

**EFFECT OF PHOSPHORUS ENRICHED ORGANIC MANURE ON
NUTRIENT AVAILABILITY, PHOSPHORUS FRACTIONS, P USE
EFFICIENCY AND YEILD OF CHICKPEA UNDER INCEPTISOL**

by

Miss. Suryawanshi Varsha Bhausahab
(Reg. No.019/085)

A thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI - 413 722, DIST. AHMEDNAGAR
MAHARSHTRA, INDIA**

In partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY



DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR
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Dr. Ritu S. Thakare

(Chairman and Research Guide)

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POST GRADUATE INSTITUTE

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RAHURI - 413 722, DIST. AHMEDNAGAR

MAHARASHTRA, INDIA

2021

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

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This is to certify that the thesis entitled, “**EFFECT OF PHOSPHORUS ENRICHED ORGANIC MANURE ON NUTRIENT AVAILABILITY, PHOSPHORUS FRACTIONS, P USE EFFICIENCY AND YEILD OF CHICKPEA UNDER INCEPTISOL**”, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bonafide research work carried out by **MISS. SURYAWANSHI VARSHA BHAUSAHEB** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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Date : /09/2021

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LIST OF ABBREVIATIONS

%	:	Per cent
AR	:	Analytical Reagent
@	:	At the rate of
$\mu\text{g g}^{-1}$:	Microgram per gram
C	:	Carbon
CD	:	Critical difference
Cfu	:	Colonies forming unit
Cm	:	Centimeter (s)
Cu	:	Copper
dS m^{-1}	:	Deci Siemens per meter
DAS	:	Days After Sowing
DHA	:	Dehydrogenase
EC	:	Electrical Conductivity
<i>et.al.</i>	:	Et allia. (any others)
Fe	:	Iron
Fig.	:	Figure
FYM	:	Farm yard manure
g	:	Gram (s)
GRDF	:	General recommended dose of fertilizer
Ha	:	Hectare
<i>i.e.</i> ,	:	Id est (That is)
K/K ₂ O	:	Potassium
kg ha^{-1}	:	Kilogram per hectare
kg	:	Kilogram (s)
KMnO ₄	:	Potassium permanganate
mm	:	Millimeter
m	:	Meter
mg kg^{-1}	:	Milligrams per kilogram
ml	:	Milliliter (s)
MOP	:	Muriate of potash
Mn	:	Manganese
MW	:	Meteorological week
N	:	Nitrogen
<u>N</u>	:	Normal
NaOH	:	Sodium Hydroxide
NaF	:	Sodium Floride
NH ₄ Cl	:	Ammonium Chloride
NS	:	Non-significant
no.	:	Number
^o C	:	Degree Celsius
P/P ₂ O ₅	:	Phosphorus
pH	:	Negative logarithm of hydrogen ion activity
ppm	:	Parts per million
PNP	:	P-nitrophenol
PSB	:	Phosphate solubilizing bacteria
PEOM	:	Phosphorus enriched organic manure
q	:	Quintal (s)

q ha ⁻¹	:	Quintal per hectare
RBD	:	Randomized block design
RDF	:	Recommended dose of fertilizer
SE (m±)	:	Standard Error of mean
S	:	Sulphur
SSP	:	Single super phosphate
SE	:	Standard error
SOC	:	Soil organic carbon
viz.	:	Videlicet (namely)
t ha ⁻¹	:	Tons per hectare
temp.	:	Temperature
TPF	:	Triphenyl formazan
Zn	:	Zinc

ABSTRACT

EFFECT OF PHOSPHORUS ENRICHED ORGANIC MANURE ON NUTRIENT AVAILABILITY, PHOSPHORUS FRACTIONS, P USE EFFICIENCY AND YIELD OF CHICKPEA UNDER INCEPTISOL

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A candidate for the degree

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SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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Research Guide: Dr. Ritu S. Thakare

Department: Soil Science and Agricultural Chemistry

Considering the soil phosphorus availability, problems, requirement and role of phosphorus in pulses for productivity and quality, the present field experiment entitled “Effect of phosphorus enriched organic manure on nutrient availability, phosphorus fractions, P use efficiency and yield of chickpea under Inceptisol” was conducted at STCR Farm, Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, during *Rabi* 2020. The experiment was laid out in randomized block design with seven treatments replicated three times. The treatments comprised of T₁- Absolute control, T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹+ 5 t ha⁻¹ FYM), T₃-100% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation, T₄-75% P₂O₅ through Phosphorus enriched organic manure and 25% P₂O₅ through chemical fertilizer and N and K as per recommendation, T₅-60% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation, T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through Phosphorus enriched organic manure + 5 t ha⁻¹ FYM, and T₇-RDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹).

Experimental soil was medium deep black belonging to Inceptisol order and taxonomically classified as montomorillonitic isohyperthermic family of *Vertic Haplustepts*. Textural class was clayey and slightly alkaline in reaction (pH 8.14), low in soluble salts (EC 0.28 dSm⁻¹), low in available nitrogen (203.84 kg ha⁻¹), low in available phosphorus (12.7 kg ha⁻¹), very high in available potassium (627.2 kg ha⁻¹). The DTPA extractable micronutrient Zn was low (0.47 mg kg⁻¹) and Fe, Mn and Cu were sufficient (5.48, 10.41 and 0.56 mg kg⁻¹, respectively).

The significantly maximum plant height (57.00 cm), number of branches plant⁻¹ (3.01) and number of pods plant⁻¹ (87.67) and number of nodules plant⁻¹ (27.30) recorded in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatments. The significantly highest seed yield (35.58 q ha⁻¹) and straw yield (62.66 q ha⁻¹) was found in treatment of GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM).

The effect of phosphorus enriched organic manure on soil pH and EC after harvest of crop as influenced by different treatments were found to be non-significant. While, the maximum organic carbon content (0.64 %) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) which was at par with the treatment T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM). Available nitrogen and phosphorus content (214.00 and 14.31 kg ha⁻¹, respectively) and Fe, Mn, Zn and Cu micronutrient concentrations (5.83, 11.01, 0.57 and 0.62 mg kg⁻¹, respectively) in soil at harvest were significantly higher in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM). Available potassium content in soil at harvest was significantly highest (622.67 kg ha⁻¹) in treatment T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM).

The significantly highest values of phosphorus fractions observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments except Ca-P which was observed highest in treatment T₇ RDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹). However, the increased order of P fractions was noted as Ca-P>org-P>Red-P>Al-P>Fe-P>Saloid-P>Occl-P. The total-P content of soil showed non-significant result.

The significantly highest fungal (22.31 and 19.62 × 10⁴ g⁻¹ soil, respectively), actinomycetes (38.86 and 32.92 × 10⁶ g⁻¹ soil, respectively) and bacterial (46.32 and 41.03 × 10⁷ g⁻¹ soil, respectively) populations and activities of dehydrogenase enzymes (45.58 and 30.84 µg TPFg⁻¹ soil 24 hr⁻¹, respectively) and alkaline phosphatase enzymes (66.53 and 38.17 (µg PNP g⁻¹ soil hr⁻¹, respectively) were observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) among all the other treatments at flowering and at harvest of chickpea.

The nutrient concentration in grain as influenced due to phosphorus enriched organic manure showed non-significant result. The significantly highest total uptake of nitrogen, phosphorus and potash (122.66, 25.80 and 81.21 kg ha⁻¹, respectively) were observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM).

The significantly highest phosphorus use efficiency (28.34 %) observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) followed by treatment T₂.

The result of present investigation concluded that the application of GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) to chickpea grown in Inceptisol found significantly superior in enhancing the growth parameters, yield and quality parameters of chickpea, also the total uptake of N, P and K and soil fertility status (available N, P, K, Fe, Mn, Zn and Cu) improved under this treatment.

1. INTRODUCTION

The major edible pulses are beans, lentils, peas, and chickpeas. Pulses contain high percentage of protein nearly three times more than cereals (Umadevi and Ganesan 2007). In 2017, 55 million metric tons of pulses were produced worldwide, which is up from 50.19 million metric tons production in 2015. The per capita availability of pulses in India has been continuously decreasing which is 32.52 g day^{-1} against the minimum requirement of 80 g day^{-1} per capita as prescribed by Indian Council of Medical Research (ICMR), New Delhi. Indiscriminate and continuous unscientific use of chemical fertilizers to field crops created an adverse effect on soil physical, chemical and biological properties there by affecting the sustainability of crop production, besides causing environmental pollution (Virmani 1994). Therefore, it is necessary to agricultural scientists to evolve strategies to increase production and productivity of pulses to meet the dietary protein requirements of increasing population of the country.

Grain legumes play an important nutritional role in the diet of millions of vegetarian people in the developing country like India as a cheap source of protein and are thus sometimes grain legumes are referred as the poor man's meat. The legume crops are normally grown in rotation with cereals because of their proved role in biological nitrogen fixation (Merga and Haji 2019). The legume cultivation improves soil fertility. Cultivation of kharif pulses benefits the succeeding crops. The organic manures contains the substantial organic carbon and also both macro and micronutrients which are helpful to maintain under improve physical conditions of soil and fertility status and their effect on crop yields. Among summer pulses, rice bean, cowpea showed more beneficial effects in succeeding cereal crops. These benefits are more in succeeding crops when summer pulses are raised with optimum dose of fertilizers phosphorus with a micronutrients like cobalt and molybdenum (Pandher *et al.* 1976).

The chickpea (*Cicer arietinum*) is an edible *rabi* legume of the family Leguminous; high in protein, dietary fiber, folate and dietary mineral content and one of the earliest cultivated vegetables (Zohary and Maria 2000). It is healthy source of carbohydrates for persons with insulin sensitivity or diabetes (Deppe 2010). One hundred grams of mature boiled chickpea grains contains 164 calories, 2.6 grams of fat (of which only 0.27 grams is saturated), 7.6 grams of dietary fiber and 8.9 grams of protein. Chickpeas also provide dietary phosphorus ($49\text{--}53 \text{ mg } 100^{-1} \text{ g}$). As chickpea has a deep tap root system that extend upto 120 cm deep which enhances its capacity to withstand drought conditions, it is usually beneficial to those areas having where relatively and a low level of rainfall of predominance. It yields the best when it grown on sandy loam soils having an appropriate drainage system as this crop is very sensitive to the excess water availability and a lack of such system can significantly hamper the yield levels.

The world's total production of chickpea covers around 8.5 million metric tons annually and is grown over 10 million hectares of land approximately. The Desi type chickpea contribute to around 80% and the Kabuli type around 20% in the total production of chickpea. India is the largest producer of this pulse contributing to around 70% of the world's total production. Desi type chickpea largely dominate the more ratio of production in India. Regarding the consumption pattern, all most all of the chickpea is consumed in the countries where it is produced. According to the World Trade Statistics, the total world exports of chickpea in 2002 were 743 thousand tons (Anonymous, 2021).

There is a vast scope for increasing productivity of chickpea by adopting various agro-techniques. For achieving the potential crop yield per unit area, high yielding varieties should be coupled with proper agronomic and also soil management practices. Amongst various factors known to augment the crop production, fertilizers added with manure and suitable agronomic practices play a pivotal role to boost up the productivity of crops. Currently, 40 to 50 per cent increase in agricultural production can be credited to fertilizers alone (Tondon 1994). However, judicious use of fertilizers along with manures is of vital importance to achieve higher productivity of crops.

Over the last several years, India has been the top producer of chickpeas, also known as garbanzo beans, worldwide. In 2019, the production volume of chickpeas in India amounted to near around 14 million metric tons. Turkey came in second at an estimated 630,000 metric tons of chickpeas. The recent liberalization has expanded the demand for chickpea from international markets in addition to the growing domestic demand.

The crop productivity under organic production system can be enhanced through optimizing the nutrient requirement of crop at different stages. Organic systems rely on management of organic matter to enhance the soil fertility and productivity (Naik *et al.* 2014). Incorporation of organic manure with chemical fertilizers increase the crop productivity with increase in soil organic carbon content, infiltration rate, water retention, aggregation and aggregate stability in water.

Among the major nutrients, pulses have more requirement of phosphorus. Thus, phosphorus deficiency in soils is usually the key factor for poor yield of pulses. Yield of pulses can be improved significantly by applying phosphorus on the basis of soil test value and crop requirement information. Phosphorus is an important mineral element for nutrition of grain legumes as it helps in root development, biological nitrogen fixation, participates in the synthesis of phosphates and phospho-proteins and takes part in energy fixing and releasing process in soil (Singh and Yadav 2008). Phosphorus transformation and its mobility in the soil-plant system are controlled by a combination of soil biological, chemical and physical process. The amount, forms and dynamics of soil P are influenced by a number of factors including soil types and

environmental conditions, as well as land –use pattern and also other crop and soil management practices (Attiwell and Adams 1993; Frossard *et al.* 2000). Phosphorus (P) is an essential nutrient both as a part of several key plant structure compounds and also as catalysis in the conversion of numerous key biochemical reactions in plants. P is noted especially for its role in capturing and converting the sun's energy into useful plant compounds; thus, P is essential for the general health and vigour of plants. Some specific growth factors that have been associated with P are: stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased N-fixing capacity of legumes, improvements in crop quality, and increased resistance to plant diseases (Griffith 2010).

Phosphorus is required by all crop plants but it is limited in soil. Thus, phosphorus must be added to soil for the extensive plant growth that is desired for crop production. The transformation and rate of reversion of applied P in soil is governed by factors like soil organic matter content, incorporation of crop residues, soil microbial population, cropping systems and nature, quantity of manures and fertilizer. Generally, fertilizer P is added to increase concentration of P in soil solution. But added P undergoes a series of reactions in soil and forms products of varying solubility. Around 3–4 million tons of applied inorganic P fertilizers have been leached into the surface groundwater through infiltration, drainage, or surface runoff (Hong-ling *et al.* 2010; Jaisi *et al.* 2011), which in turn cause the eutrophication or red tide in the water ecosystems (Vohla *et al.* 2011; Niyungeko *et al.* 2018). It is estimated that around 80% of applied P becomes unavailable to plants due to its immobile nature in the soil and has ability to form complexes with other nutrients such as aluminium (Al) and iron (Fe) (Rana *et al.* 2020; Teng *et al.* 2020).

Fractions of inorganic phosphorus in soil are known to be as immediate sources for supplying P to crop utilization. A number of attempts have been made to study the fate of applied P and its subsequent recovery as different inorganic fractions like Saloid-P, Al-P, Fe-P, Ca-P, reductant P, occluded Al-P and Fe-P based on fractionation procedure (Chang and Jackson 1957) and to relate the various inorganic P fractions with available P extracted by various chemical methods. Thus, chemical fractionations of soil inorganic phosphorus have been used to evaluate the contribution of various inorganic phosphorus fractions towards P nutrition to different crops and to find out the transformation of added phosphatic fertilizers into various inorganic phosphorus fractions in relation to availability of P to crops. Information on P transformations in soil have been reported mostly from the laboratory experiments conducted over short periods without involving crop plants and such laboratory results may not be applicable directly under the actual field conditions where soil-plant fertilizer form a complex

and amalgamated system to predict soil-P dynamic and their effects on P availability to crops and their effects on yield.

The basic concept of integrated nutrient management (INM) is the supply of nutrients required by plant for sustaining the desired crop productivity with minimum deleterious effect on soil health environment. Integrated nutrient management intended for four major goals to be achieved. These are to maintain soil productivity, to ensure sustainable productivity, to prevent degradation of the environment and to reduce expenditure on the cost of chemical fertilizers (Sharma 2004).

Phosphorus enriched organic manure is known as a green chemistry phosphatic fertilizer. Addition of natural minerals or synthetic oxides in water-insoluble forms that contain micronutrients such as copper, zinc, and cobalt in manure may improve the efficiency of phosphorus enriched organic manure. Phosphate rich organic manure is produced by co-composting high-grade (32% P_2O_5) rock phosphate in very fine size (say 80% finer than 54 microns). Needless to say, that the finer the rock phosphate the better is the agronomic efficiency of phosphorus enriched organic manure.

Phosphorus rich organic manure may be a more efficient way of adding phosphorus to soil than applying alone chemical P fertilizers. Mobility of manure-P may be related to its chemical forms because organic P is reported to be more mobile than inorganic P (Hannapel *et al.* 1964a, 1964 b). Nevertheless, the forms of P in manure may not be the only factor dictating the mobility of P in soil. Other benefits of phosphorus enriched organic manure are that it supplies phosphorus to the second crop planted in a treated area as efficiently as the first. P chemical fertilizers are expensive and they are not capable of supplying more than one nutrient to crops. Therefore, the current trend is to explore the INM practice that is possibility of supplementing chemical fertilizers with organic and biofertilizers. Organic manures contain all the essential elements but their content is too low to satisfy the need of the fast growing and high yielding varieties of crops. Considering the above facts of increasing the productivity of chickpea, role of P in crop production, its chemistry in soil for its availability to crops and the significance of INM, the present field experiment entitled, “Effect of phosphorus enriched organic manure on nutrient availability, phosphorus fractions, P use efficiency and yield of chickpea under inceptisols” was taken at STCR project, MPKV, Rahuri, with the following objectives:

1. To assess the effect of phosphorus enriched organic manure on nutrient availability, phosphorus fractions and P use efficiency.
2. To assess the effect of phosphorus enriched organic manure on soil microbial count and enzyme activities.
3. To assess the effect of phosphorus enriched organic manure on nutrient uptake and chickpea yield.

2. REVIEW OF LITERATURE

The current global scenario firmly emphasizes the need to adopt eco-friendly agricultural practices for sustainable food production. The integrated nutrients management would serve the dual purpose of minimizing pollution and utilizing wastes for enhancing the soil productivity. It envisages comprehensive management approach to improve soil health in terms of physical, chemical and biological properties. The utilization of enriched organic manures for crop productivity was found beneficial to soil production. In this context, the literature pertaining the use of organic manures and their effects on crop growth as well as on soil properties has been reviewed. Attempts are, therefore, made to present a brief summary of work carried out previously relating to the problem under study which has been highlighted and reviewed under the given headings.

2.1 Effect of Organic Manure on Phosphorus Fractions and P Use Efficiency

2.2 Effect of Organic Manure on Soil Physical and Chemical Properties

2.3 Effect of Organic Manure on Soil Enzymes

2.4 Effect of Organic Manure on Soil Microbial Population

2.5 Effect of Organic Manure on Yield

2.6 Effect of Organic Manure on Nutrient Uptake

2.1 Effect of Organic Manure on Phosphorus Fractions and P Use Efficiency

Phosphorus in soil occurs in various forms of phosphorus as saloid bound P, Fe-Reductant soluble P, Occluded P, Ca-P and organic. Since, these forms of phosphorus have different solubilities mobility and thereafter, the availability of P to crops and uptake of P by crops depend upon the quantities of different forms of phosphorus in soils. Manure application has been reported to increase soil concentration of both total and soluble P, as well as concentration of specific P form, including stable organic P moieties (Waldrip-Dail *et al.*, 2009).

Szott and Melendiz (2001) reported that agroforestry system conserve P in form that are more crop-available than those found in annual cropping system on two tropical sites: an Ultisols in Yurmiagas, Peru and inceptisols in Turrialba, Costa Rica. In both sites, the Hedley P fractions were compared in annual cropping, alley cropping, multistrata agroforestry and old forest systems. They found that under non-fertilized conditions the multistrata and forest system maintained more and a greater proportion of P in plant available resin form than the annual alley cropping systems, the results further showed that greater resin P was associated with greater amount and percentage of P in bicarbonate fractions and less P in residual fractions. However, resin P increased even more when inorganic P fertilizers were combined with organic residue additions.

Basavaraj and Manjunathaiah (2002) studied the effect of phosphorus levels with phosphorus enriched manures on phosphorus transformation into different forms in Vertisol

using maize as a test crop. The results indicated that the application of P-enriched poultry manure at one t ha⁻¹ along with P-levels increased the conversion of applied P into Saloid-P, Al-P, Fe-P, Ca-P, Reductant-soluble-P and occluded-P.

Murthy *et al.* (2002) studied the transformation of added phosphorus into distinct fractions under incubation of a few Vertisol pedons of different parentage. Applied phosphate transformed mostly into Ca-P followed by Fe-P and Al-P, and in general increased with increasing rates of phosphorus application in all the pedons irrespective of their parentage.

Sheeba and Kumaraswamy (2005) observed that amongst the manures, urban compost manure applied @ 12.5 t ha⁻¹ improved the maximum status of total P (895 ppm), organic P (144 ppm) and inorganic P (743 ppm) followed by the use of FYM @ 12.5 t ha⁻¹.

Dutta and Mukhopadhyay (2007) carried out fractions of some acid soils in west Bengal (India) selecting four different soil series of west Bengal. The soils were acidic (pH :4.21 to 5.67) in nature with moderate to high in organic carbon content. They observed that different inorganic form of soil P, in general decreased in order, Al-P >Fe-P>reductant-soluble P >Ca-P >Occluded P >Saloid P.

Abolfazli *et al.* (2012) studied the effects of phosphorous fertilizer (PF) from sources of triple superphosphate (TSP) and di-ammonium phosphate (DAP) and organic fertilizer (OF)s from sources of cow dung manure (CDM) and municipal solid waste compost (MSWC) on phosphorous (P) fractions include aluminium- P (Al-P), iron-P (Fe-P), Reductant soluble-P (RS-P), calcium-P (Ca-P) and available- P (Olsen-P) fractions under rice cultivation condition. The trials were carried out in calcareous and acidic soils at Department of Soil Science, Faculty of Agriculture, University of Guilan, Iran. Results showed that Ca-P was the predominant form of P in calcareous soil while, Fe-P and Al-P were predominated in acidic soils. In calcareous soil, all forms of P under submerged conditions had been increased because of using PFs both alone and in combination with OFs. In acidic soil, significant amounts of P fractions were found only in Fe-P and RS-P fractions. Accordingly, Fe-P fraction increased in 10 mg kg⁻¹ treatment and RS-P increased in MSWC treatment. Among the inorganic P fractions in calcareous soil, only RS-P; and in acidic soil, Ca-P and Fe-P significantly correlated to Olsen-P.

Rehim *et al.* (2012) conducted an experiment to explore the role of different phosphorus (P) levels and application methods in improving P uptake and phosphorus use efficiency (PUE) on calcareous soils at Departments of Soil Science and Agronomy, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan. Five P levels viz., 0.0, 27.0, 47.0, 81.0 and 111.0 kg P₂O₅ ha⁻¹ and three application methods i.e., broad casting, band placement and top dressing was included in the study. The experiment was conducted with and without FYM application. Band placement of P at 81 kg P₂O₅ ha⁻¹ improved P uptake and PUE with and without FYM application. Nonetheless, application of 111.0 kg P₂O₅ ha⁻¹ resulted

in maximum Olsen P and PUE of wheat. Broad casting of P performed poor at all P levels. Application of FYM with P fertilizer improved wheat yield and PUE as compared with fertilizer alone.

Lourenzi *et al.* (2015) studied P accumulation in the soil and transfer of P forms in surface runoff from a Hapludalf soil under no-tillage subjected to successive swine effluent applications and the research was carried out in the Agricultural Engineering Department of the Federal University of Santa Maria, Brazil, on a Typic Hapludalf soil and the results showed that in areas with successive swine effluent applications, practices that promote higher water infiltration into the soil are required, e.g., crop rotation and no-tillage system. The high amounts of P applied in swine effluent caused significant increases in available P levels in the soil, resulting in transfer in runoff in the following order: available P > soluble P > particulate P.

Nayak *et al.* (2015) observed the effect of organic and inorganic fertilization on depth wise distribution of different forms of phosphorus in Vertisol was performed under rice crop on soil samples obtained from the ongoing long term fertilizer experiment project at Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwa Vidyalaya, Raipur. All P 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 in Vertisol. The integration with FYM showed pronounced effect on P fractions. Maximum portion of applied P was transformed in Ca-P followed by Red-P, Fe-P and Al-P. Percentage distribution of different forms of P at 0-15 cm, 15-30 cm and 30-60 cm soil depths was also studied. The higher amount of all P fractions (%) were recorded in surface layer (0-15 cm) than at sub surface (15-30 cm) and low in deep layer (30-60 cm).

