	569	547	533
100% NP	493	465	445
100% N	462	461	450
100% NPK + FYM	589	569	556
50% NPK + BGA	544	525	496
50% NPK + GM	555	529	505

Treatment	3. Exchangeable K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	652	618	606
50% NPK	683	676	667
100% NPK	685	676	669
150% NPK	705	695	690
100% NPK + Zn	697	690	685
100% NP	655	619	609
100% N	662	607	603
100% NPK + FYM	708	700	690
50% NPK + BGA	681	672	658
50% NPK + GM	684	673	660

Treatment	4. Non-exchangeable K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	1520	1365	1299
50% NPK	2028	1995	1722
100% NPK	2164	2069	1688
150% NPK	2278	2135	1861
100% NPK + Zn	2181	1920	1660
100% NP	1724	1580	1568
100% N	1538	1491	1398
100% NPK + FYM	2267	2082	1773
50% NPK + BGA	2048	1855	1693
50% NPK + GM	2004	1958	1705

Appendix III:Average data of distribution of different forms of P (kg ha^{-1}) at three soil depths.

Treatment	1.saloid-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	3.48	2.99	2.49
50% NPK	5.56	4.66	3.91
100% NPK	7.24	7.06	6.69
150% NPK	8.98	7.97	7.35
100% NPK + Zn	6.99	5.69	5.15
100% NP	7.79	6.89	5.46
100% N	3.13	2.85	2.36
100% NPK + FYM	8.88	8.25	7.53
50% NPK + BGA	5.65	4.95	3.78
50% NPK + GM	5.84	4.98	3.90

Treatment	2. Al-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	32.79	28.45	23.47
50% NPK	52.20	43.35	35.48
100% NPK	57.15	53.09	45.17
150% NPK	61.36	57.92	53.93
100% NPK + Zn	54.51	51.84	49.91
100% NP	55.78	52.45	48.97
100% N	38.20	27.09	22.04
100% NPK + FYM	61.63	58.39	54.38
50% NPK + BGA	49.74	45.86	33.99
50% NPK + GM	48.58	45.35	36.92

Treatment	3. Fe-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	52.34	47.87	40.69
50% NPK	67.66	62.92	48.16
100% NPK	81.57	72.28	56.92
150% NPK	84.56	78.71	65.49
100% NPK + Zn	79.15	72.01	60.77
100% NP	73.68	62.79	57.12
100% N	55.58	46.87	38.02
100% NPK + FYM	85.40	80.96	65.38
50% NPK + BGA	66.89	60.04	45.88
50% NPK + GM	65.24	58.73	50.37

Treatment	4.Red-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	90.67	82.41	77.11
50% NPK	119.45	99.84	87.76
100% NPK	129.90	112.79	98.47
150% NPK	134.01	115.97	112.07
100% NPK + Zn	127.09	116.57	105.34
100% NP	107.22	106.64	103.55
100% N	94.33	89.97	79.58
100% NPK + FYM	132.22	123.05	110.58
50% NPK + BGA	118.34	92.78	84.65
50% NPK + GM	121.01	95.98	85.90

Treatment	5.Ca-P		
	(0-15 cm)	**(15-30 cm)**	**(30-60 cm)**
Control	168.99	155.73	138.38
50% NPK	183.88	177.43	158.00
100% NPK	208.87	199.87	169.95
150% NPK	214.62	198.57	188.24
100% NPK + Zn	207.32	191.39	180.79
100% NP	196.98	194.62	175.11
100% N	171.54	159.41	134.29
100% NPK + FYM	213.00	202.82	190.27
50% NPK + BGA	188.77	172.88	156.99
50% NPK + GM	189.98	179.32	159.44

Treatment	6.Available P		
	(0-15 cm)	**(15-30 cm)**	**(30-60 cm)**
Control	9.6	7.6	5.9
50% NPK	20.3	18.5	16.2
100% NPK	29.0	26.8	23.0
150% NPK	31.1	28.4	26.8
100% NPK + Zn	28.7	26.7	23.7
100% NP	28.0	24.6	25.5
100% N	8.6	7.9	5.9
100% NPK + FYM	30.1	29.2	27.5
50% NPK + BGA	18.7	17.3	16.0
50% NPK + GM	20.7	18.7	17.7

Appendix IV: Percentage distribution of different forms of K (%) under soil depths.

Treatment	1.Water soluble K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	0.05	0.05	0.04
50% NPK	0.07	0.06	0.06
100% NPK	0.08	0.07	0.06
150% NPK	0.09	0.07	0.07
100% NPK + Zn	0.07	0.07	0.06
100% NP	0.06	0.05	0.05
100% N	0.06	0.05	0.05
100% NPK + FYM	0.08	0.07	0.07
50% NPK + BGA	0.06	0.06	0.05
50% NPK + GM	0.07	0.06	0.06

Treatment	2.Available K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	1.52	1.48	1.40
50% NPK	1.82	1.70	1.63
100% NPK	1.84	1.78	1.74
150% NPK	1.88	1.81	1.79
100% NPK + Zn	1.82	1.76	1.72
100% NP	1.64	1.60	1.54
100% N	1.60	1.59	1.55
100% NPK + FYM	1.87	1.82	1.78
50% NPK + BGA	1.76	1.71	1.63
50% NPK + GM	1.79	1.73	1.65