Song *et al.* (2017) carried out a field trial with three treatments and three types of annually rotated vegetables was conducted in calcareous soil in a greenhouse. Compared with the values of the inorganic P (Pi) fractionation, including Ca-P, Al-P and Fe-P, significantly increased over time by 310.89 mg kg⁻¹, 36.21 mg kg⁻¹, and 18.77 mg kg⁻¹, respectively, with organic manure treatment and by 86.92 mg kg⁻¹, 175.87 mg kg⁻¹, and 24.27 mg kg⁻¹ with chemical fertilizer treatment. These results suggest that the large amounts of P were released from Ca-P and Al-P and were taken up by vegetables in the calcareous soil, and the excessive application of P fertilizer, especially organic manure, resulted in a substantial accumulation of Pi (Ca-P, and Al-P).

Rigo *et al.* (2018) studied phosphorus fractions in the soil under the crop-livestock system after six years of application of organic or mineral fertilizers. The experiment was conducted on a Rhodic Kandiudox (Nitossolo Vermelho Distroférico) in Brazil in a randomized block design, using a 5 × 3 + 1 factorial scheme, with four replicates. Result showed that successive use of organic or mineral fertilizers for six years in the crop livestock system

considerably raises the labile and moderately labile P fractions up to the 0.20 m depth and, with less intensity, raises the non-labile fractions up to the 0.10 m depth. The soil P increase associated with fertilizer input raises soybean and corn yields, and it does not exceed the critical P limit according to local environmental legislation.

Bhavsar *et al.* (2018) carried out phosphorus fractionation study at Nagpur in relation to soil properties. Majority of soils of the study area were clayey in nature, neutral to moderate alkaline in reaction, soil organic carbon was moderate to moderately high in soils, EC values for these soils within safe limits, moderately calcareous in nature. The available phosphorus content of the soils was low to moderately high. Available P was significant positively correlated with Total-P, Organic -P, and Ca-P, Organic carbon had significant positive correlation with Total- P, Organic-P, Fe-P and Ca-P, Total-P and organic-P had significant positive correlation with all the fractions except Occl-P. The results further showed that all the form of inorganic P were highly significant and positively correlated with each other except Al-P and Occl-P.

Sudhakaran *et al.* (2018) investigated the effect of 32-year long-term integrated nutrient management treatments (control, Inorganics fertilizers only, Inorganics fertilizers + N substituted FYM, wheat cut straw (WCS), green manure (GM) and Farmers practices) on soil p fractions and availability of P at Mahatma Phule Krishi Vidyapeeth, Rahuri. The P status of the different soil P-fractions (Saloid-P, Fe-P, Al-P, Red-P, Occl-P and Ca-P) were analysed from 0-15 cm and 15-30 cm soil depths and their correlation with available-P was studied and suggested that the adoption of integrated nutrient management comprising 50 % RDF + 50 % N-FYM helps to circumvent P-deficiency under sorghum-wheat sequence in Vertisol.

Mahmood *et al.* (2020) studied the transformation of P into different organic (Po) and inorganic (Pi) fractions, and their role in the plant P uptake and winter wheat (*Triticum aestivum* L) production at State Key Laboratory of Crop Stress Biology in Arid Areas, Northwest University, Yangling, China. Result showed that different P rates significantly increased the available P, particularly $\text{NaHCO}_3\text{-P}_i$, in the inorganic P fractions compared to P_0 treatment. Among all Pi fractions, the maximum fraction, known as apatite ($\text{HCl}_D\text{-P}_i$), was found in the P_{200} treatment with the range of 165 to 245.9 mg kg^{-1} . $\text{HCl}_D\text{-P}_i$ accounted for 32% of total P, which can be transformed into the available P form with the passage of time.

Wierzbowska *et al.* (2020) studied the effect of sewage sludge and composted sewage sludge and municipal waste on the content of various forms of P in soil. The experiment scheme: C, control; NPK; FYM; DGSS, dried and granulated sewage sludge; CSS, composed sewage sludge; CSSS, composted sewage sludge and straw; CMMW, composted mixed municipal waste; CMGW, composted municipal green waste. The content of bound P was determined in the fractions: F_1 , easily soluble; F_2 , exchangeable; F_3 , organic; F_4 , carbonate; F_5 , stable organic-mineral and mineral bonds; and F_6 , residual. The NPK fertilisation as well as the soil fertilisation

with organic substances raised the P-total content and of P bound in the fractions: F₃, F₄, F₅ and F₆. The highest amount of phosphorus in the studied soil was in fraction F₃ (phosphorus in organic compounds) and the lowest in fraction F₁ (phosphorus in the ionic form as H₂PO₄⁻ and HPO₄²⁻). Composted sludge and straw introduced into the soil increased the content of readily soluble P (F₁), while, the NPK effect was reversed. NPK fertilisation and enhancement of soil organic matter (except CSSS, CMGW) led to a reduction of the P content in F₂ fraction.

Ghosh *et al.* (2021) studied the effect of organic and inorganic sources of nutrients with inclusion of microbial inoculants/biofertilizer and lime on different inorganic fractions of phosphorus (P) in acidic soil at College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar. The test crop maize was 17th crop in the sequence. The INM practices include i) soil test dose (STD) as pure inorganic source ii) combination of inorganic with organic in the form of either farm yard manure (FYM) @ 5 t ha⁻¹ or vermicompost @ 2.5 t ha⁻¹ iii) inclusion of microbial inoculant/biofertilizer (*Azotobacter*, *Azospirillum* and PSB (1:1:1) and soil amendment in the form of lime @ 0.2 lime requirement (LR) compared with iv) absolute control, i.e., without any fertilization. The results showed cultivation without any fertilizer caused a decrease in available-P, saloid P (Sal-P), aluminium phosphorus (Al-P), calcium phosphorus (Ca-P) and total P but there is accumulation of iron phosphorous (Fe-P), reductant phosphorous (Red-P) and occluded phosphorous (Occ-P).

Lu *et al.* (2021) studied the effects of substituting chemical P fertilizer with pig manure (NKM) on rice yield, phosphorus use efficiency (PUE) and P balance at Soil and Fertilizer Institute of Hunan Province, Hunan Academy of Agricultural Sciences, Yuanda, Furong District, Changsha, China. The N, P and K input under NKM was 1.2, 0.8 and 1.2 times of the combined chemical fertilizer treatment (NPK), respectively. Result showed that NKM treatment reduced the crop P uptake leading to decreased PUE compared with NPK.

2.2 Effect of Organic Manure on Soil Physical and Chemical Properties

Integrated phosphorus management practices were found beneficial for sustaining soil health in terms of building up of organic carbon, availability of macro and micronutrients (Desai *et al.*, 2009). The reports of researchers appeared in literature on effect of phosphorus enriched organic manure on chemical and physical properties of soil are reviewed below.

Parham *et al.* (2003) studied microbial populations and community structures in soils under different management systems in a long-term continuous winter wheat, experiment was conducted in Southern Medical University, Oklahoma, United States. The richness and evenness of the bacterial community were enhanced by manure treatment and treatments that included N and P, which were positively correlated with soil productivity.

Bhattacharya *et al.* (2004) studied the effect manuring on soil organic carbon, bulk density and water retention characteristics under Soybean-wheat cropping sequence in northern-

western Himalaya's. Result showed that the soil bulk density at various depths (0- 15, 15-30 and 30-45 cm) significantly reduced by application of FYM @ 10 t ha⁻¹.

Sharma (2004) examined the integrated nutrient management in rice-wheat cropping system in Indian Rice Research Institute, Hyderabad, Telangana and confirmed that the application of FYM @ 10 t ha⁻¹ increased available NPK over the chemical fertilizers treated plot in rice-wheat sequence.

Singh *et al.* (2005) reported that soil organic carbon and available P content increased significantly due to organic farming practice compared to the control as well as chemical fertilizer application.

Rajshree and Bharati (2005) reported that the application FYM decreased the bulk density and increased the organic carbon content of soil when it was applied @ 7.50 t ha⁻¹ along with 50 kg ha⁻¹ nitrogen and 30 kg ha⁻¹ phosphorus.

Ghuman and sur (2006) reported that application of FYM@18 t ha⁻¹ recorded lower bulk density (1.36 Mg m⁻³) over FYM applied @ 6 t ha⁻¹ the bulk density (1.4 Mg m⁻³) and control increase the bulk density up to 1.43 Mg⁻³. They also noticed that organic carbon was maintained at higher level with increase in available N, P, K over control.

Kumar *et al.* (2006) revealed that decrease in soil pH and electrical conductivity and increase in organic carbon with the application of organic manures along with balance fertilizers.

Urkurkar *et al.* (2006) reported that the pH of soils and electrical conductivity was slightly declined in all the treatments containing green manure/farmyard manure/rice-straw residue except in that treatment which had received only inorganic fertilizers. Farmyard manure recorded more decrease in electrical conductivity (15%) to that of 100% RDF which had reached highest values.

Tejada and González (2009) reported that vermicompost had a positive effect on the soil biological properties and rice quality and yield parameters with respect to the no vermicompost amended soil. This increase in soil biological properties produced an increase in the plant nutrition, which increased rice quality and yield.

Dasci *et al.* (2010) carried out research at Ataturk University farm in Erzurum, Turkey and evaluated the effects of phosphorus fertilization and phosphorus solubilizing bacteria (*Bacillus megaterium* var. *phosphaticum*) applications on the chemical composition of forage from a natural meadow area. Result showed that the forage P and Ca contents were increased, but K and Mg contents decreased following phosphorus fertilization. While, bacteria application increased K and Mg contents of forage and Ca content decreased. There was no notable change in P content of forage following the application of bacteria. The results indicated that P fertilizer and bacteria applications have positive effects on forage quality of meadows.

Roy *et al.* (2010) studied the effect of different amendments to soil on the plant growth and productivity. The paddy straw and *Ageratum conyzoides* residues was used as direct mulch, compost, and vermicompost in different plots planted with *Zea mays*, *Phaseolus vulgaris* and *Abelmoschus esculentus*, separately in three experimental plots and revealed that different amendments affected crops differently and the pre-treatment of crop/plant residues like vermicomposting are invariably beneficial and contributed to crop growth and available N in soil.

Dadhich *et al.* (2011) conducted the research at Udaipur to studied the integrated use of fertilizer P, FYM and biofertilizer on soil properties, reported that the application of increasing levels of P, FYM and biofertilizer significantly increased the organic carbon, CEC, available N, P and K contents in soil.

Jadhav *et al.* (2011) found that the application of organic manure resulted in significantly higher in soil organic carbon, available NPK than chemical fertilizers but was on par with the integrated nutrient treatment.

Kokani *et al.* (2015) studied the effect of farm yard manure, phosphorus and sulphur on yield of summer black gram and post-harvest status of nutrients under South Gujarat condition at college farm, Navsari Agricultural University, Navsari. The protein content, protein yield was recorded significantly higher under the incorporation of 5 t FYM ha⁻¹ over control. The organic carbon content, available nitrogen and phosphorus status of soil were also found significantly higher under same treatment.

Rajkhowa *et al.* (2016) studied an appropriate nutrient management practice for increasing green gram productivity, improving soil health, and thus bringing sustainability to pulse production system in the hilly terrains of North East India. Nutrient management practices significantly influenced the yield components, yield, soil nutrient status, as well as microbial population in soils. Integrated use of 50% RDF + VC 2.5 t ha⁻¹ + lime 4 q ha⁻¹ resulted in significantly improved the soil organic carbon (2.5 %), bacterial and fungal population, pH and available N, P₂O₅ and K₂O compared to recommended dose of fertilizer applied alone.

Erhunmwunse *et al.* (2019) studied the nutrient mineralization pattern of poultry manure compost enriched with inorganic nitrogen (N) and phosphorus (P) fertilizer nutrients in an Ultisol at Department of Soil Science and Land Resources Management, Obafemi Awolowo University, Ile-Ife, Nigeria. Compost applied at the rate of either 5 or 10 g kg⁻¹ was blended with N (50 kg N ha⁻¹) and P (30 kg P ha⁻¹). The combination of compost and inorganic N and P increased carbon (C) and P mineralization by 4–8% and 56–289%, respectively, over the application of either compost or inorganic N and P. However, P addition influenced the amount of C mineralized. Inorganic N and P, on the other hand, were better at increasing N mineralization than compost blended with inorganic N and P over a short time.

Almeida *et al.* (2019) conducted a greenhouse experiment using animal manure incorporated in a clayey soil, at a rate that equates to the P needs of *Brachiaria* at Soil Department, University of São Paulo (USP), and Results showed that the application of enriched animal manure increased the contents of Ca, Mg, and K over time. Soil fertilized with cow manure resulted in the greatest contents of P while, soil with turkey manure presented the highest production of dry matter with the lowest contents of P in soil. There was an increase in Na content in soil with the application of animal manure. Fertilization with animal manure presents the potential to supply P, Ca, Mg and K for plants. Enriched cow manure appears to be the most viable option to improve the phosphorus and organic matter in soil because of high C/N.

Gao *et al.* (2019) conducted an experiment with two cotton cultivars (CCRI 79 and LMY 28) and three phosphorus (P) levels: 3, 8 and 12 mg P₂O₅ kg⁻¹ as P0, P1 and P2, respectively at Jiangsu Key Laboratory of Phylogenomic and Comparative Genomics, School of Life Science, Jiangsu Normal University, Xuzhou, P.R., China. The soil water-soluble organic carbon content increased as the soil available P increased, while, there were no significant variations for soil total organic matter content among the three available phosphorus levels.

Billah *et al.* (2020) carried out a field experiment to evaluate the impact of rock phosphate enriched composts and chemical fertilizers both individually and in combination with plant growth promoting rhizobacteria (PGPR) on wheat productivity and soil chemical and biological and biochemical properties at Department of Soil Science, University of Haripur, Haripur, Pakistan and demonstrated significant increments in crop agronomic and physiological parameters with *Pseudomonas sp.* inoculated RPEC1 (rock phosphate + poultry litter + *Pseudomonas sp.*) over the un-inoculated untreated control. However, among all other treatments i.e., RPEC2 (rock phosphate + poultry litter solubilized with *Proteus sp.*), RPC (rock phosphate + poultry litter), HDP (half dose inorganic P from Single Super Phosphate-SSP 18% P₂O₅) and SPLC (poultry litter only); RPEC1 remained the best by showing increases in soil chemical properties (available phosphorus, nitrate nitrogen and extractable potassium).

Elkhlifi *et al.* (2021) studied the efficacy of various phosphate-lanthanum (P-La) modified sewage sludge biochar (SSBC, La-SSBC, SSBC-P, La-SSBC-P) on soil phosphate-retention and ryegrass (*Lolium perenne L.*) growth in an alkaline soil (excess CaCO₃). La-SSBC-P treatment significantly altered the chemical characteristics of post-harvest alkaline soil, such as pH, electrical conductivity (EC), cation exchange capacity (CEC), soil organic matter (SOM), limestone (CaCO₃), phosphate, and lanthanum contents. In comparison to the SSBC treatment, soil available phosphorous (AP) contents under La-SSBC-P were enhanced by 6.7 times after loading biochar with P and La (La-SSBC-P). Overall, results showed that the P-loaded lanthanum decorated biochar (La-SSBC-P) could be used as a potential substitute for P-fertilizer under the experimental conditions.

2.3 Effect of Organic Manure on Soil Enzyme

Soil enzymes play key role in the transformation, recycling and availability of plant nutrients in soil. Enzymes mediate the activities performed by microbes in soil. The enzymes are largely regulated by its origin and distribution, soil, moisture, temperature, pH and substrate and used as indicators for monitoring biological status of soil (Nannipieri *et al.*, 1983). Literature available on activity of soil enzymes *viz.*, dehydrogenase and alkaline phosphatase and their effect on phosphorus availability is presented here.

Batra (2004) reported that dehydrogenase activity of soil is varied with variation in the content of soil organic carbon. He found higher dehydrogenase activity in soil with higher organic carbon content (0.9 to 1 %).

Singh and Ramesh (2005) observed the higher soil enzyme activities in the organic amended soils over soil with inorganic fertilizer application and they noticed the highest dehydrogenase activities in soil amended with FYM @ 4 t ha⁻¹ which was on par with soil amended with poultry manure @ 2 t ha⁻¹.

Balakrishnan *et al.* (2007) reported that the application of compost in combination with farmyard manure and phosphate solubilising bacteria significantly increased the soil microflora such as bacteria, fungi and actinomycetes and soil enzyme activities such as dehydrogenase, alkaline phosphatase, cellulase and urease.

Ramesh *et al.* (2008) after three cropping system cycles of soyabean-wheat observed that three organic manure which is poultry manure, vermicompost and cattle dung manure vis-à-vis chemical fertilizer, enzyme activity of soil (dehydrogenase and phosphatase activity) was significantly improved in organic manure treatments compared to chemical fertilizers.

Chang *et al.* (2010) evaluated the effects of different application rates of compost (Rate 1, 270 kg N ha⁻¹ y⁻¹; Rate 2, 540 kg N ha⁻¹ y⁻¹; Rate 3, 810 kg N ha⁻¹ y⁻¹; Rate 4, 1,080 kg N ha⁻¹ y⁻¹) were compared with the effects of chemical fertilizer (CF) and no application of fertilizer treatments in Department of Nursing, Mackay Medicine, Nursing and Management College, Taipei. Soil enzyme activities increased significantly in the compost-treated soils compared with the chemical fertilizer-treated soil and no significant rate increase was observed in the enzymatic activities studied for compost applications higher than a Rate 2 treatment. However, all enzymatic activities examined showed significant linear correlations with the organic matter contents of the soils.

Lemanowicz *et al.* (2015) studied the activity of alkaline and acid phosphatase in soil under winter triticale fertilized with cattle farmyard manure (FYM) stored in various conditions: aerobic, anaerobic, and aerobic, with burnt lime added. The application of FYM stored under aerobic conditions with burnt lime added resulted in a significant increase in the alkaline phosphatase activity in soil (1.00 mm pNP·kg⁻¹·h⁻¹ for a depth of 0-15 cm, and 0.830 mm

pNP·kg⁻¹·h⁻¹ for 15-30 cm). However, there is a significant inhibition of acid activity (1.381 mm pNP·kg⁻¹·h⁻¹ for a depth of 0-15 cm, and 1.275 mm pNP·kg⁻¹·h⁻¹ for 15-30 cm). Recorded a highly significant correlation between the content of available phosphorus and the activity of alkaline phosphatase in soil ($r=0.731-0.879$; $p<0.05$).

Basak and Gajbhiye (2018) conducted a pot culture experiment for two consecutive years in the late rainy season to evaluate the efficiency of rock phosphate charged compost as an organic P fertilizer source in senna at ICAR-Directorate of Medicinal and Aromatic Plants Research, Boriavi, Anand, Gujarat, India. Both acid and alkaline phosphatase activities in soil were influenced by P sources, while, alkaline phosphatase found significantly higher with RPCC application. So, it could be concluded from the study that enriched compost effectively supplement costly chemical fertilizer like DAP as a P source. The result from the study may be recommended for efficient P management in both commercial as well as organic cultivation of senna.

Gao *et al.* (2019) conducted an experiment with two cotton cultivars (CCRI 79 and LMY 28) and three phosphorus (P) levels: 3, 8 and 12 mg P₂O₅ kg⁻¹ as P₀, P₁ and P₂, respectively at Jiangsu Key Laboratory of Phylogenomic and Comparative Genomics, School of Life Science, Jiangsu Normal University, Xuzhou, P.R., China. There were positive correlations between invertase and cellulose activities with soil organic carbon and inorganic-nitrogen (N); these correlated negatively with soil C/N ratio and available phosphorus level. In addition, high soil available phosphorus can raise soil available phosphorus and enhance alkaline phosphatase activity, which had a significant negative relationship with the soil C/P ratio.

Billah *et al.* (2020) carried out a field experiment to evaluate the impact of rock phosphate enriched composts and chemical fertilizers both individually and in combination with plant growth promoting rhizobacteria (PGPR) on wheat productivity and soil chemical and biological and biochemical properties at Department of Soil Science, University of Haripur, Haripur, Pakistan. Among all treatments i.e., RPEC2 (rock phosphate + poultry litter solubilized with *Proteus sp.*), RPC (rock phosphate + poultry litter), HDP (half dose inorganic P from Single Super Phosphate-SSP 18% P₂O₅) and SPLC (poultry litter only), the RPEC1 (rock phosphate + poultry litter + *Pseudomonas sp.*) remained the best by showed increases in alkaline phosphatase activity.

2.4 Effect of Organic Manure on Soil Microbial Population

Soil and manures have a variety of microbes they convert unavailable form of nutrients into available forms to the plant growth. The mineral phosphate solubilizing microbes, which include bacteria, fungi and actinomycetes are ubiquitous and their number and type varies with soil, climate and vegetation. The organic material in combination with fertilizers enhance the biological activities and in turn increase the mineralization of nutrients (Qureshi *et al.*, 2005).

Judicious use of organic manure and fertilizer is thus essential to maintain biological activity of soil for sustainable agriculture.

Dinesh *et al.* (2000) studied soil microbial biomass as influenced by organic manure (poultry manure, farmyard manure, *sesbania* and *Gliricidia*) in soils of rice-rice system. Soils freshly amended and soils previously amended with organic manures registered significantly greater microbial biomass (total bacteria, fungi, actinomycetes) than the unamended control.

Naidu *et al.* (2000) studied the effect of manures, bio and chemical fertilizers on the soil microbial population. The results showed that application of manures with biofertilizers harboured significantly more microbes in soil over control. The bacterial, fungal and actinomycetes count were maximum under FYM 35 t ha⁻¹ + *Azospirillum* + phosphate solubilizing bacteria.

Sharma *et al.* (2000) reported that microbial population enhanced significantly due to crop residues and FYM as compared to the chemical fertilizers alone.

Rajni Rani and Sanoria (2001) studied the soil microbial population as affected by biofertilizers and other amendments during soybean growth. The results showed that total bacterial population was negatively correlated with fungal population and positively with actinomycetes and PSB population at all growth stages of soybean. The soil microflora ranked in the order of total bacteria > actinomycetes > fungi > PSB.

Panda *et al.* (2003) studied the effect of phosphorus levels and biofertilizers on microbial population in the rhizosphere of wheat. The results showed that phosphorus has a positive influence on the population of *Pseudomonas striata*. The application of P up to 40 kg P₂O₅ ha⁻¹ significantly increased the population of phosphate solubilizing microorganism. Thus, application of 40 kg P₂O₅ ha⁻¹ along with inoculation with phosphate solubilizing microorganisms maintained the optimum microbial population in the rhizosphere.

Parham *et al.* (2003) studied the microbial populations and community structures in soils under different management systems in a long-term continuous winter wheat experiment. The richness and evenness of the bacterial community were enhanced by manure treatment and treatments that included N and P, which were positively correlated with soil productivity.

Selvi *et al.* (2004) reported that bacteria, fungi and actinomycetes proliferated well under continuous application of NPK and FYM treatments. Among the microbes, bacterial population was highest compared to fungi and actinomycetes.

Zhang-Hui *et al.* (2004) studied the effects of biological-organic-inorganic complex fertilizer on soil microorganism activity. The results showed that on the application of this fertilizer, the population of bacteria, fungi and actinomycetes and the total population of the microorganism increased by 165.38, 189.47, 48.72 and 104.7%, respectively over control.

Tapas and Gupta (2005) studied the effect of fertilizers with different phosphorus levels on soybean and soil microflora. The results showed that doses of P fertilizer at the rate of 60, 80 and 100 kg ha⁻¹ proved suitable for maximizing bacterial population and minimizing fungal population of the rhizosphere soils at different crop growth stage.

Manna *et al.* (2007) conducted field experiment to study the influence of FYM and fertilizer P on the activity of PSB in a soyabean-wheat rotation for five-year duration and reported that the greatest PSB activity was measured when legume cereal sequence was taken and their activities increased significantly with the application of manure.

Chang *et al.* (2010) conducted the study at Department of Nursing, Mackay Medicine, Nursing and Management College, Taipei and evaluated that the soil microbial biomass, populations of bacteria, fungi and actinomycetes increased significantly in the compost-treated soils compared with the chemical fertilizer CF-treated soil.

Erhunmwunse *et al.* (2019) studied the nutrient mineralization pattern of poultry manure compost enriched with inorganic nitrogen (N) and phosphorus (P) fertilizer nutrients in an Ultisol at Department of Soil Science and Land Resources Management, Obafemi Awolowo University, Nigeria. The addition of compost stimulated bacterial and actinomycete populations, while, fungal populations were unaffected. Actinomycetes and bacteria had similar and higher relationship trend with C (R² = 0.24) and P (R² = 0.47) mineralization and were key determinants in nutrient mineralization from compost in this Ultisol.

2.5 Effect of Organic Manure on Yield

Application of phosphorus in combination of organic and inorganic sources to pulse crop are very effective and called as master key element for increasing yield. An adequate supply of phosphorus has been reported good for better growth, yield, quality and enormous nodule formation in legumes (Sammauria *et al.*, 2009). The experiment carried out by some researchers on various aspects of IPM for increasing crop yield and productivity is reviewed below

Singh *et al.* (2000) conducted field experiment for three years on black clay soil under rainfed condition and reported that application of FYM improved the yields of arhar by 16.6 per cent over NPK alone.

Malarkodi and Singaram (2002) reported that combined application of rock phosphate and single super phosphate in 1:1 ratio along with farmyard manure (12.5 t ha⁻¹) and phosphobacteria increased significantly the dry matter production, yield (grain and straw) and yield parameters of rice over application of 100 per cent rock phosphate alone by comparable with application of 100 per cent single superphosphate alone.

Patil (2002) conducted a field experiment on clayey soil during *Kharif* season at Junagadh (Gujarat) on pigeon pea. He reported that application of FYM 5 t ha⁻¹ significantly

increased yield and yield attributes such as number of pods per plant, grains per pod, weight of grains per plant and test weight.

Bharat *et al.* (2003) reported that grain and straw yields of moong increased due to application of phosphorus alone and inoculation with phosphorus solubilizing microbes. Both phosphorus application and phosphorus solubilizing microbes also significantly affected the contents and uptake of N, P and K in moong.

Jayaramasoundari *et al.* (2003) studied the residual effect of phosphorus applied to cotton, on the growth and yield of the succeeding green gram. The highest dry matter production and grain yield were obtained when green gram was grown after harvest of cotton treated with rock phosphate enriched with FYM + phosphobacteria + SSP (100% of recommended rate for green gram). However, a higher benefit cost ratio was obtained with rock phosphate enriched FYM + phosphobacteria + SSP at 50% of recommended rate.

Patel and Thakur (2003) reported that yield attributes and yield of black gram were significantly influenced with the application of phosphorus levels, phosphorus solubilizing bacteria and farmyard manure. The application of phosphorus 60 kg P₂O₅ ha⁻¹ in combination with phosphorus solubilizing microbes (5 kg ha⁻¹) and farm yard manure (1 t ha⁻¹) significantly increased the yield attributes and yield of black gram.

Nishanth and Biswas (2007) studied the efficient use of rice straw and indigenous source of phosphorus and potassium in crop production through composting technology at Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi, India. Various enriched composts were prepared using rice straw, rock phosphate (RP), waste mica and bioinoculant (*Aspergillus awamori*) and kinetics of release of phosphorus and potassium from enriched composts and their effect on yield and nutrient uptake by wheat (*Triticum aestivum*) were carried out. Data in pot experiments revealed that enriched composts performed poorly than diammonium phosphate during initial stages of crop growth, but they out yielded at the latter stages, particularly at maturity stage, as evident from their higher yield, uptake, nutrient recoveries and fertility status of P and K in soils. Moreover, enriched composts prepared with RP and waste mica along with *A. awamori* resulted in significantly higher biomass yield, uptake and recoveries of P and K as well as available P and K in soils than composts prepared without inoculant.

Bajracharya and Rai (2009) studied the effect of vermicompost in combination with or without soil and mineral fertilizers on the yield and other attributes of chickpea in the screenhouse of Soil Science Division, Khumaltar. The results showed that an encouraging effect of vermicompost application on the plant height, root length and biomass dry weight of chickpea when vermicompost was applied in equal ratio with soil (5 kg each pot⁻¹) and 10:20:15 kg N:P₂O₅:K₂O kg ha⁻¹. Vermicompost with equal ratio of soil (5 kg each pot⁻¹) also produced the

highest mean grain yield of 10.6 gm per pot. However, no significant treatments effects were observed for root length and straw weights of the chickpea.

Kumawati *et al.* (2009) studied the effect of organic manures, PSB and phosphorus fertilization on growth and yield of kharif mungbean at Department of Agronomy, Rajasthan Agricultural University, Bikaner, India. The results revealed that application of organic manures, PSB and phosphorus fertilization markedly influenced the growth and yield of mungbean. Results showed that application of vermicompost, seed inoculation with PSB and 40 kg P₂O₅ ha⁻¹ significantly increased the growth attributes i.e., plant height, number of branches plants⁻¹, dry matter accumulation meter⁻¹ row length, chlorophyll content, effective nodules, dry weight of nodules plant⁻¹, total nodules plant⁻¹ and finally seed yield (8.09 q ha⁻¹) of mungbean.

Basir *et al.* (2008) studied the level of phosphorus and FYM for chickpea and studied their effect on agronomic characteristics. An experiment was carried out at the Agricultural Research Farm of NWFP Agricultural University, Peshawar. The results suggested that the application of FYM to chickpea did not affect its yield significantly while, phosphorus fertilizer at the rate of 60 kg ha⁻¹ proved effective for optimum production.

Saravanan *et al.* (2013) studied the effect of organic manure and chemical fertilizers on the yield attributes and macronutrient levels of green gram at Department of Biotechnology, St. Joseph's College, Trichy. The maximum number of pods and pod length was observed in treatment which received FYM+10%NPK whereas, number of seeds was maximum in FYM+composted coir pith (CCP) 2:1 treatment. Macro nutrients such as calcium, phosphorus, iron, sodium and potassium were estimated both in fresh and dry seeds. In which the integrated approach recorded better availability of these nutrients in fresh and dry seeds of green gram than the individual application.

Badini *et al.* (2015) studied the effect of different phosphorus levels on the growth and seed yield of chickpea at Pulses Research Station, Agriculture Research Institute, Tandojam. Two chickpea varieties (V1=D.G-92 and V2=D.G-89) were evaluated against six phosphorus levels (F1=36-00 kg ha⁻¹, F2=36-15 kg ha⁻¹, F3=36-25 kg ha⁻¹, F4=36-35 kg ha⁻¹, F5=36-45 kg ha⁻¹ and F6=36-55 kg ha⁻¹). It was concluded that the growth and seed yield of chickpea varieties consecutively improved with increasing phosphorus levels; and highest phosphorus level of 55 kg ha⁻¹ resulted in maximum seed yield ha⁻¹; while, chickpea variety DG-92 showed its superiority over D.G-89 for all the growth and yield traits.

Kokani *et al.* (2015) studied the effect of farm yard manure, phosphorus and sulphur on yield of summer black gram and post-harvest status of nutrients under South Gujarat condition at college farm, Navsari Agricultural University, Navsari. Plant height at 60 DAS and harvest, number of branches, seed (1149 kg ha⁻¹) and stover (2652 kg ha⁻¹) yields of black gram were recorded significantly higher under the incorporation of 5 t FYM ha⁻¹ over control. Phosphorus

applied @ 40 kg ha⁻¹ was recorded significantly superior plant height at 60 DAS and harvest, number of branches, number of pods plants⁻¹, number of seeds pods⁻¹, length of pod, grain (1171 kg ha⁻¹) and stover (2667 kg ha⁻¹) yields as well as protein yield (232.10 kg ha⁻¹) of black gram and available phosphorus in soil (41.97 kg ha⁻¹) over control. Significantly the higher plant height at 60 DAS and harvest, number of branches plants⁻¹, number of pods plants⁻¹, seeds pod⁻¹, grain (1153 kg ha⁻¹), stover (2548 kg ha⁻¹) as well as protein yield of black gram and available S (21.63 ppm) in soil were observed under 20 kg S ha⁻¹ compared to control.

Meena *et al.* (2016) carried out a field experiment during *Kharif* at the Research farm of Soil Science, Allahabad School of Agriculture, laid out in randomized block design, consisted nine treatments and three replications, it was observed that growth and yield of green gram in treatment N-20, P-40, K-40 + FYM @ 10 t ha⁻¹ and *Rhizobium* was maximum. Maximum plant height (50.66 cm), number of leaves plant⁻¹ (33.00), number of branches plant⁻¹ (4.66) at 60 DAS, number of cluster plant⁻¹ (9.33), number of pods plant⁻¹ (37.33) and total seed yield (12.10 q ha⁻¹) were found to be significant over all other treatment. Adequate plant nutrient supply holds the key for improving the growth and food grain production of crop.

Ditta *et al.* (2017) studied the effect of different combinations of rock phosphate and compost (0:100, 25:75, 50:50, 75:25 and 100:0) and time of application (30, 15, 7, 3 and 0 days before sowing), each was conducted in two consecutive pot experiments at Department of Environmental Sciences, Shaheed Benazir Bhutto University, Khyber Pakhtunkhwa, while, the rate of application (100–1000 kg ha⁻¹) was investigated under field conditions, in comparison to control (recommended P fertilizer) and result showed that the application of RP-EC, with the ratio of 50:50 (RP:Compost) and application rate of 800 kg ha⁻¹ before 7 days of sowing, exhibited maximum growth and development, and can be highly recommended for optimum production of chickpea.

Yadav *et al.* (2017) studied the effect of different organic manures on growth and yield of chickpea (*Cicer arietinum L.*) at Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). Results revealed that application of vermicompost 2 t ha⁻¹ recorded significantly tallest plant (54.70 cm), total number of root nodules (40.73 plant⁻¹), effective root nodules (36.05 plant⁻¹), pods (50.12 plant⁻¹), seed yield (1916 kg ha⁻¹) and haulm yield (2998 kg ha⁻¹) compared to other organic manure treatments. Among liquid organic manures, application of panchagavya 3 per cent remained on par with vermiwash 10 per cent also recorded significantly tallest plant (54.48 cm), total number of root nodules (39.78 plant⁻¹), effective root nodules (35.10 plant⁻¹), pods (49.54 plant⁻¹), seed yield (1888 kg ha⁻¹) and haulm yield (2804 kg ha⁻¹) as compared to cow urine and control.

Ade *et al.* (2018) studied effect of phosphorus and biofertilizers on growth, yield and economics of pigeon pea (*Cajanus cajan L. Millsp.*) under rainfed condition at Experimental

Farm, Agronomy Section, College of Agriculture, Latur. The application of phosphorus @ 60 kg ha⁻¹ given significantly higher growth and yield attributes, gross monetary return, net monetary return and B: C ratio over the rest of the levels of phosphorus. Whereas, net monetary returns (NMR) were remained at par with 50 kg P ha⁻¹. Among three biofertilizer treatments, dual seed inoculation with *Rhizobium* + PSB was recorded higher growth and yield attributes, gross monetary return, net monetary return and B: C ratio than the individual seed inoculation of *Rhizobium* or PSB.

Basak and Gajbhiye (2018) conducted a pot culture experiment for two consecutive years in the late rainy season and evaluated the efficiency of rock phosphate charged compost as an organic P fertilizer source in senna. A fixed dose of P (40 kg ha⁻¹), considered optimum for quality produce was supplied from different sources like Di-ammonium phosphate (DAP), Single Super Phosphate (SSP), Rock phosphate (RP) and RP charged compost (RPCC). Total fresh and dry herbage yield (leaf+pod) was significantly higher under different P treatments than the control. Application of RP, SSP, DAP and RPCC increased fresh herbage yield up to 6.7, 22.6, 35.1 and 48.1%, respectively over the control. The highest herbage yield and sennoside content was recorded under RPCC application. The result from the study may be recommended for efficient P management in both commercial as well as organic cultivation of senna.

Koireng *et al.* (2018) studied the residual influence of organic manures and micro nutrients applied to potato on growth and yield of succeeding green gram in an organic cropping system, under alluvial soil at Directorate of Research, Central Agricultural University, Imphal, Manipur, India. Application of 50% RDF + 10t FYM ha⁻¹, recorded highest grain and haulm yields of 952.05 and 2638.85 kg ha⁻¹, respectively.

Rekha *et al.* (2018) studied the effect of FYM, phosphorus and PSB on nutrient content and uptake by green gram on loamy sand at Agronomy Instructional Farm, C.P. College of Agriculture, Sardarkrushinagar Dantewada Agricultural University, Sardarkrushinagar, Gujarat. The results revealed that significantly the highest seed (727 kg ha⁻¹) and stover (1399 kg ha⁻¹) yields of green gram was recorded due to application of 40 kg P₂O₅ ha⁻¹ + PSB @ 10 t FYM ha⁻¹.

Rabari *et al.* (2020) carried out an experiment on loamy sand soils of Centre for Research on IFS, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat and assessed the effect of rock phosphate enriched different organic manures on growth and yield of wheat. The results indicated that the 60 kg P₂O₅ application through diammonium phosphate resulted in highest yield (5103 kg ha⁻¹), number of tillers per meter row length (92.42), number of effective tillers per meter row length (77.42), spike length (8.22 cm) and number of grains per plant (53.13) than rest of the treatments of phosphorus rich organic manures. Even through vegetable waste and vermicompost incubated media also resulted in higher number of tillers,

effective tillers, number of spikes per meter row length and number of grains per ear over the control.

Sonet *et al.* (2020) carried out an experiment and evaluated the effects of phosphorus (P) fertilizer application on growth, yield, and yield components of lentil at the agronomy research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Four lentil varieties (BARI Masur-4, BARI Masur-5, BARI Masur-6, and BARI Masur-7) and four levels of P (0, 20, 40 and 60 kg P₂O₅ ha⁻¹) were used in this experiment as treatment variables. The highest seed yield (1.98 t ha⁻¹) was obtained from the combination of BARI Masur-7 with 40 kg P₂O₅ ha⁻¹, and the lowest (1.08 t ha⁻¹) was from BARI Masur-5 with 0 kg P₂O₅ ha⁻¹. Results revealed that the application of P fertilizer offers a large scope for obtaining a higher yield of lentil in Bangladesh. However, the application of P fertilizer at the rate of 40 kg P₂O₅ ha⁻¹ would be the optimum for achieving higher yield irrespective of varieties.

Appiah *et al.* (2021) studied the effect of eleven rates of P₂O₅ fertilization for growth and yield of maize at University for Development Studies, Department of Agronomy, Northern, Ghana. Results of the evaluation indicated significant effect of P₂O₅ rate on maize plant height, leaf area index, days to 50% flowering, cob weight, cob length, 100 seed weight, straw weight and grain yield. Increasing P₂O₅ rates had pronounced effect on growth, on grain yield and on yield components of maize. Application of P₂O₅ 50 kg ha⁻¹ resulted in maximum leaf area index (3.84), 100 seed weight (23.49 g), straw weight (9.3 t ha⁻¹) and grain yield (3.09 t ha⁻¹) as compared to the minimum values in the control treatments (1.57, 14.8 g, 3.3 t ha⁻¹ and 0.71 t ha⁻¹ respectively).

Chaudhari *et al.* (2021) carried out the field experiment on loamy sand soils of Centre for research on IFS, Sardarkrushinagar Dantewada Agricultural University, Sardarkrushinagar, Gujarat and assessed the response of wheat to different phosphorus rich organic manure (PROMs) and PSB under varying levels of phosphorus and its residual effect on summer green gram. The result indicated that an application of full dose of phosphorus (60 kg ha⁻¹) in form of PROMs incubated with vermicompost in presence of PSB (0.03% W/W) was found significant superior in increasing yield and yield attributes of wheat. While, the application of full dose of phosphorus (60 kg ha⁻¹) in the form of PROMs incubated with farm compost with absence of PSB was noticed lower in yield and yield attributes.

Elkhlifi *et al.* (2021) studied the efficacy of various P-La modified sewage sludge biochar (SSBC, La-SSBC, SSBC-P, La-SSBC-P) on soil phosphate-retention and ryegrass (*Lolium perenne* L.) growth in an alkaline soil (excess CaCO₃). The results revealed that germination percentage, plant dry biomass, plant height, and the total amount of P in the ryegrass leaves were significantly (P < 0.05) improved under La-SSBC-P treatment as compared to other treatments.

Overall, results showed that the P-loaded lanthanum decorated biochar (La-SSBC-P) could be used as a potential substitute for P-fertilizer under the experimental conditions.

Gebremariam and Tesfay (2021) studied the effect of P rates on chickpea yield at Department of Plant Sciences (Horticulture Program), Aksum University, Shire, Ethiopia. Results revealed significant effects of P rate (30–200 kg P₂O₅ ha⁻¹) on nodule number, mass and rating plant⁻¹, plant height, and branches plant⁻¹; pods and grains plant⁻¹, grain and biomass yields, 100-grain weight, and harvest index (HI) compared to the control. P rates response has been affected by moisture level, pH, available P and N, and variety. Particularly, joint use of P rate and rhizobium inoculation on chickpea has been stated to improve nodulation, growth, and yield and soil fertility.

Khan *et al.* (2021) studied the impact of different phosphorus (P) fertilizers and organic manures alone and in combination with *Bacillus sp.* MN-54 on growth, yield, nutrient uptake, chlorophyll (SPAD value) and crude proteins content of chickpea at Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. The simple manure (SM), processed manure (PM), single super phosphate (SSP), and rock phosphate (RP) were applied individually and in different combinations to the soil in pots, and the chickpea seeds treated with *Bacillus sp.* MN-54 were sown in the selective pots. Results showed that individual use of SM, PM, SSP, RP, and strain MN-54 significantly increased (p 0.05) the growth and yield of chickpea as compared to control treatments. While, the combined use of SM or PM, SSP or RP, and MN-54 further enhanced this effect. Among different treatments, combined use of RP, PM and MN-54 proved the most effective treatment and showed increase of 37.5 and 42.6% in shoot and root lengths, 43.4 and 38.3% in fresh and dry shoot weights, 36.1 and 36.5% in fresh and dry root weights, 45.8% in no. of pods, 43.6% in nodules counts and 16.0% in 100-grain weight.

Meena *et al.* (2021) carried out experiment in *Kharif* at Rajasthan College of Agriculture, Udaipur (Rajasthan). The treatments comprised of four levels of phospho enriched compost (PEC) i.e., control, PEC @ 2.0, 4.0 and 6.0 t ha⁻¹ and four levels of zinc i.e., Control, Zn @ 2.0, 4.0 and 6.0 kg ha⁻¹. Result showed the increasing levels of phospho enriched compost and zinc up to 4 t ha⁻¹ and 4 kg ha⁻¹, respectively increased significantly (P=0.05) the number of nodules per plant, number of pods per plant, number of seeds per pod, test weight, seed yield, stover yield of black gram and the combined application of phospho enriched compost @ 6 t ha⁻¹ along with zinc @ 6 kg ha⁻¹ was found to record higher seed and stover yield.

2.6 Effect of Organic Manure on Nutrient Uptake

Nutrients are absorbed by plants only in inorganic forms. Hence, organic forms of nutrients have to mineralize for uptake of nutrients by plants. Nutrient transport towards root, absorption by roots and translocation of nutrients and their assimilation within the shoot and

leaves occurred simultaneously. When nutrients are in deficiency range in plants, yield are significantly reduced. Availability of nutrients for plant growth and their uptake by plant depends on nutrient availability in soil which is influenced by the application of manure and fertilizer. Here, past literature on effect of fertilizer and manure P application on nutrient uptake of crop is presented.

Rao and Dart (1980) studied the response of farmyard manure on nutrient uptake by pigeon pea, found that application of FYM significantly increased the N and P uptake in the Alfisol and Vertisol soils.

Balasubramaniyan (1997) conducted an experiment in Tamil Nadu on red sandy loam soil, reported that addition of 12.5 t FYM ha⁻¹ resulted in higher N, P and K uptake by groundnut crop.

Parmar *et al.* (1998) conducted a field experiment during summer seasons on vegetable pea in cold decent soils of Himachal Pradesh. The results revealed that uptake of N, P, and K was significantly increased with increase in dose of FYM as compared to control.

Patil (2002) conducted a field experiment on clayey soil during *Kharif* season at Junagadh (Gujarat) on pigeon pea. He reported that content and uptake of nitrogen, phosphorus and potassium by grain as well as stover were significantly increased with 100 % RDF ha⁻¹ i.e., 25: 50: 0 N: P₂O₅: K₂O ha⁻¹.

Jat and Ahlawat (2006) carried out a field experiment at the Indian Agricultural Research Institute, New Delhi, India and revealed that application of 3t vermicompost/ha to chickpea improved dry matter accumulation, grain yield and grain protein content in chickpea, soil N and P and bacterial count, dry fodder yield of succeeding maize, total N and P uptake by the cropping system over no vermicompost. Seed inoculation of chickpea with *Rhizobium* PSB (phosphate solubilizing bacteria) increased dry matter accumulation, grain yield and protein content of chickpea, dry fodder yield of succeeding maize and total N and P uptake by the cropping system over no inoculation and inoculation with *Rhizobium* alone. *Rhizobium* with and without PSB also increased soil N content over no inoculation. Application of phosphorus up to 26 kg P ha⁻¹ to chickpea improved dry matter accumulation, grain yield and protein content of chickpea, dry fodder yield of succeeding maize and total N and P uptake by cropping system. Application of 13 and 26 kg P ha⁻¹ increased soil N and P content over no phosphorus.

Singh and Singh (2012) studied the individual and interactive effect of P and Zn on yield, nutrient content and nutrient uptake of chickpea (*Cicer arietinum L.*). An increase in P uptake by grain and straw with applied P was recorded but it was decreased at higher level of applied Zn. The content and uptake of Zn in grain and straw increased significantly with increasing levels of Zn.

Khan *et al.* (2021) conducted a research at Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan to studied the impact of different phosphorus (P) fertilizers and organic manures alone and in combination with *Bacillus sp.* MN-54 nutrient uptake on chickpea. The simple manure (SM), processed manure (PM), single super phosphate (SSP), and rock phosphate (RP) were applied individually and in different combinations to the soil in pots, and the chickpea seeds treated with *Bacillus sp.* MN-54 were sown in the selective pots. Results showed that individual use of SM, PM, SSP, RP, and strain MN-54 significantly increased ($p < 0.05$) the nutrient uptake of chickpea as compared to control treatments. While, the combined use of SM or PM, SSP or RP, and MN-54 further enhanced this effect. Among different treatments, combined use of RP, PM and MN-54 proved the most effective treatment showing increase of 31–36% nutrient uptake over control treatments.

Meena *et al.* (2021) carried out experiment in *Kharif* at Rajasthan College of Agriculture, Udaipur (Rajasthan). The treatments comprised of four levels of phospho enriched compost (PEC) i.e., control, PEC @ 2.0, 4.0 and 6.0 t ha⁻¹ and four levels of zinc i.e., Control, Zn @ 2.0, 4.0 and 6.0 kg ha⁻¹. Result showed the increasing levels of phospho enriched compost and zinc up to 4 t ha⁻¹ and 4 kg ha⁻¹, respectively increased significantly ($P=0.05$) the nutrient content (N, K and Zn) and uptake (N, P, K and Zn) in seed and stover of black gram.

3. MATERIAL AND METHODS

In order to study the “Effect of phosphorus enriched organic manure on nutrient availability, phosphorus fractions, P use efficiency and yield of chickpea under inceptisol” was conducted on STCR research farm, Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, during *Rabi* 2020. The material used and methods adopted are discussed in this chapter.

3.1 Material

3.1.1 Experimental Site

The field experiment was laid out during *Rabi*, 2020, at STCR Research Farm of Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, Dist. Ahmednagar, Maharashtra (India).

3.1.2 Soil

The soil from the experimental site of the present study was grouped under Inceptisols order belongs to Pather soil series and taxonomically classified as of *Vertic Haplustepts*. The experimental soil was medium deep black with 70 cm depth. The initial properties of experimental soil are given in Table 3.1.