Treatment	3.Exchangeable K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	2.17	2.15	2.12
50% NPK	2.22	2.19	2.18
100% NPK	2.22	2.20	2.19
150% NPK	2.25	2.24	2.23
100% NPK + Zn	2.23	2.22	2.21
100% NP	2.18	2.14	2.10
100% N	2.20	2.09	2.08
100% NPK + FYM	2.25	2.23	2.21
50% NPK + BGA	2.21	2.20	2.16
50% NPK + GM	2.21	2.20	2.16

Treatment	4.Non-exchangeable K		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	5.07	4.74	4.55
50% NPK	6.58	6.48	5.64
100% NPK	7.00	6.72	5.51
150% NPK	7.26	6.89	6.03
100% NPK + Zn	6.98	6.19	5.36
100% NP	5.75	5.45	5.41
100% N	5.11	5.14	4.82
100% NPK + FYM	7.22	6.64	5.68
50% NPK + BGA	6.64	6.07	5.55
50% NPK + GM	6.47	6.40	5.58

Appendix V: Percentage distribution of different forms of P (%) under soil depths.

Treatment	1.saloid-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	0.07	0.06	0.06
50% NPK	0.11	0.09	0.08
100% NPK	0.13	0.13	0.14
150% NPK	0.16	0.15	0.14
100% NPK + Zn	0.12	0.10	0.09
100% NP	0.14	0.13	0.10
100% N	0.06	0.06	0.05
100% NPK + FYM	0.16	0.15	0.14
50% NPK + BGA	0.11	0.10	0.08
50% NPK + GM	0.11	0.10	0.08

Treatment	2.Al-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	0.66	0.61	0.54
50% NPK	1.00	0.85	0.76
100% NPK	1.01	0.95	0.92
150% NPK	1.06	1.06	1.01
100% NPK + Zn	0.96	0.93	0.92
100% NP	1.03	0.97	0.94
100% N	0.77	0.54	0.49
100% NPK + FYM	1.08	1.04	1.00
50% NPK + BGA	0.92	0.92	0.73
50% NPK + GM	0.91	0.89	0.79

Treatment	3.Fe-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	1.05	1.02	0.94
50% NPK	1.29	1.23	1.03
100% NPK	1.44	1.30	1.16
150% NPK	1.46	1.44	1.23
100% NPK + Zn	1.39	1.30	1.12
100% NP	1.36	1.17	1.09
100% N	1.11	0.94	0.85
100% NPK + FYM	1.50	1.44	1.20
50% NPK + BGA	1.24	1.20	0.99
50% NPK + GM	1.23	1.15	1.08

Treatment	4.Red-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	1.81	1.76	1.78
50% NPK	2.28	1.95	1.88
100% NPK	2.29	2.03	2.01
150% NPK	2.31	2.12	2.10
100% NPK + Zn	2.23	2.10	1.94
100% NP	1.99	1.98	1.98
100% N	1.89	1.80	1.78
100% NPK + FYM	2.32	2.19	2.03
50% NPK + BGA	2.20	1.86	1.82
50% NPK + GM	2.27	1.87	1.84

Treatment	5.Ca-P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	3.38	3.32	3.20
50% NPK	3.52	3.47	3.39
100% NPK	3.68	3.59	3.47
150% NPK	3.71	3.63	3.52
100% NPK + Zn	3.64	3.45	3.32
100% NP	3.65	3.61	3.35
100% N	3.44	3.20	3.01
100% NPK + FYM	3.74	3.61	3.50
50% NPK + BGA	3.51	3.46	3.38
50% NPK + GM	3.57	3.50	3.42

Treatment	6.Available P		
	(0-15 cm)	(15-30 cm)	(30-60 cm)
Control	0.19	0.16	0.14
50% NPK	0.39	0.36	0.35
100% NPK	0.51	0.49	0.47
150% NPK	0.54	0.52	0.50
100% NPK + Zn	0.50	0.48	0.44
100% NP	0.52	0.49	0.47
100% N	0.17	0.16	0.13
100% NPK + FYM	0.53	0.52	0.51
50% NPK + BGA	0.35	0.35	0.34
50% NPK + GM	0.39	0.37	0.38

Appendix VI: Infiltration rate (mm hr^{-1})

Time	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1hrs	1.8	2	2.1	2.3	2	2.1	2.1	2.7	2.1	2.6
2hrs	1.3	1.5	1.7	1.8	1.5	1.6	1.6	2.2	1.5	2.1
3hrs	0.9	1.1	1.2	1.3	1.1	1.2	1.2	1.8	1	1.7
4hrs	0.5	0.7	0.8	0.9	0.6	1.1	0.8	1.4	0.6	1.3
5hrs	0.3	0.4	0.5	0.6	0.3	0.8	0.5	1	0.3	1
6hrs	0.2	0.2	0.2	0.3	0.2	0.5	0.2	0.7	0.1	0.7
7hrs	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.5	0.1	0.5
8hrs	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.5	0.1	0.5
9hrs	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.5	0.1	0.5