Table 3.1 Initial soil properties of experimental site

Sr. No.	Parameters	Value
1.	Particle size analysis (%)	
	Coarse sand	5.45
	Fine sand	13.28
	Silt	25.12
	Clay	54.70
2.	Textural class	Clayey
3.	Bulk density (Mg m^{-3})	1.30
4.	pH (1:2.5)	8.14
5.	EC (dSm^{-1})	0.28
6.	Organic carbon (%)	0.59
7.	Available N (kg ha^{-1})	203.84
8.	Available P (kg ha^{-1})	12.7
9.	Available K (kg ha^{-1})	627.2
10.	Available Fe (mg kg^{-1})	5.48
11.	Available Mn (mg kg^{-1})	10.41
12.	Available Zn (mg kg^{-1})	0.47
13.	Available Cu (mg kg^{-1})	0.56

In order to determine the initial soil properties of experimental soil before sowing of chickpea, the surface (0-15 cm) soil samples were collected randomly from selected spots covering experimental area. A composite soil sample was prepared and analyzed for its various soil properties. The experimental soil is clayey in texture, slightly alkaline in reaction, low in soluble salts, medium in organic carbon, low in available N and P and very high in available K content.

3.1.3 Climate

Climatically the area belongs to semiarid zone, characterized by hot summer (March to May) and general dryness in other months except in rainy months (June to September). The meteorological data with respect to temperature, humidity and rainfall was obtained from Chief Scientist, All India Coordinated Research Project on Water Management, MPKV, Rahuri and presented in Table 3.2

Table 3.2 Meteorological data during the crop growth period

Met. Week	Date	Temperature ($^{\circ}\text{C}$)		Humidity (%)		Sun-shine (hr.)	Wind velocity (km hr^{-1})	Rain-fall (mm)	Rainy days
		Max.	Min.	Morn.	Even.				
April, 2020									
14	02-08	37.0	19.0	77	19	9.5	1.2	000.0	-
15	09-15	38.1	21.3	67	18	9.7	1.3	000.0	-
16	16-22	39.1	21.9	73	20	10.2	2.0	04.0	1
17	23-29	38.1	21.8	70	20	10.3	3.2	000.0	-
18	30-06	40.1	25.1	61	17	10.6	3.2	000.0	-
May, 2020									
19	07-13	39.9	25.6	55	20	10.9	3.2	000.0	-
20	14-20	38.8	26.9	63	25	07.9	3.9	000.0	-
21	21-27	40.6	25.0	64	17	09.1	5.8	000.0	-
22	28-03	35.8	24.5	79	45	07.9	5.5	067.8	2
June, 2020									
23	04-10	31.5	24.4	81	46	06.8	4.3	027.4	2
24	11-17	32.5	24.3	87	50	06.5	2.3	066.4	4
25	18-24	32.8	24.9	83	51	06.6	4.1	018.6	2
26	25-01	32.6	23.9	93	53	06.4	2.6	143.0	6
July, 2020									
27	02-08	31.5	24.9	82	56	04.2	3.0	002.0	-
28	09-15	32.4	24.4	84	56	05.3	5.1	076.8	2
29	16-22	30.1	24.1	87	62	03.5	02.0	023.8	2
30	23-29	30.0	23.5	91	69	04.8	01.9	136.2	6
31	30-05	30.0	24.2	87	64	05.7	00.8	062.0	3
August, 2020									
32	06-12	30.2	23.8	86	64	03.4	04.1	016.6	5.1
33	13-19	26.1	23.0	90	79	00.3	02.5	056.0	2.8
34	20-26	28.7	23.4	87	64	04.2	04.2	013.2	4.8
35	27-02	29.5	23.1	86	60	04.7	04.7	002.0	5.0
September, 2020									
36	03-09	32.9	23.7	90	56	6.7	00.9	024.8	2
37	10-16	29.7	23.5	92	63	4.2	01.2	064.4	4

38	17-23	28.4	23.3	93	64	2.5	01.0	281.8	6
39	24-30	30.3	23.0	90	56	5.8	01.6	015.8	3
October,2020									
40	01-07	31.7	23.5	85	47	8.0	01.7	009.4	1
41	08-14	31.4	23.7	89	54	4.5	01.4	010.6	2
42	15-21	29.8	23.1	92	63	4.8	01.9	114.6	4
43	22-28	30.1	21.5	90	55	6.7	00.6	021.4	1
44	29-04	30.9	18.0	87	37	8.9	00.6	000.0	-
November,2020									
45	05-11	29.1	13.9	84	33	09.1	01.1	000.0	-
46	12-18	29.9	18.4	83	41	09.2	01.3	000.0	-
47	19-25	30.6	19.0	89	44	07.8	00.9	004.2	1
48	26-02	28.2	17.5	82	44	08.2	01.7	000.0	-
December 2020									
49	03-09	29.5	12.8	84	28	09.6	1.2	000.0	-
50	10-16	27.7	18.0	84	47	04.1	00.8	000.0	-
51	17-23	28.1	12.3	88	36	08.0	01.0	000.0	-
52	24-31	27.8	12.9	87	42	08.5	0.8	000.0	-
January,2021									
1	01-07	27.7	17.7	85	44	4.8	00.8	000.0	-
2	08-14	28.2	18.3	91	44	6.1	00.8	020.6	1
3	15-21	30.1	17.0	84	37	8.0	00.8	000.0	-
4	22-28	30.2	14.2	86	34	8.8	00.5	000.0	-
5	29-04	28.5	12.6	81	34	8.3	00.9	000.0	-
February,2021									
6	05-11	28.3	11.1	80	27	9.6	01.2	000.0	-
7	12-18	30.4	15.3	79	31	8.6	00.8	000.0	-
8	19-25	29.2	15.0	85	34	8.9	01.6	007.2	1
9	26-04	33.1	16.4	75	21	9.8	01.0	000.0	-
March,2021									
10	05-11	35.0	15.6	71	20	9.2	01.0	000.0	-
11	12-18	35.9	17.3	70	21	8.7	01.0	000.0	-
12	19-25	33.7	19.4	77	31	7.4	01.3	023.4	3
13	26-01	37.4	18.5	70	14	9.5	01.2	000.0	-
April,2021									
14	02-08	37.8	21.2	68	15	9.5	2.7	000.0	-
15	09-15	37.0	23.8	60	19	7.8	2.1	000.0	-
16	16-22	37.7	23.5	57	16	9.7	2.2	000.0	-
17	23-29	38.4	25.0	50	17	9.4	2.1	000.0	-

3.1.4 Seeds

Healthy chickpea seeds of *Digvijay* variety obtained from Seed Officer, Seed Science and Technology Department, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri

3.1.5 Fertilizers

The recommended doses of nutrients to chickpea were 25:50:30 kg ha⁻¹ N, P₂O₅ and K₂O and given through urea, single superphosphate and muriate of potash, respectively. In some treatment P₂O₅ given 100%, 75% and 60%, respectively through phosphorus enriched organic manure as per recommended dose

3.2 Details of Field Experiment

3.2.1 Layout and Experimental Design

A field experiment was conducted on medium deep black soil was conducted during *rabi* 2020 with chickpea as a test crop. The experiment was laid out in a randomized block design with 7 treatments and 3 replications. The gross plot size was 3.60 m x 3.45 m i.e., 12.42 m² and net plot size was 3.00 m x 2.60 m i.e., 7.8 m². The recommended spacing of 30 cm x 10 cm was adopted for dibbling of chickpea. The general recommended dose of nutrients (25:50:30 kg ha⁻¹ N, P₂O₅ and K₂O, respectively) were given to chickpea as per treatment details except T₁ at the time of dibbling of chickpea.

3.2.2 Experimental Details

Table 3.3 Experimental details

1	Name of crop	:	Chickpea
2.	Variety	:	Digvijay
3.	Soil type	:	Inceptisol
4.	Experimental location	:	STCR Farm, MPKV, Rahuri
5.	Design	:	Randomized block design (RBD)
6.	Treatments	:	07
7.	Replications	:	03
8.	Plot size	:	Gross plot: 3.60 m x 3.45 m Net plot: 3.00 m x 2.60 m
9.	Spacing	:	30 cm x 10 cm
10.	Date of sowing	:	11 November 2020
11.	Date of harvest	:	19 March 2021

3.2.3 Treatments Detail

Table 3.4 Treatments detail

Tr. No.	Treatment's detail
T ₁	Absolute control
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)

Note:

- 1) Single Super Phosphate (SSP) was chemical source of P_2O_5 in treatments where chemical fertilizers are to be applied.
- 2) Phosphorus enriched organic manure (PEOM) and FYM was applied eight days before sowing.

3.2.4 Details on Manure and Fertilizer Doses Applied in Different Treatments for Chickpea Crop

Tr.no	Treatment	Nutrient and manure applied ($kg\ ha^{-1}$)				
		N	P_2O_5	K_2O	PEOM	FYM
T ₁	Absolute control					
T ₂	GRDF (25:50:30 N, P_2O_5 and $K_2O\ kg\ ha^{-1}$ + 5 t ha^{-1} FYM)	25	50	30	-	5000
T ₃	100% P_2O_5 through Phosphorus enriched organic manure and N and K as per recommendation	25	-	30	404	-
T ₄	75% P_2O_5 through Phosphorus enriched organic manure and 25% P_2O_5 through chemical fertilizer and N and K as per recommendation	25	12.5	30	303	-
T ₅	60% P_2O_5 through Phosphorus enriched organic manure and N and K as per recommendation	25	-	30	243	-
T ₆	GRDF (25 kg N and 30 kg K_2O through chemical fertilizers, 50 kg P_2O_5 through Phosphorus enriched organic manure + 5 t ha^{-1} FYM)	25	-	30	404	5000
T ₇	RDF (25:50:30 N, P_2O_5 and $K_2O\ kg\ ha^{-1}$)	25	50	30	-	-

3.3 Proximate Analysis of Phosphorus Enriched Organic Manure

Sr. No	Parameter	Values
1.	Moisture (%)	24.80
2.	pH (1:10)	7.45
3.	EC (dSm^{-1})	0.55
4.	Organic carbon (%)	14.27
5.	C:N ratio	18.29
6.	Total N (%)	0.78
7.	Total P (%)	5.64
8.	Total K (%)	1.05
9.	Total Fe ($mg\ kg^{-1}$)	2267
10.	Total Mn ($mg\ kg^{-1}$)	1146
11.	Total Zn ($mg\ kg^{-1}$)	517
12.	Total Cu ($mg\ kg^{-1}$)	91

3.4 Field Operations

3.4.1 Manure Application

Phosphorus enriched organic manure applied as per treatment eight days before sowing in all treatments except treatment T₁, T₂ and T₇. Farm yard manure (FYM) applied as 5 t ha⁻¹ in treatment T₂ and T₆.

3.4.2 Fertilizer Application

Urea, SSP, MOP were applied as per recommendation.

3.4.3 Sowing

The chickpea seeds were dibbled on November 19, 2020 in ridges and furrow with the spacing of 30 cm x 10 cm.

3.4.4 Gap Filing

The gaps observed in experimental plots were filled after 7 DAS.

3.4.5 Irrigation

Field capacity of soil moisture was maintained by irrigating the field. Two irrigations were given during the crop growth period as per requirement considering rainfall and crop growth stages.

3.4.6 Weeding and Inter Culturing

Two inter culturing and hand weeding was carried out.

3.4.7 Harvesting

The chickpea plants in net plots after full maturity were harvested carefully for grain and stover yield and samples were taken for nutrients concentration and uptake studies of chickpea.

3.4.8 Collection of Plant Sample

For studying the uptake of nutrient by chickpea crop plant sample (leaves and stalk) were collected after harvest of chickpea crop from field, crushed and weighted 10 gm in paper bag. After processed, samples analysed for N, P, K, content.

3.5 Field Studies

The crop response to treatments under the present investigation was evaluated on the basis of biometric, bio-chemical and soil studies, which are given here after (Table 3.7).

3.5.1 Plant Height (cm)

Height of randomly selected 5 plants from each net plot was measured from ground level to the top of the main shoot at harvest were counted and recorded.

3.5.2 Number of Branches Plant⁻¹

Branches for five randomly selected plants from each net plot at the time of harvesting were counted and average number was calculated.

3.5.3 Number of Nodules Plant⁻¹

Little water was applied to five plants to soften the soil and then plants were dugged out carefully at 40 and 80 days after sowing. The roots were washed with clean water in a bucket to remove adhered soil particles. Then nodules were counted and their average number per plant was calculated.

3.5.4 Number of Pods Plant⁻¹

The total number of pods from five tagged plants under each treatment was counted and average value was computed.

3.5.5 Test Weight (g)

Hundred seeds were counted randomly from each net plot yield and their weight in gram was recorded as test weight of each treatment.

3.5.6 Grain and Straw Yield (kg ha⁻¹)

The grain and straw produced from each net plot was collected and recorded separately in kg. The yield per net plot was then converted into kilogram per hectare (kg ha⁻¹).

3.6 Laboratory Studies

3.6.1 Laboratory Material

3.6.1.1 Glassware

The necessary glassware *viz.* beaker, conical flask, volumetric flask, pipette, glass rod, burette, funnel, Buchner funnel, measuring cylinder, digestion tubes etc. were used for analytical work.

3.6.1.2 Equipments

The equipment *viz.* digestion and distillation unit, hot air oven, weighing balance, grinding machine, mechanical shaker, kel plus digestion, spectrophotometer, flame photometer, atomic absorption spectrophotometer, pH meter, conductivity meter, etc. were used during the laboratory analysis.

3.6.1.3 Chemicals

High purity (AR grade) chemicals were used *viz.* sulphuric acid, sodium hydroxide, hydrogen peroxide, hydrochloric acid, potassium permanganate, potassium chloride, silver nitrate, barium chloride, potassium Ferro cyanide, ammonium acetate, ammonium chloride, ammonium hydroxide, boric acid, ethanol, methanol, triethanolamine, phenolphthalein, methyl red, calcon, bromocresol green etc.

3.6.2 Methods

3.6.2.1 Soil analysis

In order to study the physical and chemical properties of soil, a representative composite soil sample were collected 0-30 cm depth from experimental field. Surface soil samples were drawn before sowing and after harvest of the chickpea crop. The soil samples were collected in

cloth bags and then air dried in the shade for processing. The samples were then pounded thoroughly in wooden mortar with pestle and sieved through 2 mm sieve for analysis of physical and chemical properties of the soil by using the standard analytical methods as indicated in Table 3.5. For biological properties the fresh soil samples were used for analysis. The soil samples were analysed at initial and at harvest of chickpea

3.6.2.2 Plant analysis

The plant and grain samples were collected at harvest of chickpea. The samples were air dried in shade and then dried in oven at 70°C till constant weight. The whole plant sample of each treatment was ground through a stainless-steel Willey mill after oven drying. Digestion of plant and grain samples were done and used for estimation of nutrient concentration *viz.* N, P, K.

3.6.2.3 Nutrient uptake

The uptake of major and minor nutrient was worked out by multiplying dry matter accumulation to N, P and K concentration at harvest by using the following formula.

$$\text{Uptake of nutrients (kg ha}^{-1}\text{)} = \frac{\text{Total dry matter (kg ha}^{-1}\text{)} \times \text{Concentration of element (\%)}}{100}$$

Table 3.5 Standard methods for analysis of soil, plant and manure samples

Sr. No.	Parameter	Method	Reference
SOIL ANALYSIS			
1	Texture	International pipette	Piper (1966)
2	Bulk density (Mg m ⁻³)	Core method	Black and Hartage (1986)
3	pH (1:2.5)	Potentiometry	Jackson (1973)
4	EC (1:2.5) (dSm ⁻¹)	Conductometry	Jackson (1973)
5	Organic carbon (%)	Wet oxidation	Nelson and Sommer (1982)
6	Available N (kg ha ⁻¹)	Alkaline permanganate	Subbiah and Asija (1956)
7	Available P (kg ha ⁻¹)	Colorimetric 0.5 M NaHCO ₃ (pH 8.5)	Watanabe and Olsen (1965)
8	Available K (kg ha ⁻¹)	Flame photometry N N NH ₄ OAc (pH 7.0)	Jackson (1973)
9	Inorganic P fractions (Saloid-P, Al-P, Fe -P, Ca-P, Occluded-P, Red- P)	Modified method of Chang and Jackson	Peterson and Corey (1966)

10	Micronutrients (Fe, Zn, Mn, Cu)	Atomic absorption spectrophotometer	Lindsay and Norvell (1978)
11	Dehydrogenase activity ($\mu\text{g TPF g}^{-1}$ soil 24 hr^{-1})	Spectrophotometry	Casida <i>et al.</i> (1964)
12	Alkaline phosphatase ($\mu\text{g PNP g}^{-1}$ soil hr^{-1})	Spectrophotometry	Tabatabai and Bremner (1969)
13	Fungal count ($\times 10^4 \text{cfu g}^{-1}$ soil)	Serial dilution plate	Dhingra and Sinclair (1993)
13	Bacterial count ($\times 10^7 \text{cfu g}^{-1}$ soil)	Serial dilution plate	Dhingra and Sinclair (1993)
14	Actinomycetes count ($\times 10^6 \text{cfu g}^{-1}$ soil)	Serial dilution plate	Dhingra and Sinclair (1993)
PLANT ANALYSIS			
15	Total N (%)	Microkjeldahl ($\text{H}_2\text{SO}_4 + 30\% \text{H}_2\text{O}_2$)	Parkinson and Allen (1975)
16	Total P (%)	Vanadomolybdate yellow colour method (Triacid) $\text{H}_2\text{SO}_4 : \text{HClO}_4 : \text{HNO}_3$ (1:4:10)	Piper (1966)
17	Total K (%)	Flame photometry	Chapman and Pratt (1961)
MANURE ANALYSIS			
18	pH (1:10)	Potentiometry	Jackson (1973)
19	EC (1:10) (dSm^{-1})	Conductometry	Jackson (1973)
20	Total organic carbon (%)	Dry combustion	Black (1982)
21	Total N (%)	Microkjeldahl (Digestion distillation)	Parkinson and Allen (1975)
22	Total P (%)	Vanadomolybdate yellow colour	Piper (1966)
23	Total K (%)	Flame photometry	Chapman and Pratt (1961)
24	Micronutrients (Fe, Zn, Mn, Cu)	Atomic Absorption Spectrophotometer	Zoroski and Burau (1977)

3.6.2.4 Procedure for phosphorus fractions determination

Fractions of phosphorus are divided into three active fractions and two relatively inactive fractions. The active fractions are calcium phosphate, aluminium phosphate and iron phosphate, while, inactive fractions include reductant soluble and occluded-P. Calcium- P is present as discrete particles whereas, Aluminium-P and Iron-P occurs as films and /or adsorbed on clay or silt surfaces. The occluded P consists of Fe-P and Al-P fractions surrounded by an insert coat of another material that prevents the reaction of these phosphates with the soil solution. Reductant soluble forms occurs with an insert material that may be partially or totally dissolved under anaerobic conditions. Phosphorus fractions were determined as outlined by Petersen and Corey (1966).

The original method employed by Chang and Jackson (1957) were used with few modifications suggested by Petersen and Corey (1966) and which are described here in brief.

Each of the P fraction was extracted from 1g soil (< 0.15mm) by extracting it successively with different extractants, developing colour by using acid molybdate and reducing agent and colour intensity measured on spectronic-20 Spectrophotometer. The details of flow-scheme followed was as below:

Saloid bound phosphorus (Sal-P)

One gram of soil (< 0.15mm) extracted with 1N NH_4Cl and P content in extract was estimated by chlorostannous-reduced molybdophosphoric blue colour method in sulphuric acid system.

Aluminium bound phosphorus (Al-P)

To the soil previously extracted with NH_4Cl , was again extracted with 0.5 N NH_4F (pH 8.2) and the P in the extract was estimated by chlorostannous-reduced molybdophosphate blue colour method, in hydrochloric acid system.

Iron bound phosphorus (Fe-P)

The residue from the first step (Sal-P) was shaken with 0.1 N NaOH solution for 17 hours so as to extract Fe-P. Phosphorus in the extract was determined by chlorostannous reduced molybdophosphoric blue colour method, in sulphuric acid system.

Reductant soluble phosphorus (RS-P)

The soil was suspended in 0.3 M sodium citrate solution (tribasic salt) and shaken for 15 minutes with 0.5 g sodium dithionate. The reductant soluble P was estimated by chlorostannous-reduced molybdophosphoric blue colour method, in sulphuric acid system.

Occluded phosphorus (Occl-P)

After estimation of RS-P, the soil residue left was treated with 0.25 ml 0.1 M NaOH and shaken for one hour. After centrifugation, a supernatant solution was used for determination of

Occluded-P by employing chlorostannous reduced molybdophosphorus blue colour method, in sulphuric acid system.

Calcium phosphorus (Ca-P)

The residue from previous (Occl-P) extraction was washed with saturated NaCl solution and suspended with 0.5 N H₂SO₄ and the phosphorus was estimated by chlorostannous reduced molybdophosphoric blue colour method, in sulphuric acid system.

Organic phosphorus (Org-P)

This was obtained by subtracting the total inorganic phosphorus (summing up of all the mineral fractions) from total phosphorus in soil.

Total phosphorus (Total P)

One gram of 0.5 mm sieved soil was weighed and transferred to a 300 ml platinum crucible and 30 ml of 60 per cent HClO₄ was added and digestion was carried out on sand bath at 130°C till the dense fumes of HClO₄ evolved. When digestion was completed, the flask was removed and cooled. The 50 ml of distilled water was added to the flask and solution was filtered into 100 ml volumetric flask and volume was made with distilled water. An aliquot from this was used for estimation of total P by using vanado molybdophosphoric acid reagent and the intensity of yellow colour was read at 470 nm spectrophotometer (Jackson, 1973).

Note: After extraction of P fractions in respective extractant, follow either method 1 or method 2 for further estimation.

Method 1

- I. Pipette an aliquot of test solution containing from 0.005 mg to 0.045 mg P ($\mu\text{g ml}^{-1}$) into a 125 ml separating funnel marked at 20 ml.
- II. Add 5 ml of ammonium molybdate solution and dilute to 20 ml.
- III. Add 10 ml of Butan-2-ol, shake for 2 minutes, discard the aqueous layer.
- IV. Wash the inorganic layer once with 10 ml of 0.5 M H₂SO₄.
- V. Add 15 ml of diluted Tin (II) chloride solution and shake for 1 minute.
- VI. Discard the aqueous layer and transfer the organic phase to a 50 ml volumetric flask, the funnel being rinsed into the flask with ethanol.
- VII. Dilute with ethanol.
- VIII. Take reading at 730 nm on spectrophotometer after 40 minutes to 18 hrs later.

Method 2

- I. Pipette an aliquot of test solution containing up to 0.050 mg P ($1 \mu\text{g ml}^{-1}$) when diluted to 50 ml volumetric flask and dilute to 20 ml.
- II. Add 1 drop of dinitrophenol solution and 1:1 NH₄OH until slight permanent yellow colour is produced.
- III. Discharge the colour by adding 1 drop of 2 M HCl.

- IV. Add 5 ml of ammonium molybdate solution and dilute to volume.
- V. Add 5 drops of Tin (II) chloride solution in burette exactly 15 minutes before reading the transmission at 655 nm in spectrophotometer

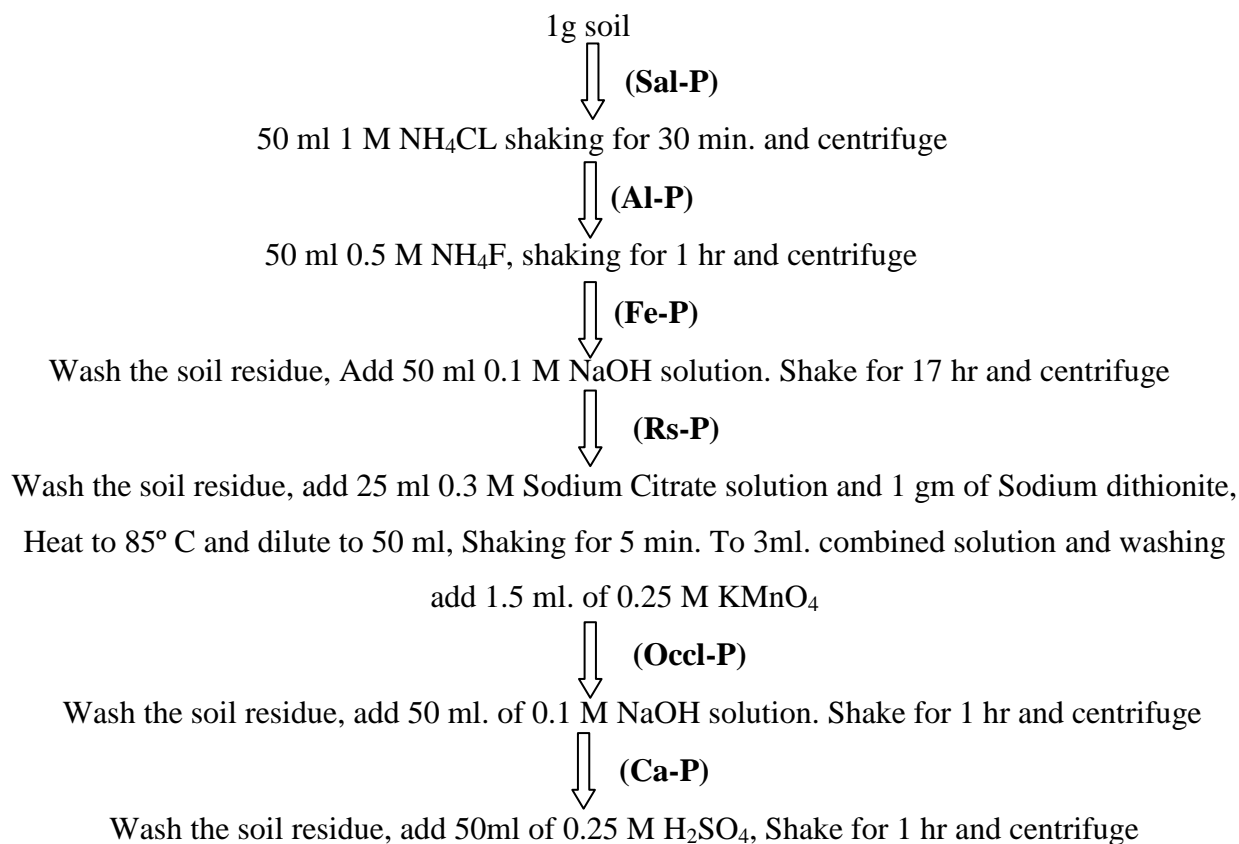


Fig-3.2, Flow chart of phosphorus fractionation from soil

3.6.2.5 Procedure for microbial population determination

For isolation of actinomycetes, bacteria and fungi from soil, three different media were selected. The composition of these media is given below

- **Kenkinght Medium (for actinomycetes)**

I.	Dextrose	1.0 g
II.	Potassium hexametaphosphate	0.1 g
III.	Sodium nitrate	0.1 g
IV.	Potassium chloride	0.1 g
V.	Magnesium sulphate	0.1 g
VI.	Agar	15.00 g
VII.	Distilled water	1000 ml

- **Yeast Extract Mannitol Agar (for Bacteria)**

I.	Mannitol	10 g
II.	Potassium hydrogen phosphate	0.5 g
III.	Magnesium sulphate	0.2 g
IV.	Sodium chloride	0.1 g
V.	Yeast extract	1.0 g

VI.	Agar	20 g
VII.	Distilled water	1000 ml
	• Rose Bengol Agar (for Fungi)	
I.	Glucose	10.00 g
II.	Peptone	5.00 g
III.	Potassium dihydrogen sulphate	1.00 g
IV.	Magnesium sulphate	0.5 g
V.	Streptomycin	30.00 mg
VI.	Rose bengol	0.035 g
VII.	Agar	15.00 g
VIII.	Distilled water	1000 ml

Preparation of medium

Agar- agar shreds were boiled in 500 ml of distilled water. In another beaker about 500 ml distilled water and all chemical ingredients were added and mixed properly. Both these mixtures were mixed properly, filtered through muslin cloth and made up the volume to 1000 ml with distilled water. The respective media were transferred in 500 ml conical flasks, plugged with non- absorbent cotton, tied these plugs with paper by thread and sterilized at 6.82 kg (15 lb) pressure for 15 minutes in an autoclave.

Method

Take 1.0 g of soil sample in 9 ml sterile distilled water and mix thoroughly.



This gave 10^{-1} dilution of soil sample, subsequently prepare 10-fold dilutions of above suspension from 10^{-1} to 10^{-10} in sterile distilled water



Transfer 1 ml aliquot of suitable dilution from (10^{-3} to 10^{-4} for fungi), (10^{-6} to 10^{-7} for bacteria), (10^{-5} to 10^{-6} for actinomycetes) to sterile Petri plate separately.



Pour the semi- solidifiable media which is prepared for respective organism at temperature 45°C to petri plates under aseptic condition.



After solidification of medium, these plates were incubated at $30^{\circ}\pm 2^{\circ}\text{C}$ in an inverted position in incubator

Fig-3.3, Flow chart of microbial population counts from soil

After the required incubation time for the formation of microbial colonies under study, count the colonies of micro-organisms through electronic counting machine.

3.6.2.6 Procedure for enzymes determination

Alkaline phosphatase

The activity of phosphatase can be determined by means of a phosphate originating in the process of mineralization of natural phosphoesters, e.g., phytin, or using organic fractions following the mineralization of “artificial” organic substrates (3-naphthylphosphate, p-nitrophenylphosphatase). In most instances p-nitrophenylphosphatase (Tabatabai and Bremner, 1969) are used as substrate being split up by phosphomonoesters to get ROH and HPO_4^{2-} .

The assay of alkaline phosphatase enzyme was carried by using method described by Tabatabai and Bremner (1969) based on the incubation of soil samples mixed with a buffer solution of p- nitrophenol is stained, and measured spectrophotometrically at 440 nm.

Reaction

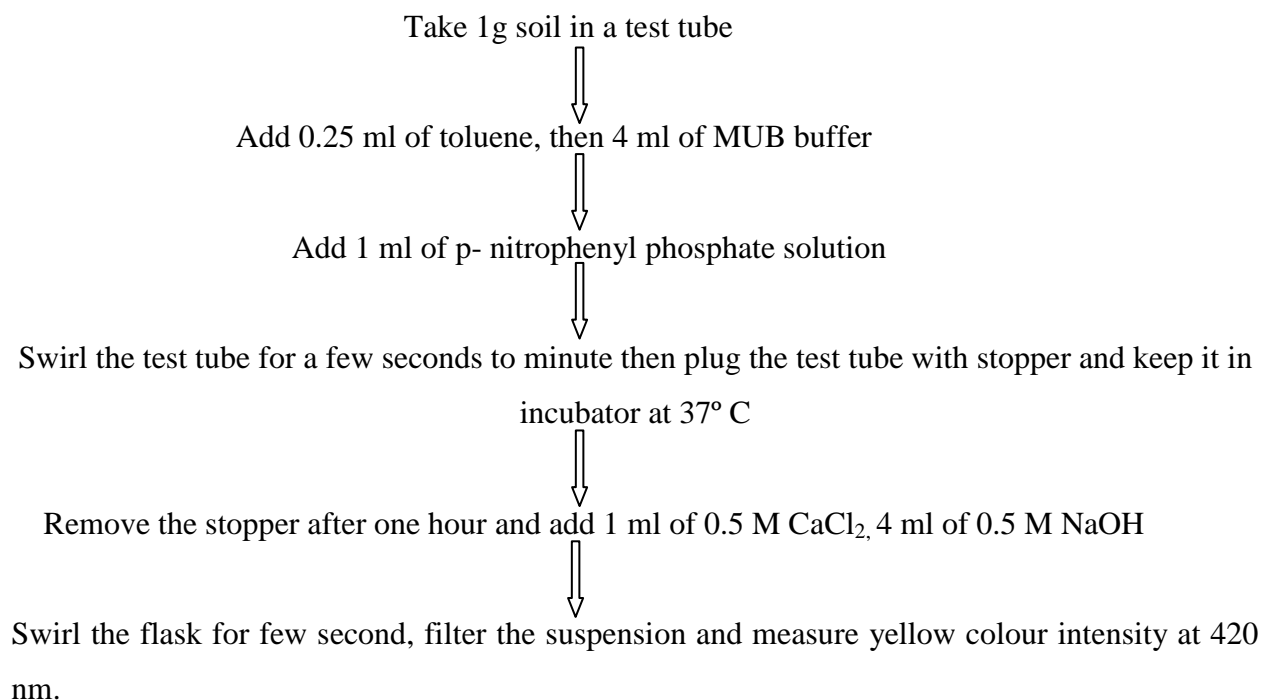
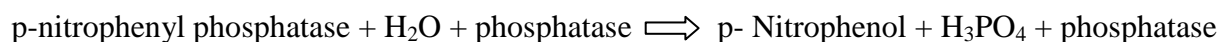


Fig-3.4 Flow chart for determination of alkaline phosphatase activity

Dehydrogenase

The method used for determination of DHA activity in soil is developed by Casida *et al.* 1964. According to this method, specific dyes such as the triphenylterazolium chloride (TTC), that can specify the flow of electrons transport system (ETS) activity. By the reduction of colourless, water soluble substrate (TTC) by dehydrogenase present in soil environment, an insoluble product with red colour (triphenyl formazan TPF) is formed.

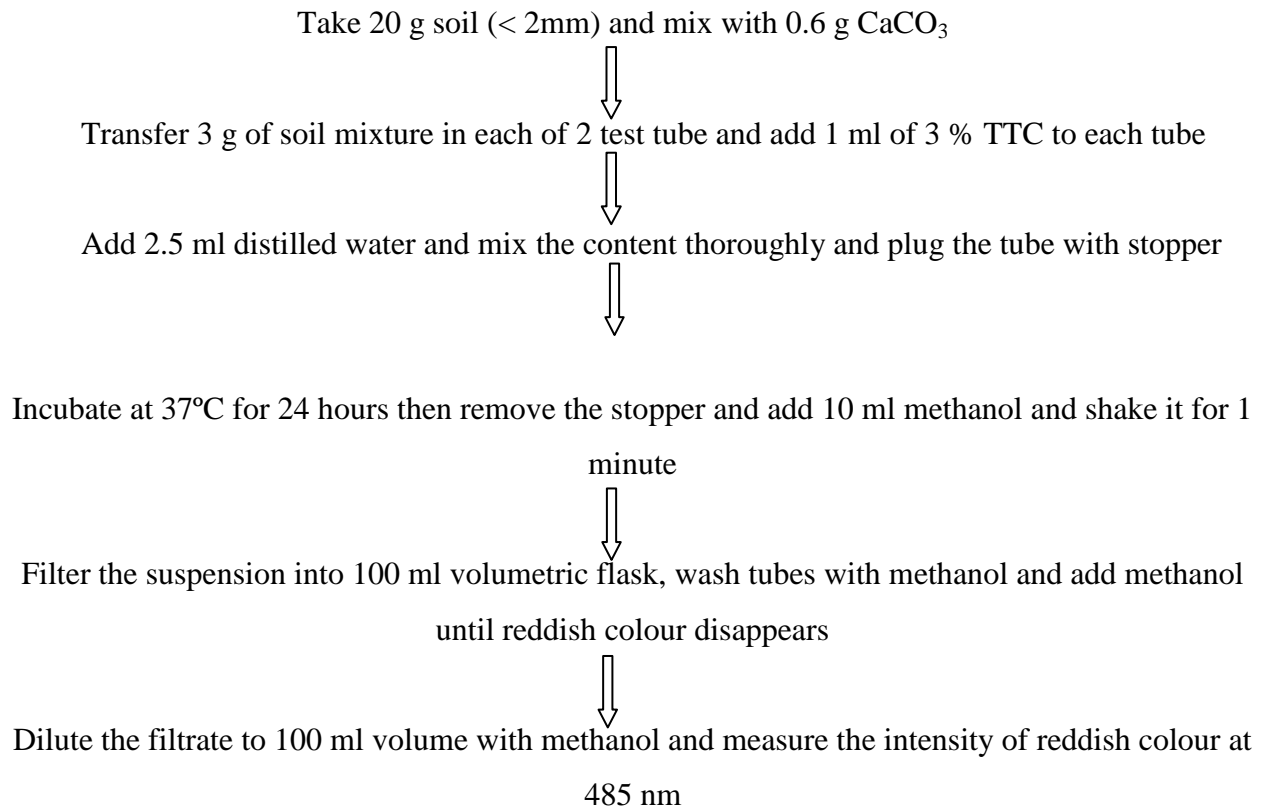


Fig-3.5, Flow chart for determination of dehydrogenase activity

3.7 Statistical Analysis

The field experiment was conducted by using randomized block design. The data obtained was analysed as per the methods described by Panse and Sukhatme (1995)

4. RESULTS AND DISCUSSION

A major agricultural research priority is to sustain soil productivity and to develop better method to monitor changes in soil physical, chemical and biological properties as affected by management. It is well established that organic amendment to the soil can positively affect soil productivity. It is thought that this benefit result from increased fertility and microbial activities.

The present investigation was carried out in respect to assess the effect of phosphorus enriched organic manure on nutrients availability, uptake and microbial activities. The results obtained were discussed under.

4.1 Growth Parameters of Chickpea

4.2 Chickpea Yield

4.3 Soil pH, EC and Organic Carbon Content after Harvest of Chickpea

4.4 Soil Available NPK Content after Harvest of Chickpea

4.5 Available Micronutrients Content after Harvest of Chickpea

4.6 Soil Phosphorus Fractions after Harvest of Chickpea

4.7 Soil Fungal, Actinomycetes and Bacterial Population at Flowering and at Harvest of Chickpea

4.8 Soil Dehydrogenase and Alkaline Phosphatase Enzyme Activities at Flowering and at of Chickpea

4.9 Nutrient Concentration in Grain and Straw of Chickpea

4.10 Total Nutrient Uptake of Chickpea at Harvest

4.11 Phosphorous Use Efficiency of Chickpea Crop

4.1 Growth Parameters of Chickpea

The data pertaining to effect of phosphorus enriched organic manure on growth parameters of chickpea crop are presented in table 4.1 and significant variations in growth parameters of chickpea were observed due to phosphorus enriched organic manure treatments to chickpea.

4.1.1 Plant Height

The maximum plant height (57.00 cm) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatments being at par with treatments T₂, T₃ and T₄. The RDF treatment (T₇) recorded the plant height of 57.33 cm. The lowest plant height (46.67 cm) was observed in treatment T₁ absolute control. Results (Table 4.1) indicated that the addition of phosphorus enriched organic manure and FYM significantly increased the plant height. Application of organic manures under the treatment T₆, T₂, T₃ and T₄ increased the plant height by 11.05, 9.74, 7.79 and 6.51 per cent, respectively over application of RDF only (T₇). The higher plant height under organic manure treatment might be due to the positive role of organic manure on nutrient availability to crop, which influenced by better physical condition and may

produce phytohormones, which stimulates the growth and increase in plant height. These results are in agreement with the findings of Meena *et al.* (2021).

Table 4.1 Growth parameters of chickpea as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	Growth parameters			
		Plant height (cm)	No. of branches plant ⁻¹	No. of pods plant ⁻¹	Nodule count plant ⁻¹
T ₁	Absolute control	46.67	2.10	57.67	15.00
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	56.33	2.99	84.33	20.60
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	55.33	2.88	79.67	24.00
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	54.67	2.84	78.00	21.00
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	51.67	2.78	75.67	19.60
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	57.00	3.01	87.67	27.30
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	51.33	2.80	73.33	20.33
	SE m (±)	1.55	0.29	3.27	0.012
	CD At 5%	4.79	0.88	10.09	0.039

4.1.2 Number of Branches

The significantly maximum number of branches plant⁻¹ (3.01) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) which was at par with all treatments except T₁ (absolute control) which was recorded lowest number of branches plant⁻¹ (2.10). More availability of NPK which enhanced the root mass due to which more uptake of nutrients and increment in photosynthesis activity which produces the maximum number of branches per plant. Similar results were observed by Rabari *et al.* (2020)

4.1.3 Number of Pods

The significantly highest number of pods plant⁻¹ (87.67) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatments being at par with treatments T₂, T₃ and T₄ (table 4.1). The RDF treatment (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹) recorded the lower number of pod plant⁻¹ (73.33) as compared to the treatments which comprised of phosphorus enriched organic manure and FYM. However, per cent increase over for number of pods plant⁻¹ under T₆, T₂, T₃ and T₄ were 19.56, 15.00, 8.65 and 6.37 per cent, respectively over RDF treatment. This could be due to adequate moisture and temperature due to addition of organic manure and FYM which facilitates better physical, chemical and biological condition and more uptake of NPK, due to which increase in plant metabolism and enhancement in number of pods. Similar finding was noted by Koireng *et al.* (2018)

4.1.4 Nodule Count

The number of nodules plant⁻¹ significantly highest (27.30) in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) which is followed by the treatment T₃ i.e., 100% P₂O₅ through phosphorus enriched organic manure and N and K as per recommendation (24.00). The lowest nodule count (15.00) was noted under absolute control treatment. The increase in the nutrient pool and the positive role of organic manure from FYM on nutrient availability to crop, which influenced by better physical condition and may produce phytohormones, which stimulates the growth and development of roots nodules and better assimilation of nutrients. These results are in agreement with the findings of Meena *et al.* (2021)

4.2 Chickpea Yield

The data pertaining to effect of phosphorus enriched organic manure on yield of chickpea crop are presented in table 4.2 and depicted in fig. 4.1.

The significantly highest seed yield (35.58 q ha⁻¹) was found in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatments and at par with treatment T₂-GRDF i.e., 25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM (34.67 q ha⁻¹). The least seed yield (24.49 q ha⁻¹) was observed in control treatment.

Further, it was observed that application of 100% P₂O₅ through phosphorus enriched organic manure along with N and K significantly recorded the higher seed yield (32.19 q ha⁻¹) as compared to 75 % and 60 % P₂O₅ through phosphorus enriched organic manure treatments. While, as compared to integrated nutrient management treatments, the RDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹) treatment recorded lower seed yield (30.62 q ha⁻¹).

Table 4.2 Chickpea yield as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	Seed yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
T ₁	Absolute control	24.49	51.75
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	34.67	61.70
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	32.19	58.61
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	31.88	58.31
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	31.04	56.74
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	35.58	62.66
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	30.62	55.80
SE m (+)		0.90	1.59
CD at 5%		2.78	4.91

It is evident from the data that the treatments T₃, T₄, T₅ and T₆ which consist of phosphorus enriched organic manure, increased the seed yield of chickpea by 5.13, 4.11, 1.37 and 16.20 per cent, respectively over RDF alone treatment.

Result (Table 4.2) further indicated that significantly maximum straw yield (62.66 q ha⁻¹) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments and which was at par with treatments T₂, T₃ and T₄. The least straw yield (51.75 q ha⁻¹) was observed in control treatment.

It was noticed that inclusion of phosphorus enriched organic manure significantly increased the straw yield of chickpea when compared with only RDF (55.80 q ha⁻¹). Similar results were noticed for FYM.

However, magnitude of increase in straw yield under T₃, T₄, T₅ and T₆ treatments which included phosphorus enriched organic manure as a source of phosphorus were 5.04, 4.50, 1.68 and 12.29 per cent, respectively over chemical fertilizer treatment (RDF alone).

In present study, the result of significant increase in yield of chickpea due to addition of organic manure with phosphatic fertilizer confirmed with the earlier reports of Khan *et al.* (2021) who were reported that inclusion of organic manure in IPM enhances favorable physio-chemical condition, biological status which is responsible for availability of nutrients, root growth, direct

impact on moisture retention and reduction in P fixation phenomenon, beneficial effects on soil microbial population which leads to the solubilization of nutrients. The C: N ratio of manure had the favorable effects on the process of mineralization of nutrients in soil and their effects in increasing yields of crops.

4.3 Soil pH, EC and Organic Carbon Content after Harvest of Chickpea

The data on effect of phosphorus enriched organic manure on soil pH, EC and organic carbon content after harvest of chickpea was depicted in table 4.3

Table 4.3 Soil pH, EC and organic carbon content after harvest of chickpea as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	pH (1:2.5)	EC (d Sm ⁻¹)	OC (%)
T ₁	Absolute control	8.15	0.29	0.57
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	8.11	0.32	0.63
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	8.12	0.30	0.60
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	8.12	0.30	0.60
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	8.13	0.32	0.61
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	8.10	0.34	0.64
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	8.14	0.29	0.58
	SE m (±)	0.015	0.01	0.002
	CD at 5%	NS	NS	0.008

4.3.1 pH

The results presented (Table 4.3) revealed that effect of phosphorus enriched organic manure on soil pH after harvest of crop as influenced by different treatments were non-significant. However, numerically the higher pH is observed in T₁ treatment (8.15) absolute control and lowest (8.10) value in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through Phosphorus enriched organic manure + 5 t ha⁻¹ FYM).

4.3.2 Electrical Conductivity

The data presented revealed that the EC in soil ranged in 0.29 to 0.34 d Sm⁻¹ however, the effect of phosphorus enriched organic manure on soil EC after harvest of crop as influenced by

different treatments were non-significant. The higher EC was observed in T₆ treatment (0.34 d Sm⁻¹) i.e., GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through Phosphorus enriched organic manure + 5 t ha⁻¹ FYM) and numerically lower EC (0.29 d Sm⁻¹) was recorded under absolute control and RDF treatments.

4.3.3 Organic Carbon

The data (Table 4.1 and Fig. 4.2) indicated that, significantly maximum organic carbon content (0.64 %) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other and found to be at par with treatment T₂-GRDF (25:50:30 N, P₂O₅ and K₂O + 5 t ha⁻¹ FYM) (0.63 %). While, per cent increase in organic carbon content under the treatments T₂, T₃, T₄, T₅ and T₆ due to the addition of organic manures were 8.62, 3.45, 3.45, 5.17 and 10.34 per cent, respectively over RDF treatment. An increase in organic carbon content in this study could be due to the application of phosphorus enriched organic manure and FYM to chickpea. Increase in organic carbon might be due to the addition of organic matter through more biomass, root mass, defoliation may have created favorable effect on soil organic carbon. These results are in close conformity with the observation of Kokani *et al.* (2015), Erhunmwunse *et al.* (2019) and Gao *et al.* (2019).

4.4 Soil Available NPK Content after Harvest of Chickpea

The data presented in table 4.4 and illustrated in fig. 4.3 showed the soil available nutrient content at harvest of chickpea as influenced by different treatments.

4.4.1 Available Nitrogen

Available nitrogen content in soil at harvest was significantly higher (214.0 kg ha⁻¹) in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) and found at par with treatments T₂, T₃ and T₄. As compared to integrated nutrient management treatments, the RDF treatment recorded the lower values of available N (188.67 kg ha⁻¹), however, the least value of available N (176.33 kg ha⁻¹) was recorded under absolute control.

Further, it was noticed that the application of FYM and P enriched organic manures in present study increased the available N content in soil under the treatments T₂, T₃, T₄, T₅ and T₆ by 10.42, 7.07, 5.48, 2.65 and 13.43 per cent, respectively over the treatment T₇ (RDF).

The increase in available nitrogen might be due to the release of nitrogen after decomposition of organic matter and addition of nitrogen through FYM and P enriched organic manure to available pool of the soil nutrients. Similar trend of observations was reported by Dadhich *et al.* (2011) and Billah *et al.* (2020).

Table 4.4 Soil available NPK content after harvest of chickpea as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	Soil available nutrients (kg ha ⁻¹)		
		N	P	K
T ₁	Absolute control	176.33	10.33	503.00
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	208.33	13.23	622.67
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	202.00	13.11	585.67
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	199.00	12.95	572.00
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	193.67	12.11	559.00
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	214.00	14.31	609.00
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	188.67	11.81	542.33
	SE m (±)	6.05	0.50	13.55
	CD at 5%	18.64	1.54	41.75

4.4.2 Available Phosphorus

Available phosphorus content in soil at harvest was significantly influenced by the treatments and highest (14.31 kg ha⁻¹) available P was recorded in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) and found at par with treatments T₂, T₃ and T₄.

Application of phosphorus enriched organic manure significantly increased the available P content in soil over RDF and absolute control. The magnitude of increase in available P content in soil under T₃, T₄, T₅ and T₆ treatments where phosphorus enriched organic manure was applied were 11.01, 9.65, 2.54 and 21.17 per cent, respectively over RDF alone (T₇).

The mineralization and decomposition process of organic sources might have created favorable effects on built-up of the microbial population especially-P solubilizing microbes in soil and less fixation of P by soil constituents and release of various weak acids might have enhanced the available P status of soil. Similar results are in consonance with those of Almeida *et al.* (2019) and Erhunmwunse *et al.* (2019).

4.4.3 Available Potassium

The significantly highest available potassium content ($622.67 \text{ kg ha}^{-1}$) in soil at harvest was recorded in treatment T₂-GRDF (25:50:30 N, P₂O₅ and K₂O + 5 t kg ha⁻¹ FYM) which was found at par with the treatments T₆ and T₃.

Further, it is evident from the data that the combined application of organic manure and inorganic fertilizer significantly increased the available K content in soil as compared to RDF alone. The lowest potassium content in soil ($503.00 \text{ kg ha}^{-1}$) was noted with absolute control.

However, the increase in K content in soil at harvest of chickpea under T₂, T₃, T₄, T₅ and T₆ were 14.81, 7.99, 5.47, 3.07 and 12.29 per cent, respectively over RDF alone (T₇).

The higher availability of potassium during the growth period of chickpea might be due to release of organically bound K during decomposition process as well as by solubilization of insoluble K forms from minerals. These could be due to increase in the nutrient pool and the positive role of organic manure on nutrient availability to plant, which influenced by better physical condition and may produce phytohormones, which stimulates the growth and development of roots and better assimilation of nutrients. Similar trend of observations was reported by Dadhich *et al.* (2011) and Billah *et al.* (2020).

4.5 Available Micronutrients Content after Harvest of Chickpea

The data in respect to soil available micronutrients Fe, Mn, Zn and Cu as influenced by different treatments are reported in table 4.5.

The significantly highest Fe, Mn, Zn and Cu micronutrient contents (5.83 , 11.01 , 0.57 and 0.62 mg kg^{-1} , respectively) were observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatments being at par with treatment T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM, T₃-100% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation, T₄-75% P₂O₅ through Phosphorus enriched organic manure and 25% P₂O₅ through chemical fertilizer and N and K as per recommendation and T₅-60% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation). The availability of micronutrients in soil was significantly increased due to the application of P enriched organic manure and FYM. The least Fe, Mn, Zn and Cu micronutrient contents (5.13 , 10.22 , 0.44 and 0.51 mg kg^{-1} , respectively) was found in treatment T₁ absolute control.

Addition of phosphorus enriched organic manure in the treatments T₃, T₄, T₅ and T₆ along with inorganic fertilizer increases the available Fe by 6.70, 5.59, 3.72 and 8.57 per cent, respectively, Mn by 3.97, 3.48, 2.23 and 6.58 per cent, respectively, Zn by 19.56, 17.39, 8.70 and 23.91 per cent, respectively and Cu by 12.96, 11.11, 9.26 and 14.81 per cent, respectively over T₇ i.e., RDF alone.

Table 4.5 Available micronutrients content after harvest of chickpea as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	Soil available micronutrients (mg kg ⁻¹)			
		Fe	Mn	Zn	Cu
T ₁	Absolute control	5.13	10.22	0.44	0.51
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	5.77	10.83	0.56	0.61
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	5.73	10.74	0.55	0.61
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	5.67	10.69	0.54	0.60
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	5.57	10.56	0.50	0.59
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	5.83	11.01	0.57	0.62
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	5.37	10.33	0.46	0.54
	SE m (+)	0.12	0.15	0.01	0.01
	CD at 5%	0.36	0.46	0.04	0.05

More availability of micronutrients may be attributed to release of organic acids and humus which act as chelating agents thereby preventing micronutrients from their precipitation, fixation, leaching and oxidation in soil. The higher availability of micronutrients in organic P added treatment might be attributed due to its inherent capacity to add good amount of organic carbon content to soil which faster the process of mineralization of organically bound DTPA and

available micronutrients present in soil. The beneficial effect of organic manures on soil available status of micronutrients was reported by Rajkhowa *et al.* (2016).

4.6 Soil Phosphorus Fractions after Harvest of Chickpea

The data pertaining to the soil phosphorus fractions influenced by phosphorus enriched organic manure after harvest of chickpea was presented in table 4.6 and depicted in fig. 4.9 and 4.10.

4.6.1 Saloid Phosphorus (Sal-P)

The significantly highest value of saloid-P was observed (13.84 mg kg^{-1}) in T₆ treatment GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM). Among the rest of the phosphorus enriched organic manure treatments (T₃ to T₅), the treatment T₃-100% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation) recorded higher Sal-P (12.08 mg kg^{-1}) fraction and least (10.98 mg kg^{-1}) observed with 60% P₂O₅ through phosphorus enriched organic manure and N and K as per recommendation (T₅) treatment. The conversion of soluble-P into various forms of P varying in their solubility depends on the soil reaction, content of sesquioxide's free CaCO₃, Al₂O₃ and organic carbon. Similar trend of observations was reported by Bhavsar *et al.* (2018).

Table 4.6 Soil phosphorus fractions after harvest of chickpea as influenced by phosphorus enriched organic manure

Treatment	Soil phosphorus fractions (mg kg^{-1})							
	Saloid -P	Al-P	Fe-P	Red-P	Occl-P	Ca-P	Org-P	Total-P
T ₁	6.75	21.82	18.01	55.46	4.09	337.83	295.60	739.63
T ₂	12.39	27.23	22.35	66.78	9.77	333.43	342.23	814.18
T ₃	12.08	26.68	21.23	64.08	8.20	342.88	339.31	814.46
T ₄	11.12	25.04	20.61	63.47	7.19	347.24	335.21	809.88
T ₅	10.98	23.51	19.04	62.23	6.87	350.41	332.56	805.60
T ₆	13.84	28.31	23.57	68.43	11.88	330.58	344.21	820.82
T ₇	9.34	22.12	18.93	59.47	5.57	355.45	330.08	800.96
SE m (\pm)	0.003	0.002	0.003	0.12	0.003	0.12	0.12	0.38
C.D.at 5 (%)	0.009	0.009	0.010	0.38	0.010	0.39	0.38	NS

4.6.2 Aluminum Phosphorus (Al-P)

The significantly maximum content of Al-P (28.31 mg kg^{-1}) was observed in T₆ treatment GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) followed by in treatment T₂ (27.23 mg kg^{-1}) i.e., GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM). In between the phosphorus enriched organic

manure treatments (T_3 to T_6), the treatment T_6 recorded higher Al-P fraction and least (23.51 mg kg^{-1}) observed with (T_5) treatment i.e., 60% P_2O_5 through Phosphorus enriched organic manure and N and K as per recommendation. This might be due to decreased in calcium carbonate content as aluminium activity was high to precipitate phosphorus. Similar results are in consonance with those of Bhavsar *et al.* (2018) and Sudhakaran *et al.* (2018).

4.6.3 Iron Phosphorus (Fe-P)

At harvest of chickpea, the iron phosphorus fraction content was ranged between 18.01 to 23.57 mg kg^{-1} (Table 4.6). The significantly highest value of Fe-P (23.57 mg kg^{-1}) was observed in T_6 treatment GRDF (25 kg N and 30 kg K_2O through chemical fertilizers, 50 kg P_2O_5 through phosphorus enriched organic manure + 5 t ha^{-1} FYM) which is followed by treatment T_2 (22.35 mg kg^{-1}) i.e., GRDF (25:50:30 N, P_2O_5 and $K_2O \text{ kg ha}^{-1}$ + 5 t ha^{-1} FYM). As compared to the organic manure treatments, the RDF alone showed the less content of Fe-P. This might be due to high organic carbon content and decreased in calcium carbonate so the iron activity is high to precipitate P. Similar results are in consonance with those of Bhavsar *et al.* (2018) and Song *et al.* (2017).

4.6.4 Reductant Phosphorus (Red-P)

The reductant phosphorus (Red-P) fraction content in soil was ranged in 55.46 to 68.43 mg kg^{-1} at harvest of chickpea. The significantly highest value of Red-P (68.43 mg kg^{-1}) was observed in T_6 treatment GRDF (25 kg N and 30 kg K_2O through chemical fertilizers, 50 kg P_2O_5 through phosphorus enriched organic manure + 5 t ha^{-1} FYM) followed by the treatment T_2 (66.78 mg kg^{-1}). In between the phosphorus enriched organic manure treatments (T_3 to T_6), the treatment T_6 recorded higher Red-P fraction and least (62.23 mg kg^{-1}) observed with (60% P_2O_5 through Phosphorus enriched organic manure and N and K as per recommendation (T_5 treatment)). There was a conversion of P into Red-P due to application of fertilizer alone or in combination with organic manure and might be due to rise in Fe-P and Al-P content, high clay content and low pH of soil. Similar finding was noted by Bhavsar *et al.* (2018) and Sudhakaran *et al.* (2018).

4.6.5 Occluded Phosphorus (Occl-P)

At harvest of chickpea, the occluded phosphorus (Occl-P) in soil was in range of 4.09 to 11.88 mg kg^{-1} . The significantly maximum content of Occl-P fraction (11.88 mg kg^{-1}) was observed in T_6 treatment GRDF (25 kg N and 30 kg K_2O through chemical fertilizers, 50 kg P_2O_5 through phosphorus enriched organic manure + 5 t ha^{-1} FYM) followed by treatment T_2 (9.77 mg kg^{-1}) and T_3 (8.20 mg kg^{-1}) and the lowest content was recorded in absolute control (4.09 mg kg^{-1}). The RDF treatment showed the lower content of this fraction as compared to organic manure along with inorganic fertilizer treatments. Organic manure along with NPK fertilizer enhanced the Occl-P content than the optimum dose of fertilizer, it was possible that

solubilising effect of organic acids produced as a results of organic manure decomposition maintained due to applied as well as soil phosphate in higher level. Similar results are in consonance with those of Bhavsar *et al.* (2018) and Song *et al.* (2017).

4.6.6 Calcium Phosphorus (Ca-P)

The calcium phosphorus (Ca-P) fraction content in soil at harvest of chickpea was ranged between 330.58 to 355.45 mg kg⁻¹. The significantly highest value of Cal-P (355.45 mg kg⁻¹) was observed in treatment T₇-(25:50:30 N, P₂O₅ and K₂O kg ha⁻¹) which is followed by T₅ (350.41 mg kg⁻¹) i.e., 60 % P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation and T₄ (347.24 mg kg⁻¹) i.e., 75% P₂O₅ through Phosphorus enriched organic manure and 25% P₂O₅ through chemical fertilizer and N and K as per recommendation treatments. However, the lowest content of this fraction (330.58 mg kg⁻¹) was recorded in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM). Similar finding was previously noted by Nayak *et al.* (2015)

4.6.7 Organic Phosphorus (Org-P)

The organic phosphorus (Org-P) fraction content in soil was ranged between 295.60 to 344.21 mg kg⁻¹. The significantly highest value of Org-P (344.21 mg kg⁻¹) was observed in T₆ treatment GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) followed by T₂ (342.23 mg kg⁻¹) i.e., GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM). However, it was noticed that application of phosphorus enriched organic manure and FYM significantly increase the Org-P fraction as compared to RDF treatment. This might be due to the addition of phosphorus enriched organic manure with FYM which contains high organic matter content as well as organic-P. The results of present investigation are in consonance with those of Bhavsar *et al.* (2018) and Sudhakaran *et al.* (2018).

4.6.8 Total Phosphorus

The total P content in soil at harvest of chickpea showed non-significant result and the values are ranged in 739.63 to 820.82 mg kg⁻¹. However, numerically higher content (820.82 mg kg⁻¹) was recorded in T₆ treatment GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) followed by treatment T₃ (8814.46 mg kg⁻¹).

Over all scrutiny of these P fractions in soil indicated that the significantly highest value of phosphorus fractions was recorded in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) except Ca-P which was observed highest in treatment T₇-RDF (25:50:30 N, P₂O₅ and K₂O ha⁻¹). However, the increasing order of P fractions noted as Ca-P>org-P>Red-P>Al-P>Fe-P>Saloid-

P>Occl-P. These results are supported by earlier results of Sheeba and Kumaraswamy (2005). In general, from the above results regarding fractions of phosphorus, that the organic and inorganic P fractions were improved by P enriched organic manure practices in chickpea.

4.7 Soil Fungal, Actinomycetes and Bacterial Populations at Flowering and at Harvest of Chickpea

Results presented in table 4.7 and illustrated in fig. 4.4, 4.5 and 4.6 indicated the significant effect of application of phosphorus enriched organic manure on soil microbial population.

The significantly highest fungal population (22.31 and $19.62 \times 10^4 \text{ g}^{-1}$ soil, respectively) observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) among all the other treatments at flowering and at harvest of chickpea followed by T₃ treatment (20.11 and $16.40 \times 10^4 \text{ g}^{-1}$ soil, respectively) i.e., 100% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation. The magnitude of increase in fungal population at harvest under the treatments T₆ and T₃ were 205.61 and 155.45 per cent, respectively over RDF (T₇). The RDF treatment showed quite less population as compared to organic + inorganic treatments. The higher fungal population was observed at flowering stage and it declined at harvest of chickpea.

Significantly maximum populations of actinomycetes (38.86 and $32.92 \times 10^6 \text{ g}^{-1}$ soil, respectively) and bacteria (46.32 and $41.03 \times 10^7 \text{ g}^{-1}$ soil, respectively) observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) at flowering and at harvest of chickpea followed by the treatment T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM) i.e. 32.63 and $29.61 \times 10^6 \text{ g}^{-1}$ soil, respectively for actinomycetes and 42.78 and $37.13 \times 10^7 \text{ g}^{-1}$ soil, respectively for bacteria. The less population of these microorganisms were recorded in RDF as compared to INM treatments. Higher population of actinomycetes and bacteria were recorded at flowering stage and less at harvest. However, at harvest, under the treatments T₆ and T₂, the per cent increase in actinomycetes population was 121.39 and 99.13 per cent and bacterial population was 89.52 and 71.50 per cent, respectively over treatment RDF (T₇).

The increase in microbial population at flowering stage then at harvest stage could be due to higher degree of plant metabolism activities at flowering stage, there by secreting higher amount of root exudates which act as substrates to microbial population and the highest value in treatment T₆ might be attribute due to the increment in organic matter through organic manure in soil which serves as a food and energy source for microbes resulted in rapid stimulation of microbial growth, multiplication and their development in soil. These results are in close conformity with the observation of Tapas and Gupta (2005) and Erhunmwunse *et al.* (2019).

Table 4.7 Soil fungal, actinomycetes and bacterial population at flowering and at harvest as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	Microbial population					
		Fungi (cfu × 10 ⁴ g ⁻¹ soil)		Actinomycetes (cfu × 10 ⁶ g ⁻¹ soil)		Bacteria (cfu × 10 ⁷ g ⁻¹ soil)	
		At flowering	At harvest	At flowering	At harvest	At flowering	At harvest
T ₁	Absolute control	10.04	4.19	15.44	11.53	22.14	13.12
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	20.11	16.40	32.63	29.61	42.78	37.13
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	18.35	14.41	28.45	24.46	38.30	30.37
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	14.42	10.92	24.15	19.47	34.09	26.15
T ₅	60 % P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	12.06	8.31	20.95	17.11	28.20	17.17
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	22.31	19.62	38.86	32.92	46.32	41.03
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	11.84	6.42	17.83	14.87	30.13	21.65
	SE m (±)	0.004	0.006	0.006	0.006	0.02	0.003
	CD at 5%	0.012	0.021	0.021	0.019	0.06	0.009

4.8 Soil Dehydrogenase and Alkaline Phosphatase Enzyme Activities at Flowering and at Harvest of Chickpea

Results depicted in table 4.8 indicated the significant changes in enzyme activities due to the addition of phosphorus enriched organic manure.

Table 4.8 Soil dehydrogenase and alkaline phosphatase enzyme activity as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	Enzyme activity			
		Dehydrogenase ($\mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ hr}^{-1}$)		Alkaline phosphatase ($\mu\text{g PNP g}^{-1} \text{ soil hr}^{-1}$)	
		At flowering	At harvest	At flowering	At harvest
T ₁	Absolute control	15.88	9.66	27.62	19.10
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	32.80	27.27	61.12	33.47
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	30.44	24.51	58.88	31.11
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	29.90	21.59	54.86	25.71
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	29.61	18.50	49.91	24.66
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	45.58	30.84	66.53	38.17
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	28.17	13.88	48.31	25.71
	SE m (\pm)	0.003	0.003	0.003	0.012
	CD at 5%	0.010	0.011	0.010	0.037

4.8.1 Dehydrogenase Activity

The data (Table 4.8 and Fig. 4.7) showed the significantly highest activity of dehydrogenase enzyme (45.58 and $30.84 \mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ hr}^{-1}$, respectively) at flowering and at harvest of chickpea under the treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments and followed by T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM) i.e. 32.80 and $27.27 \mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ hr}^{-1}$, respectively. It was noticed that application of organics with inorganic fertilizer treatments significantly recorded the higher enzyme activity

over RDF treatment. The least enzyme activity was recorded in absolute control. However, at harvest of chickpea, per cent increase in dehydrogenase activity under the treatments T₃, T₄, T₅ and T₆ which includes phosphorus enriched organic manure were 76.58, 55.55, 33.29 and 122.19 per cent, respectively over RDF. Soil enzyme such as dehydrogenase was chosen as an index of microbial activity because it refers to a group of mostly intercellular enzymes which catalyzes the oxidation of soil organic matter and influenced by agronomic practices. Activity of this enzyme significantly correlates with soil biomass carbon. Thus, dehydrogenase activity is indicated to be good indicators of soil microbial activity. This enzyme activity increased with leguminous because of enhanced microbial activity and enzyme synthesis and accumulation due to increased carbon and nutrient availability as recorded in this present study. These results are in close conformity with the observation of Ramesh *et al.* (2008).

4.8.2 Alkaline Phosphatase Activity

Perusal of the data (Table 4.8 and Fig. 4.8) indicated that, at flowering stage, the alkaline phosphatase activity ranged between 27.62 to 66.53 $\mu\text{g PNP g}^{-1} \text{ soil hr}^{-1}$ which was decreased at harvest and ranged in 19.10 to 38.17 $\mu\text{g PNP g}^{-1} \text{ soil hr}^{-1}$. The result showed the significantly highest activity of alkaline phosphatase enzyme (66.53 and 38.17 $\mu\text{g PNP g}^{-1} \text{ soil hr}^{-1}$, respectively) in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) followed by T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM) i.e., 61.12 and 33.47 $\mu\text{g PNP g}^{-1} \text{ soil hr}^{-1}$, respectively. The RDF treatment recorded lower activity of this enzyme (48.31 and 25.71 $\mu\text{g PNP g}^{-1} \text{ soil hr}^{-1}$, respectively) as compared to INM treatments at both the stages. Inclusion of phosphorus enriched organic manure in treatments T₃ and T₆ increased the alkaline phosphatase activity at harvest of chickpea by 21.33 and 48.46 per cent, respectively over RDF.

Increase in alkaline phosphatase activity could be due to increase in mineralization of P, and increment in fungal and bacterial population. It was noticed that the enzyme activities are gradually declined from flowering to harvest of crop. This might be due to increase in amount of root exudates which positively influenced the enzymatic activities. Similar results are in consonance with those of Chang *et al.* (2010) and Basak and Gajbhiye (2018). Generally, the enzyme activities in the soil are closely related to the organic matter content. The application of balanced amounts of nutrients and manures improved the organic matter and MBC status of soils, which corresponded with higher enzyme activity.

4.9 Nutrient Concentration in Grain and Straw of Chickpea

Data on nutrient concentration in chickpea affected due the phosphorus enriched organic manure was presented in table 4.9.

Table 4.9 Nutrient concentrations in grain and straw of chickpea at harvest

Tr. No.	Treatment	Nutrient concentration in grain (%)			Nutrient concentration in straw (%)		
		N	P	K	N	P	K
T ₁	Absolute control	2.62	0.41	0.85	0.73	0.18	1.05
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	2.99	0.48	0.92	0.81	0.24	1.15
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	2.88	0.49	0.93	0.77	0.24	1.16
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	2.84	0.48	0.96	0.81	0.23	1.11
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	2.78	0.46	0.96	0.83	0.23	1.08
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	3.01	0.50	0.94	0.80	0.25	1.17
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	2.80	0.45	0.92	0.82	0.22	1.10
	SE m (±)	0.06	0.02	0.02	0.04	0.01	0.04
	CD at 5%	NS	NS	NS	NS	NS	NS

The data pertaining to the nutrient concentration in grain as well as in straw influenced due to phosphorus enriched organic manure showed non-significant result at harvest of chickpea crop. However, numerically the higher value of concentration of N and P of grain (3.01 and 0.50 %, respectively) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through Phosphorus enriched organic manure + 5 t ha⁻¹ FYM) and for K (0.96 %) it was recorded in treatments T₄ and T₅. For straw, the higher N concentration (0.83 %) was noted in treatment T₅ and for P (0.25 %) and K (1.17 %), it was recorded in T₆ treatment. While, lowest nutrient concentrations were observed in treatment T₁ absolute control.

4.10 Total Nutrient Uptake of Chickpea at Harvest

The data on nutrient uptake by chickpea crop as influenced by phosphorus enriched organic manure was incorporated in table 4.10 and illustrated in fig. 4.11.

4.10.1 Total Nitrogen

The significantly highest total uptake of nitrogen ($122.66 \text{ kg ha}^{-1}$) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments being at par with treatment T₂ ($121.80 \text{ kg ha}^{-1}$). The percent increase in total uptake of nitrogen at harvest of chickpea in T₂ and T₆ treatments were 10.22 and 10.99 per cent, respectively over RDF treatment. The lowest nitrogen uptake was recorded in absolute control. The increment in nitrogen uptake by chickpea crop might be due to the maximum availability of NPK and micronutrients in soil and due to more availability of nutrients the root mass, plant biomass was increase and it's showed the positive effect on the yield of the chickpea crop, finally showed higher nitrogen uptake. Similar results were also obtained by Khan *et al.* (2021) and Meena *et al.* (2021).

Table 4.10 Total uptake of nutrient uptake of chickpea at harvest as influenced by phosphorus enriched organic manure

Tr. No.	Treatment	Total nutrient uptake (kg ha^{-1})		
		N	P	K
T ₁	Absolute control	61.12	11.63	44.37
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha^{-1} + 5 t ha ⁻¹ FYM)	121.80	25.13	80.43
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	111.62	23.98	78.13
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	111.21	23.88	78.03
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	90.61	19.05	63.08
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	122.66	25.80	81.21
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha^{-1})	110.51	22.09	73.50
	SE m (\pm)	2.73	0.93	1.22
	CD at 5%	8.42	2.85	3.76

4.10.2 Total Phosphorus

The significantly highest total uptake of phosphorus (25.80 kg ha^{-1}) was recorded in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) which was found at par with the treatment

T₂ (25.13 kg ha⁻¹), T₃ (23.98 kg ha⁻¹) and T₄ (23.88 kg ha⁻¹). While, RDF treatment (T₇) recorded lower P uptake (22.09 kg ha⁻¹) compared to above treatments. However, increase in P uptake under the treatments T₂, T₃, T₄ and T₆ were 13.76, 8.56, 8.10 and 16.79 per cent, respectively over RDF,

More availability of phosphorus is well responsible for increase in photosynthesis activity of leguminous crop which may enhanced the phosphorus uptake by chickpea crop. Similar trend was noted by Jat and Ahlawat (2006) and Khan *et al.* (2021).

4.10.3 Total Potassium

Results (Table 4.10) showed that the significantly highest total uptake of potash (81.21 kg ha⁻¹) was recorded in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) which found at par with the treatment T₂ (80.43 kg ha⁻¹), T₃ (78.13 kg ha⁻¹) and T₄ (78.03 kg ha⁻¹). The lowest K uptake was recorded in absolute control treatment. While, RDF treatment (T₇) recorded lower K uptake (73.50 kg ha⁻¹) compared to all treatments except T₅ and T₁. The magnitude of increase in K uptake under the treatments T₂, T₃, T₄ and T₆ were 9.43, 6.30, 6.16 and 10.49 per cent, respectively over RDF.

The enhancement in uptake of potassium could be due to application of organic matter resulted in improvement in physical, chemical and biological make up of soil and improves the concentration of K in soil solution and exchangeable K complex which may helped in potassium ion uptake by plant from soil solution. These results are also supported by Singh and Singh (2012)

4.11 Phosphorous Use Efficiency

Data pertaining to P use efficiency of chickpea crop affected by phosphorus enriched organic manure was presented in table 4.11.

Perusal of the results indicated that the P use efficiency under the treatments ranged between 20.93 to 28.34 per cent. The highest phosphorus use efficiency (28.34 %) observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) followed by treatment T₂- GRDF (25:50:30 N, P₂O₅ and K₂O + 5 t ha⁻¹ FYM) (27.00 %). It was noticed that application of phosphorus enriched organic manure enhanced the P use efficiency under chickpea as compared to RDF treatment. This might be attributed to the maintenance and improvement of soil nutrient status as well as microbial activities and community compositions through the addition of organic manures. Similar results were reported by Lu *et al.* (2021) and Rehim *et al.* (2012).

Table 4.11 Phosphorus use efficiency affected by different treatments

Tr. No.	Treatment	P use efficiency (%)
T ₁	Absolute control	0.00
T ₂	GRDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹ + 5 t ha ⁻¹ FYM)	27.00
T ₃	100% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	24.69
T ₄	75% P ₂ O ₅ through Phosphorus enriched organic manure and 25% P ₂ O ₅ through chemical fertilizer and N and K as per recommendation	24.50
T ₅	60% P ₂ O ₅ through Phosphorus enriched organic manure and N and K as per recommendation	24.72
T ₆	GRDF (25 kg N and 30 kg K ₂ O through chemical fertilizers, 50 kg P ₂ O ₅ through Phosphorus enriched organic manure + 5 t ha ⁻¹ FYM)	28.34
T ₇	RDF (25:50:30 N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	20.93

The capacity of a soil to function within ecosystem boundaries is to sustain biological productivity and maintain soil health by several factors. The cropping system and crops can play an important role in soil chemical and biological properties. The overall interpretation of these diverse sets of data is that the quality of soil enhanced with the incorporation of enriched organic manures, ultimately increased the crop production per unit area.

5. SUMMARY AND CONCLUSIONS

The present investigation was planned to study the “Effect of phosphorus enriched organic manure on nutrient availability, phosphorus fractions, P use efficiency and yield of chickpea under Inceptisol”. The field experiment was conducted at STCR Farm, Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, during *Rabi* 2020.

The experiment was laid out in randomized block design with seven treatments replicated three times. The treatment comprised of T₁-Absolute control, T₂-GRDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹ + 5 t ha⁻¹ FYM), T₃-100% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation), T₄-75% P₂O₅ through Phosphorus enriched organic manure and 25% P₂O₅ through chemical fertilizer and N and K as per recommendation), T₅-60% P₂O₅ through Phosphorus enriched organic manure and N and K as per recommendation), T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through Phosphorus enriched organic manure + 5 t ha⁻¹ FYM), T₇-RDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹).

Experimental soil was medium deep black belonging to Inceptisol order and taxonomically classified as montomorillonitic isohyperthermic family of *Vertic Haplustepts*. Textural class was clayey and slightly alkaline in reaction (pH 8.14), low in soluble salts (EC 0.28 dSm⁻¹), Low in available nitrogen (203.84 kg ha⁻¹), low in available phosphorus (12.7 kg ha⁻¹), very high in available potassium (627.2 kg ha⁻¹). The DTPA extractable micronutrient Zn was low (0.47 mg kg⁻¹) and Fe, Mn and Cu were sufficient (5.48, 10.41 and 0.56 mg kg⁻¹, respectively). The results obtained and reported from present investigation are summarized and concluded in this chapter.

5.1 Effect of Organic Manure on Growth Parameter of Chickpea Crop

The significantly highest plant height (57.00 cm), number of branches plant⁻¹ (3.01), number of pods plant⁻¹ (87.67) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatments being at par with treatments T₂, T₃ and T₄. While, number of nodules plant⁻¹ (27.30) significantly highest in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) which is followed by T₃ treatment (24.00).

5.2 Effect of Organic Manure on Yield of Chickpea Crop

The significantly highest seed yield (35.58 q ha⁻¹) was found in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatments being at par with treatment T₂. While, maximum straw yield (62.66 q ha⁻¹) was observed in treatment T₆-GRDF (25 kg N and 30 kg

K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments and being at par with treatments T₂, T₃ and T₄.

5.3 Effect of Organic Manure on Soil pH, EC and Organic Carbon

Soil properties *viz.*, soil pH and EC, content at harvest as influenced by different treatments were non-significant. While, maximum organic carbon content (0.64%) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatment being at par with treatment T₂.

5.4 Effect of Organic Manure on Soil Available Nutrients

Soil available nutrients at harvest was significantly influenced by different treatments. Available nitrogen (214.00 kg ha⁻¹) and phosphorus (14.31 kg ha⁻¹) in soil at harvest was significantly higher in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all treatments being at par with treatment T₂, T₃ and T₄. Available potassium content in soil (622.67 kg ha⁻¹) at harvest was significantly highest in treatment T₂-GRDF (25:50:30 N, P₂O₅ and K₂O + 5 t ha⁻¹ FYM) and found to be at par with T₃ and T₆.

5.5 Effect of Organic Manure on Soil Available Micronutrients after Harvest of Chickpea Crop

The significantly highest micronutrients Fe, Mn, Zn and Cu contents (5.83, 11.01, 0.57 and 0.62 mg kg⁻¹, respectively) were observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the treatment being at par with treatment T₂, T₃, T₄ and T₅.

5.6 Effect of Organic Manure on Phosphorus Fractions after Harvest of Chickpea Crop

The significantly highest contents of phosphorus fractions observed in treatment T₆ - GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments except Ca-P which was highest in treatment T₇-RDF (25:50:30 N, P₂O₅ and K₂O kg ha⁻¹). However, the increasing order of P fractions noted as Ca-P>org-P>Red-P>Al-P>Fe-P>Saloid-P>Occl-P.

5.7 Effect of Organic Manure on Microbial Population at Flowering and at Harvest of Chickpea Crop

The significantly highest populations of fungi, actinomycetes and bacteria at flowering and at harvest stage were observed in treatment T₆ - GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments. The higher microbial population was observed at flowering stage

and it declined at harvest of chickpea. Application of P enriched organic manure significantly enhanced the count over RDF.

5.8 Effect of Organic Manure on Dehydrogenase and Alkaline Phosphatase Enzymes at Flowering and at Harvest of Chickpea Crop

The significantly highest dehydrogenase enzyme (45.58 and $30.84 \mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ r}^{-1}$, respectively) and alkaline phosphatase enzyme (66.53 and $38.17 \mu\text{g PNP g}^{-1} \text{ soil hr}^{-1}$, respectively) activities at flowering and at harvest stage were observed in treatment T₆-GRDF (25kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments followed by T₂. The higher enzyme activities were observed at flowering stage as over harvest stage.

5.9 Effect of Organic Manure on Total Uptake of Nutrients at Harvest of Chickpea Crop

The significantly highest total uptake of N ($122.66 \text{ kg ha}^{-1}$), P (25.80 kg ha^{-1}) and K (81.21 kg ha^{-1}) were observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatments being at par with treatment T₂ for N, and treatments T₂, T₃ and T₄ for P and K uptake.

5.10 Effect of Organic Manure on Phosphorus Use Efficiency of Chickpea Crop

The significantly highest phosphorus use efficiency (28.34 %) was observed in treatment T₆-GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) over all the other treatment followed by T₂.

As compared to the initial soil status application of GRDF (25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM) founded superior in significantly enhancing the growth parameters, yield and quality parameters of chickpea grown in inceptisol also the total uptake of N, P and K and Soil fertility status (available N, P, K, Fe, Mn, Zn and Cu).

CONCLUSIONS

From the conspectus of earlier discussion, it is concluded that the application of GRDF that is 25 kg N and 30 kg K₂O through chemical fertilizers, 50 kg P₂O₅ through phosphorus enriched organic manure + 5 t ha⁻¹ FYM significantly increased the nutrient availability, phosphorus fractions, soil microbial count, enzyme activities, improved the P use efficiency and also the highest nutrient (N, P and K) uptake and chickpea yield.

FUTURE LINE OF RESEARCH

There is a need of long-term monitoring to quantify cumulative effects of various cropping intervention eventually to make recommendations for wider dissemination and for each crop in order to enhance soil fertility and sustain food production in the rural farming communities.

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7. VITAE

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MASTER OF SCIENCE (AGRICULTURE)
IN
SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
2021

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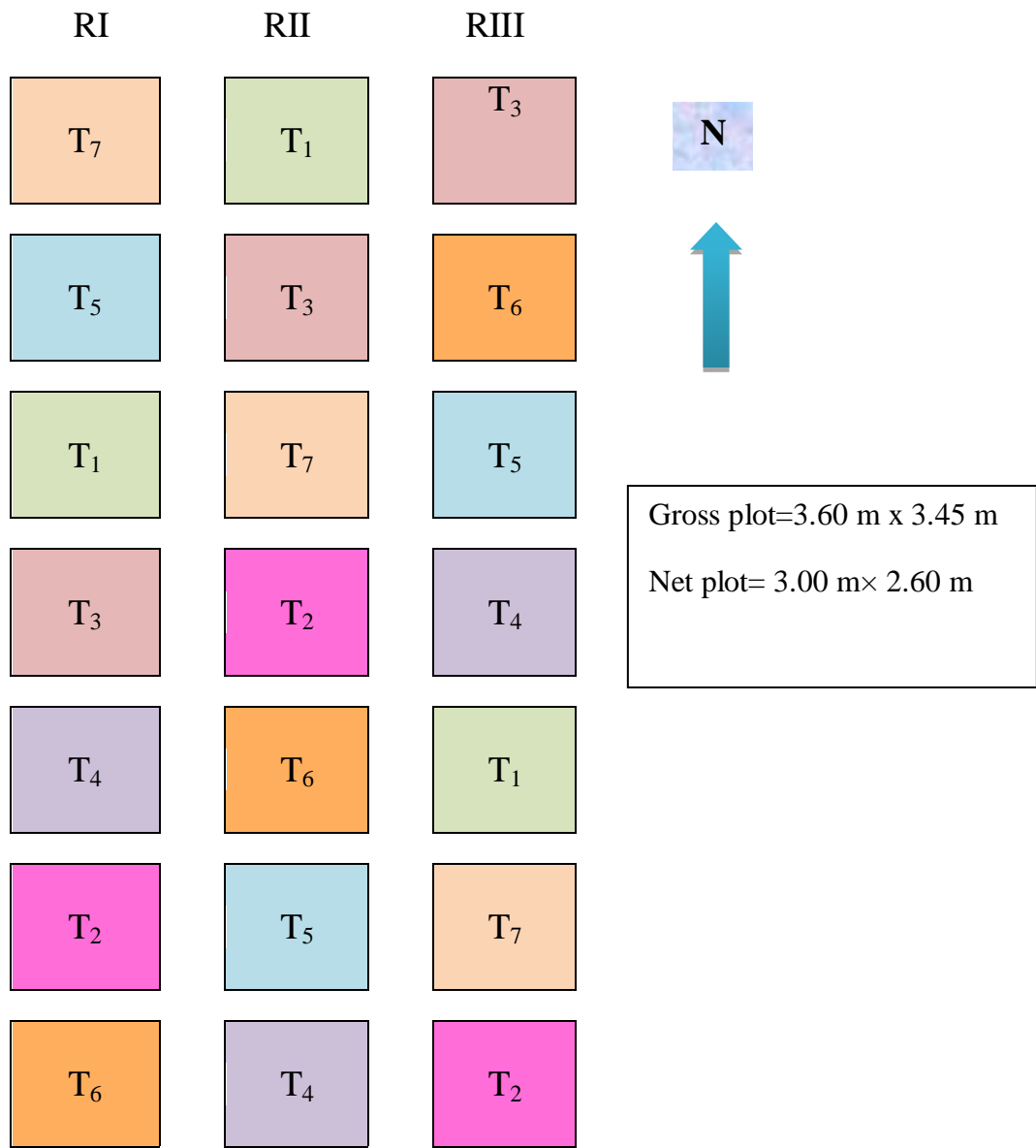


Fig 3.1 Plan of layout of field experiment

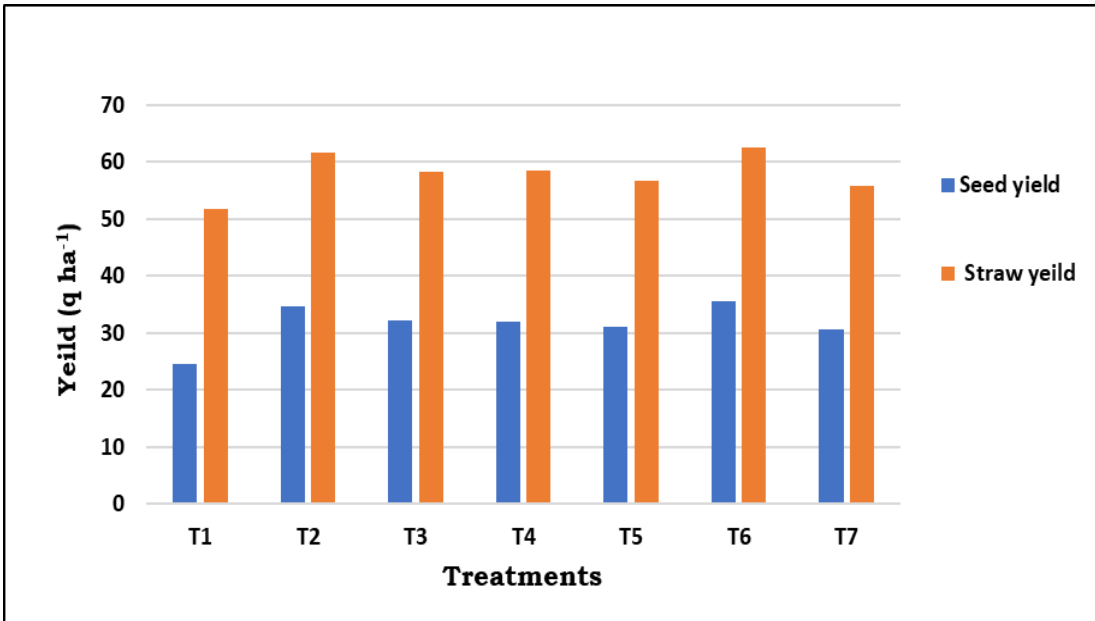


Fig. 4.1 Chickpea yield ($q\ ha^{-1}$) as influenced by phosphorus enriched organic manure

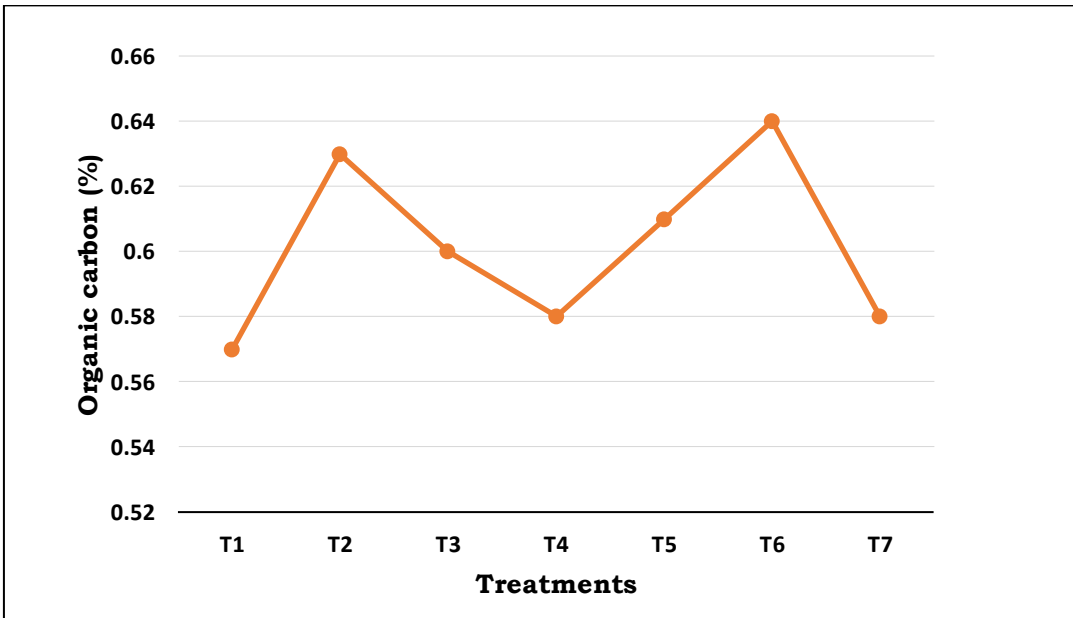


Fig. 4.2 Organic carbon (%) as influenced by phosphorus enriched organic manure

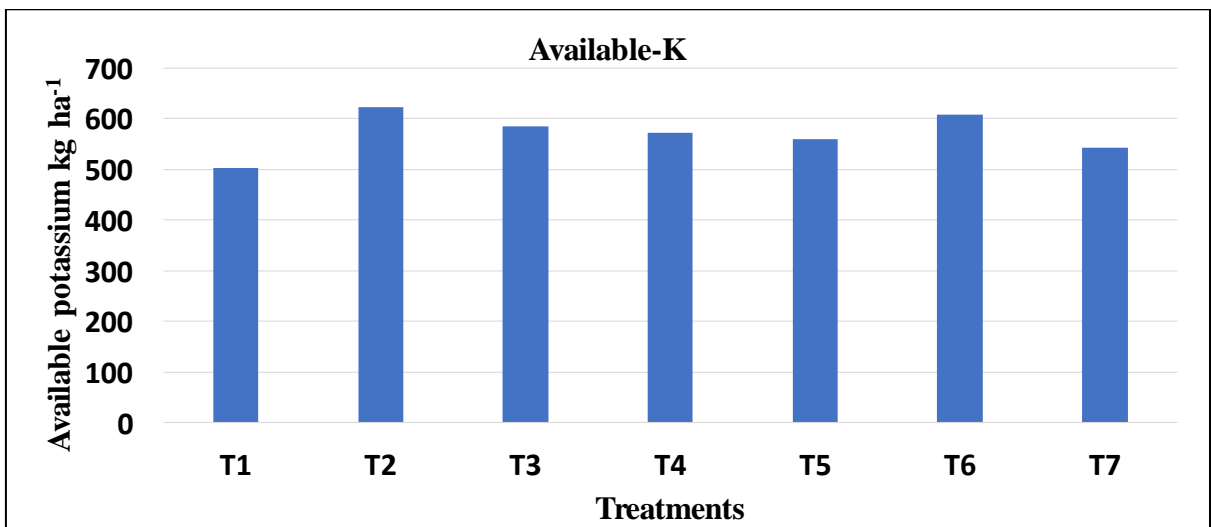
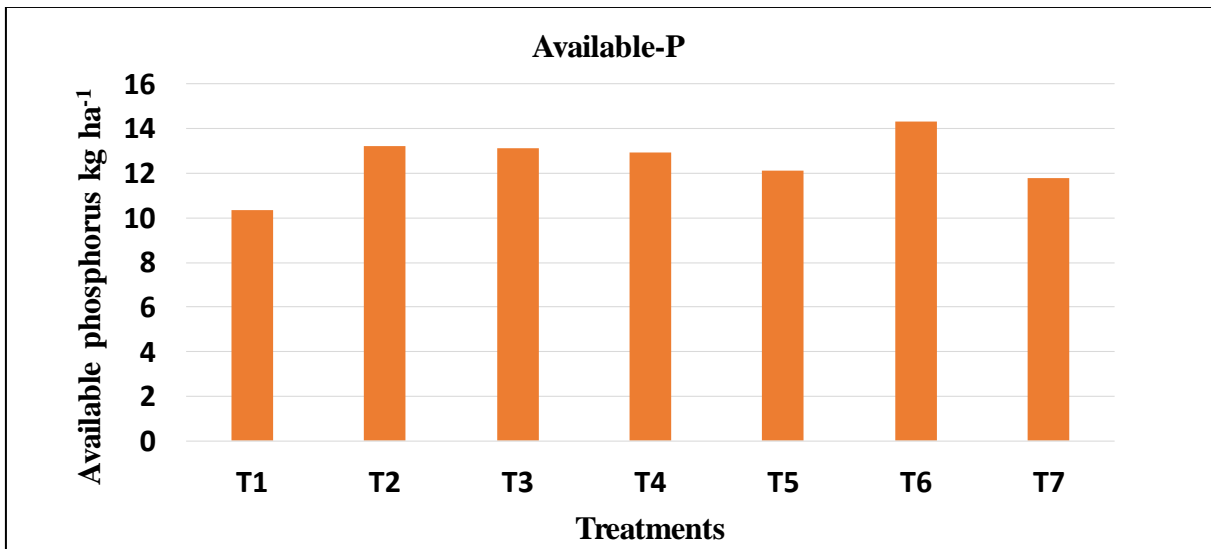
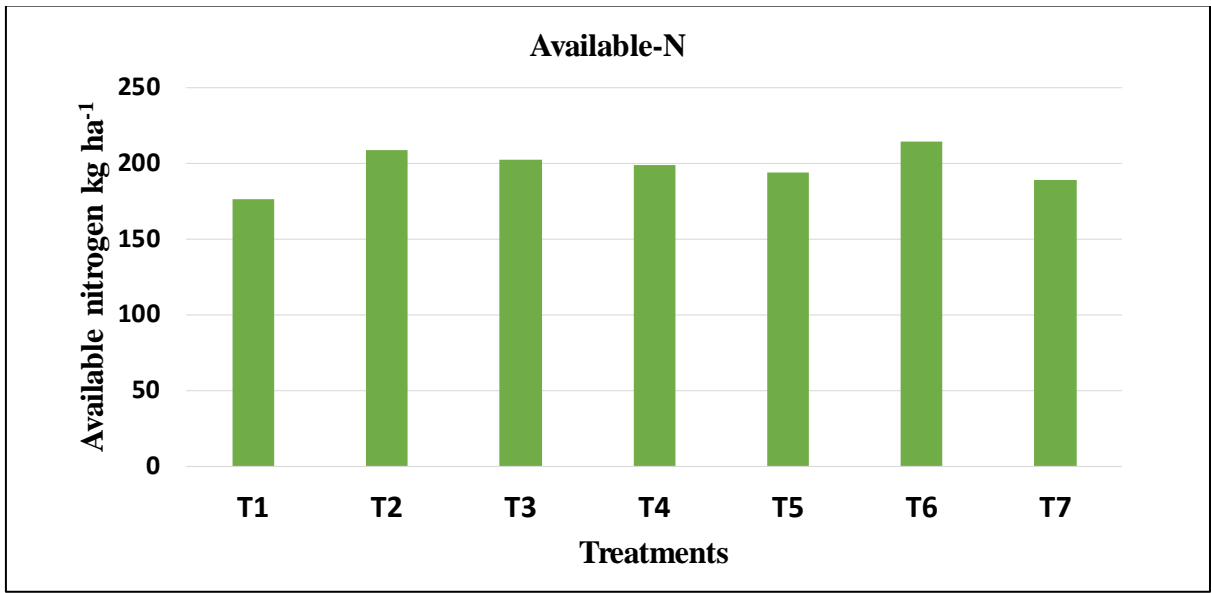


Fig. 4.3 Soil available NPK contents (kg ha⁻¹) as influenced by phosphorus enriched organic manure

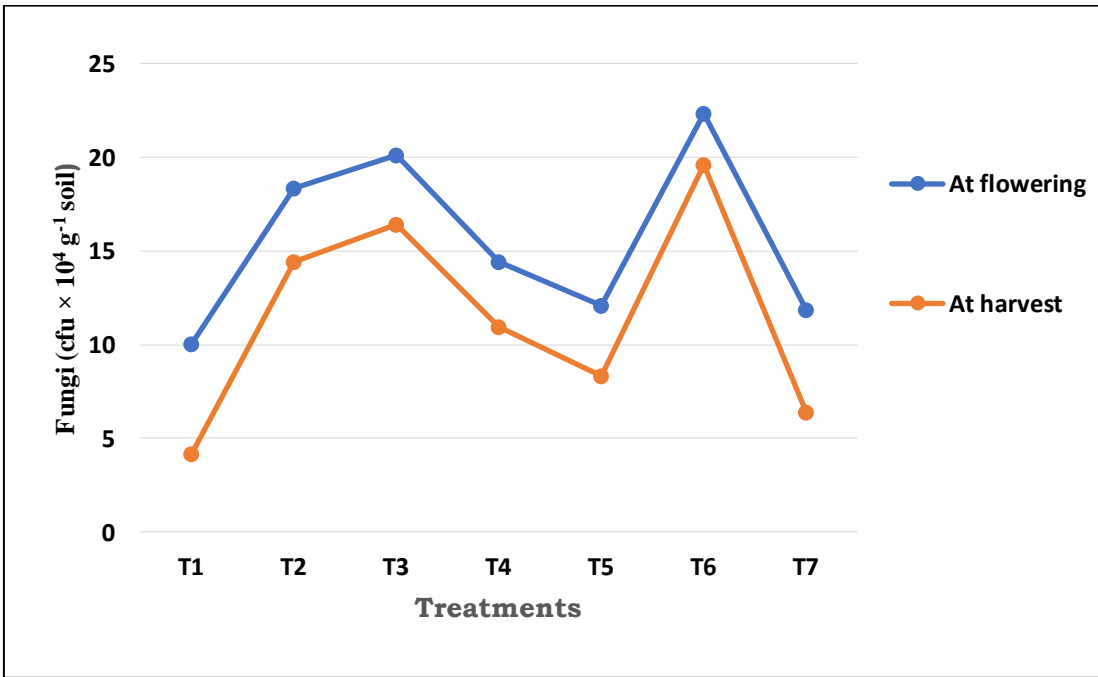


Fig. 4.4 Fungal population at flowering and at harvest of chickpea crop

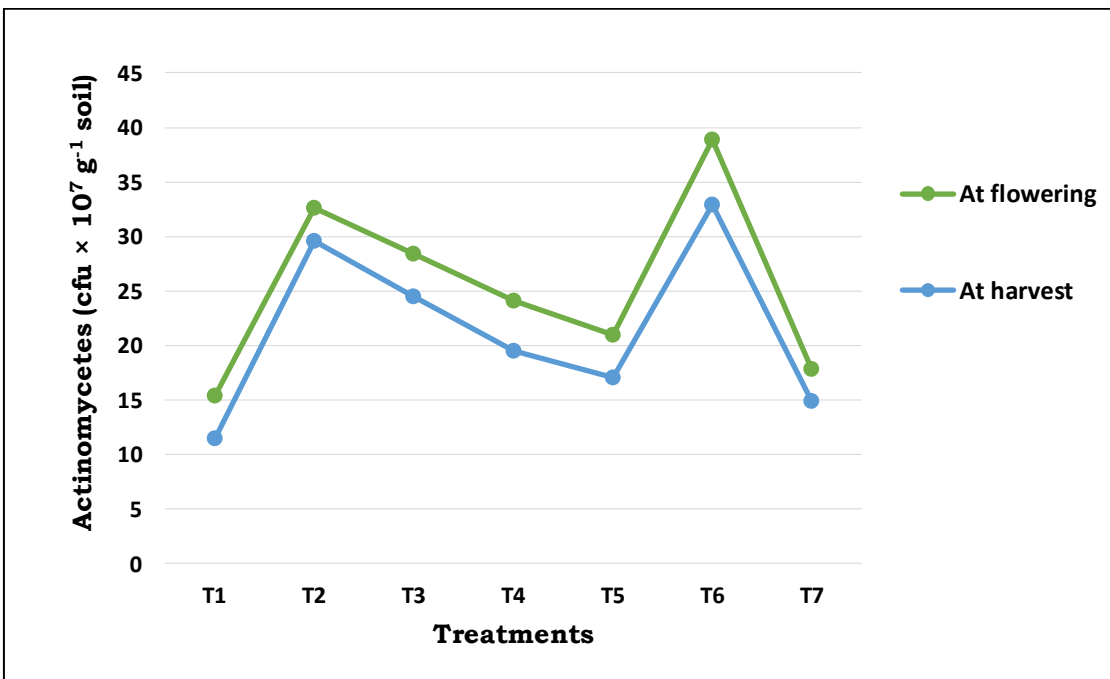


Fig. 4.5 Actinomycetes population at flowering and at harvest of chickpea crop

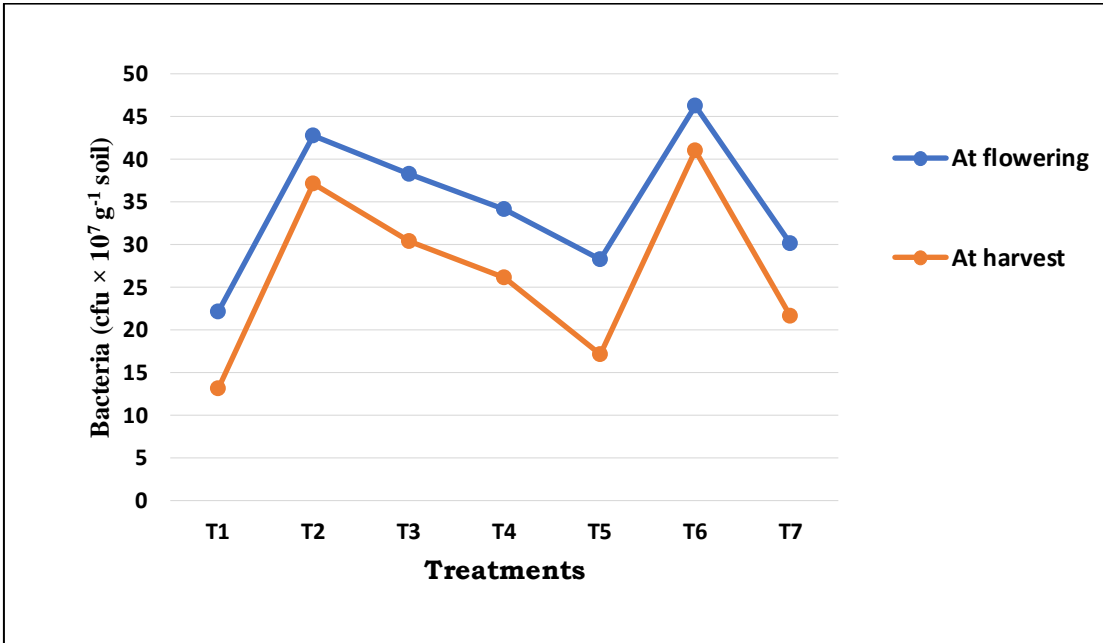


Fig. 4.6 Bacterial population at flowering and at harvest of chickpea crop

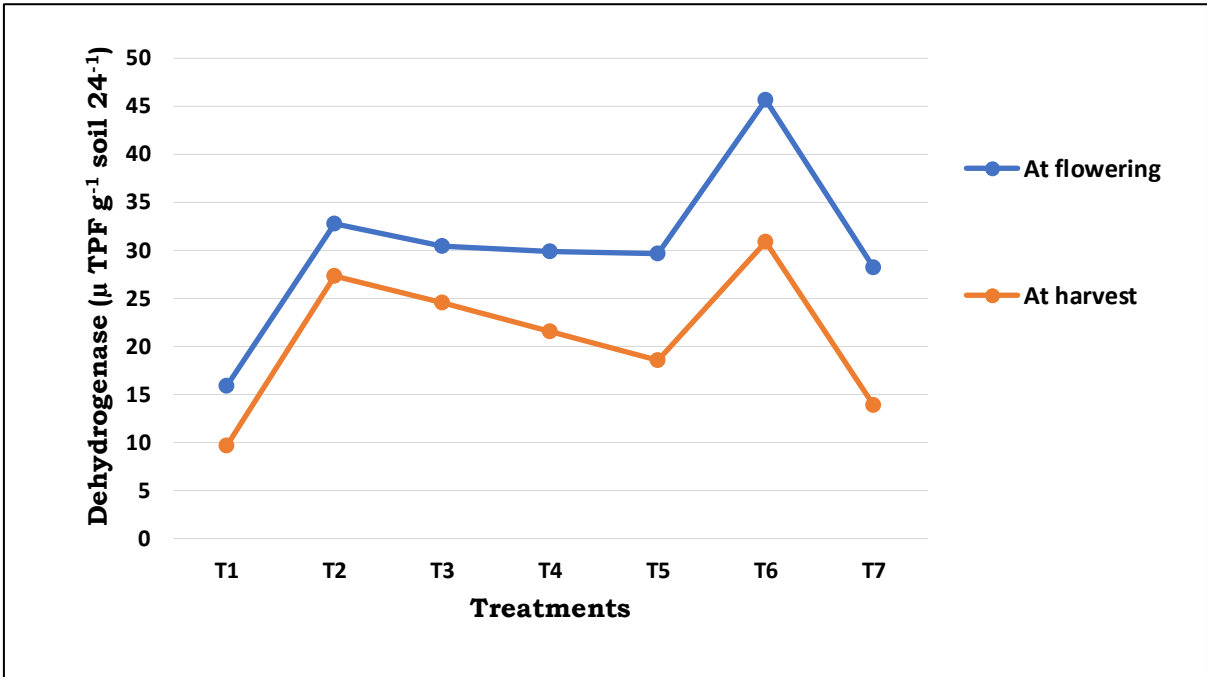


Fig. 4.7 Dehydrogenase activity at flowering and at harvest of chickpea crop

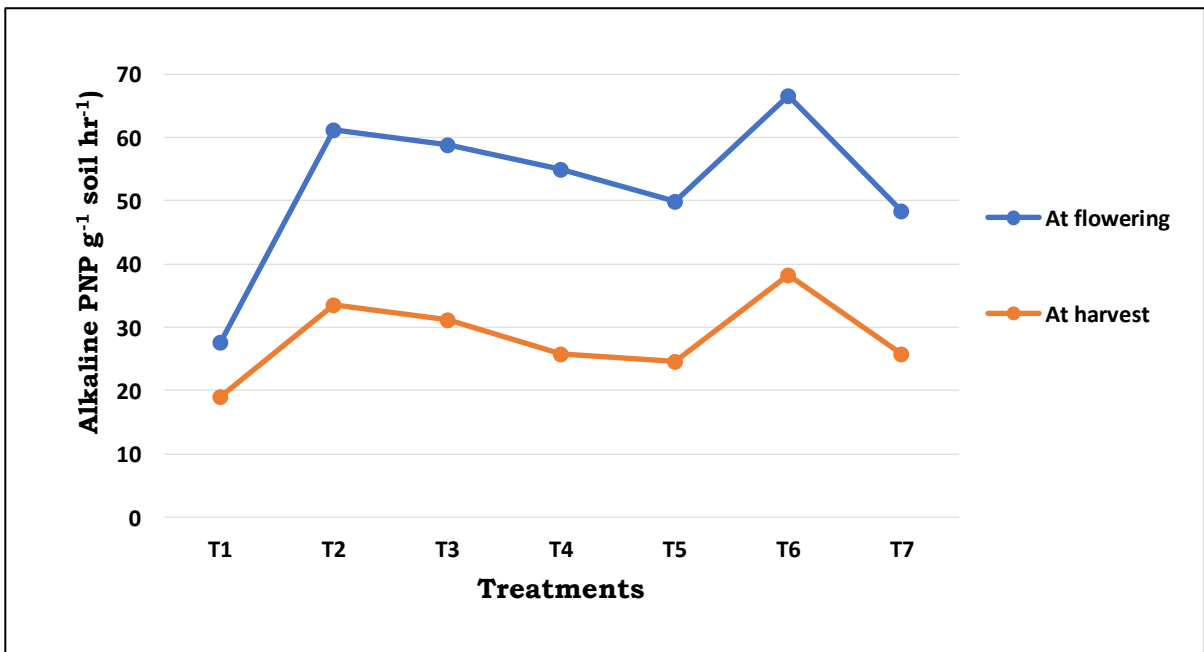


Fig. 4.8 Alkaline phosphatase activity at flowering and at harvest of chickpea crop

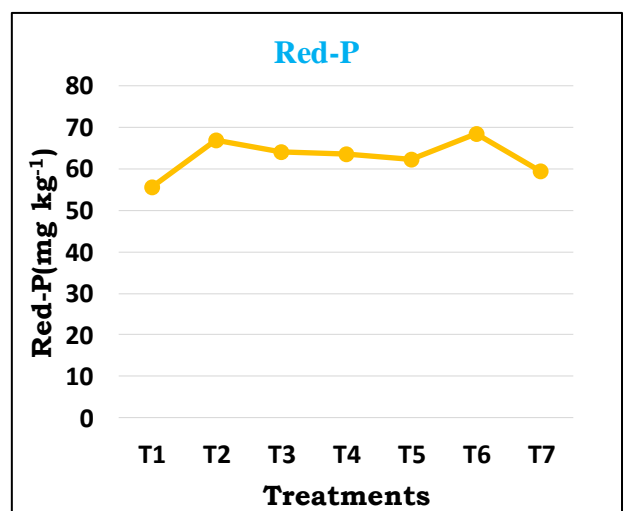
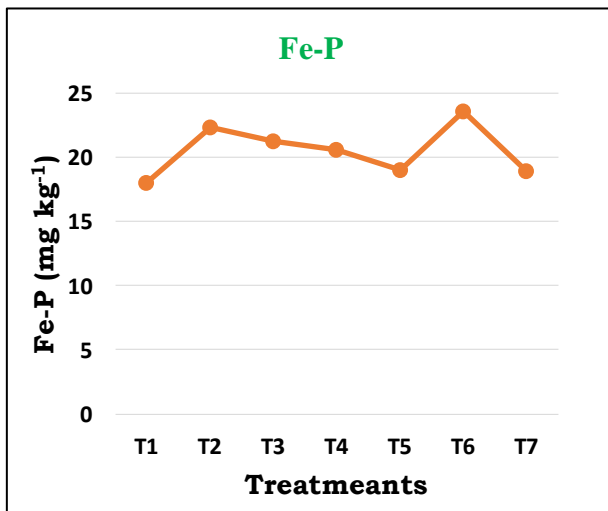
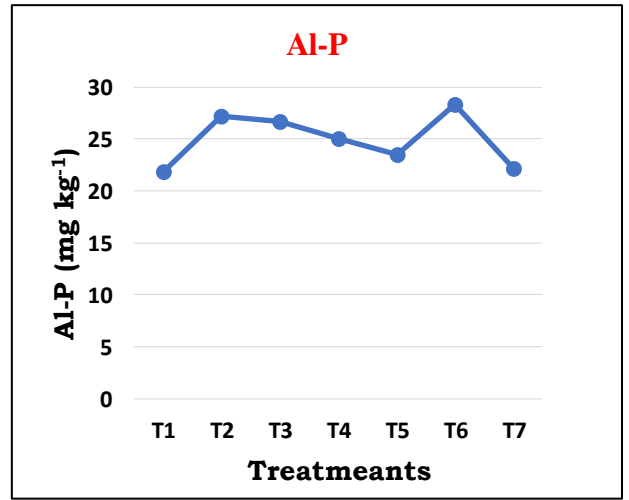
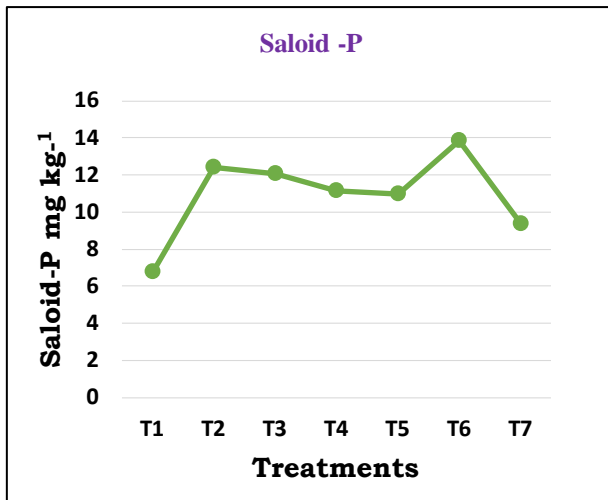


Fig.4.9 Phosphorus fractions as influenced by phosphorus enriched organic manure

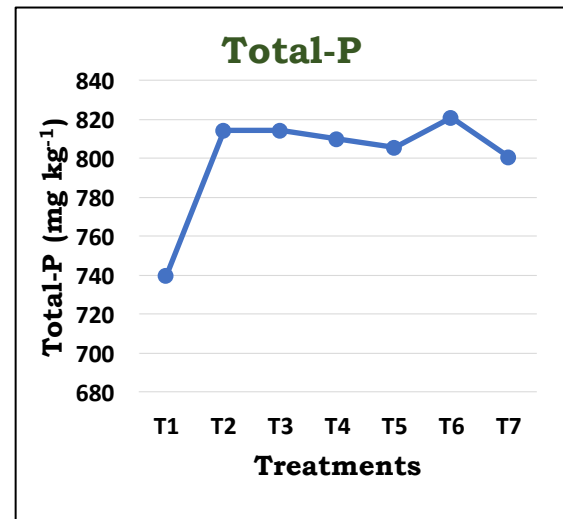
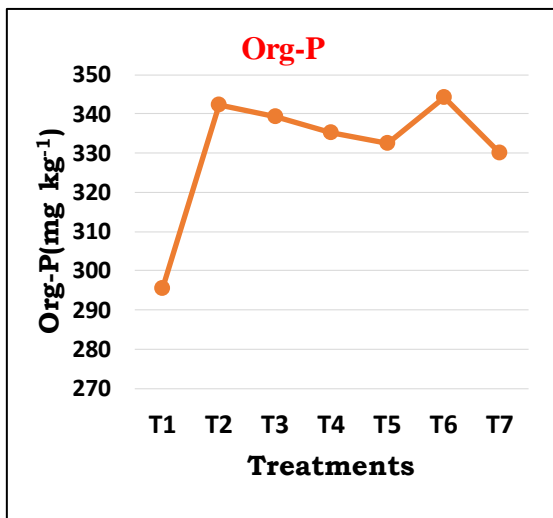
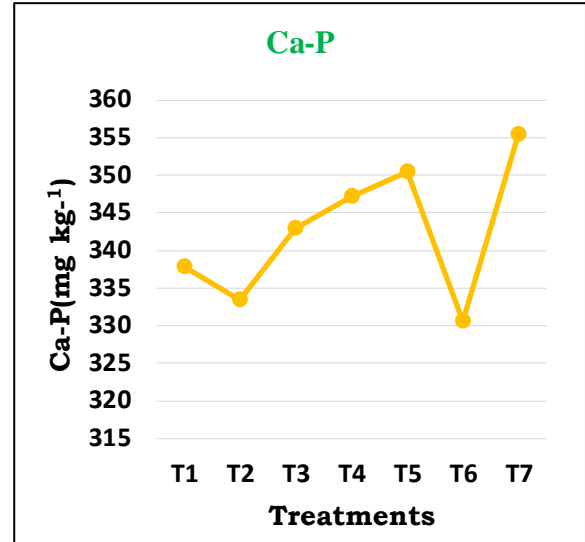
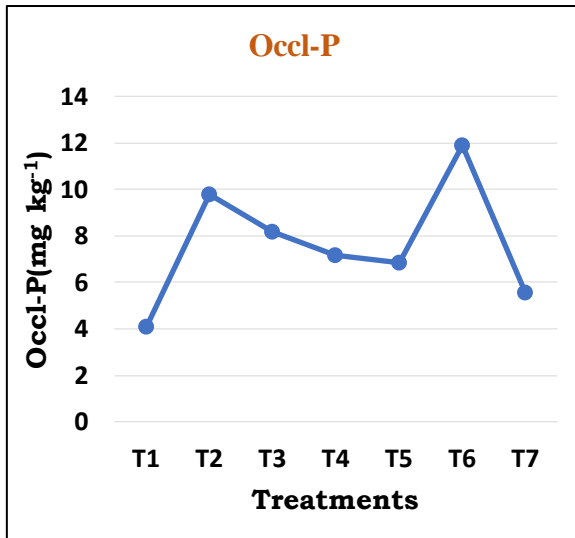


Fig. 4.10 Phosphorus fractions as influenced by phosphorus enriched organic manure

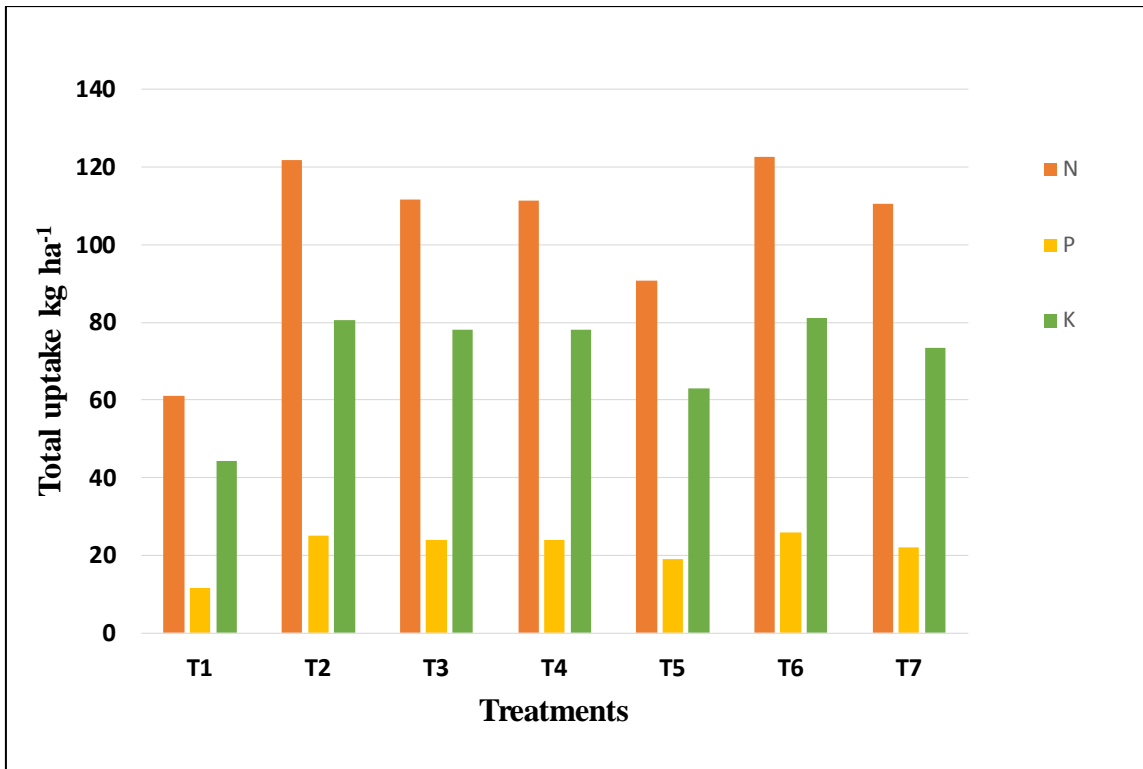


Fig. 4.11 Total uptake of NPKas influenced by phosphorus enriched organic manure



Plate 3.1 General View of Experimental Plot



T₁ –Absolute control



T₂-GRDF+ FYM



T₃-100% PEOM and Nand K as per recommendation



T₄-75% PEOM and 25% P₂O₅ and Nand K as per recommendation

Plate 3.2. a Treatment wise photographs of experimental plot



T₅-60% PEOM and N and K as per recommendation



T₆-GRDF ,50 kg P₂O₅ through PEOM and FYM



T₇-RDF

Plate 3.2. b Treatment wise photographs of experimental plot