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Influence of Phosphorus and Bio-Organic Amendments on Soil Properties of an Inceptisol in Varanasi

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Abstract

A pot experiment was conducted to evaluate the effect of phosphorus and bio-organic amendments on soil properties of an Inceptisol of Varanasi, Uttar Pradesh. The results indicate that the highest soil pH (7.44) was recorded in the control treatment (B_0), whereas the lowest pH (7.26) was observed with poultry manure (2.5 t ha^{-1}) + Rhizobium *+ PSB (B,,). Electrical conductivity (EC) was significantly affected by bio-organic treatments but remained statistically unaffected by phosphorus application. The lowest EC (0.17 dSm^{-1}) was recorded under B,, , while the highest EC (0.27 dSm^{-1}) was observed in the control. The highest soil organic carbon (0.59%), available nitrogen (201.19 kg ha^{-1}), available phosphorus (18.39 kg ha^{-1}) and available potassium (172.63 kg ha^{-1}) were recorded with the application of 40 kg P_2O_5 ha^{-1} compared to control. Among the bio-organic treatments, application of poultry manure (2.5 t ha^{-1}) combined with* Rhizobium *and PSB recorded the higher soil organic carbon (0.56%), available nitrogen (196.35 kg ha^{-1}), available phosphorus (17.48 kg ha^{-1}) and available potassium (172.16 kg ha^{-1}) respectively compared to control. Application of phosphorus and bio-organic amendments effectively improves soil fertility, enhances nutrient availability, and promotes sustainable nutrient management in the Inceptisols of Varanasi.*

Keywords: Inceptisol, phosphorus, bio-organic amendments, soil organic carbon, available nitrogen, available phosphorus, available potassium

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Introduction

Phosphorus is the second most important macronutrient after nitrogen and plays a crucial role in plant growth and development. It is involved in several physiological and biochemical processes, including energy transfer, photosynthesis, respiration, cell division, root development, flowering, seed formation, and biological nitrogen fixation. Adequate phosphorus availability promotes vigorous root growth, improves nodulation, enhances nutrient uptake, and ultimately increases crop productivity. However, phosphorus availability is often limited in Indian soils because a substantial proportion of the applied phosphorus becomes fixed in unavailable forms, thereby reducing its use efficiency.

The integrated use of inorganic fertilizers with bio-organic amendments has emerged as an effective strategy for improving soil fertility and enhancing nutrient-use efficiency. Organic amendments such as vermicompost and poultry manure improve soil physical, chemical, and biological properties by increasing soil organic matter, enhancing microbial activity, improving nutrient availability, and promoting better root growth. Furthermore, inoculation with beneficial microorganisms such as *Rhizobium* and phosphate-solubilizing bacteria (PSB) enhances biological nitrogen fixation and increases phosphorus availability by converting insoluble phosphorus compounds into plant-available forms. Integrated nutrient management, involving the combined application of mineral fertilizers, organic manures, and beneficial microorganisms, has been widely recognized as an environmentally sustainable approach for maintaining soil fertility and improving crop productivity. This approach not only increases nutrient-use efficiency but also minimizes nutrient losses, improves soil health, and supports long-term agricultural sustainability.

Materials and Methods

A pot experiment was conducted during the kharif season of 2017 in the greenhouse of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University (BHU), Varanasi, Uttar Pradesh, India. The experimental site is located at 25.2677° N latitude, 82.9913° E longitude, at an altitude of approximately 86 m above mean sea level, and falls under the semi-arid to sub-tropical climatic region of the Indo-Gangetic Plains. The experimental soil was classified as an Inceptisol with a sandy loam texture. Before the initiation of the experiment, the soil was alkaline in reaction, low in available nitrogen and medium in available phosphorus and potassium, making it suitable for evaluating the response of phosphorus and bio-organic amendments. The experiment followed a factorial completely randomized design (CRD) with three replications. The treatments consisted of three levels of phosphorus (P_0 : Control, P : 20 kg P_2O_5 ha^{-1} and P, : 40 kg P_2O_5 ha^{-1}) and five levels of bio-organics:-(B_0 : Control, B_1 : Vermicompost @ 2.5 t ha^{-1}, B_2 : Vermicompost @ 2.5 t ha^{-1} + *Rhizobium* + phosphate-solubilizing bacteria (PSB), B_3 : Poultry manure @ 2.5 t ha^{-1} and B_4 : Poultry manure @ 2.5 t ha^{-1} + *Rhizobium* + PSB).

Soil Sampling Analysis

After the harvest of the crop, representative soil samples were collected from each pot. The collected samples were air-dried under shade, gently crushed using a wooden pestle, and passed through a 2-mm sieve for the analysis of soil chemical properties. A portion of each sample was further ground and passed through a 0.2-mm sieve for the determination of soil organic carbon. Soil pH and electrical conductivity were determined in a 1:2 soil-to-water suspension using a digital pH meter and conductivity meter, respectively, following the method described by Richards (1954).Soil organic carbon was estimated by the Walkley and Black wet oxidation method using potassium dichromate ($K_2Cr_2O_7$) and concentrated sulfuric acid (H_2SO_4) (Walkley and Black, 1934).Available nitrogen was determined by the alkaline potassium permanganate ($KMnO_4$) method as described by Subbiah and Asija (1956).Available phosphorus was estimated using the 0.5 M sodium bicarbonate ($NaHCO_3$) extraction method developed by Olsen et al. (1954).Available potassium was determined by extracting the soil with neutral normal ammonium acetate, followed by estimation using a flame photometer according to the method of Hanway and Heidel (1952).

Statistical Analysis

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Factorial Completely Randomized Design (FCRD). Treatment means were compared using the Critical Difference (CD) test at the 5% level of significance (P = 0.05). Treatments exhibiting differences smaller than the calculated CD were considered statistically at par, while non-significant differences are denoted as NS.

Results and Discussion

Soil pH

Among the phosphorus levels, the highest soil pH (7.38) was recorded with the application of 40 kg P_2O_5 ha^{-1} (P_2), whereas the lowest pH (7.33) was observed under both 0 kg P_2O_5 ha^{-1} (P_0) and 20 kg P_2O_5 ha^{-1} (P_1). The marginal increase in soil pH with increasing phosphorus levels may be attributed to the buffering capacity of the soil; however, the differences were not statistically significant. Similarly, bio-organic treatments did not significantly influence soil pH. The highest pH (7.44) was recorded with control (B_0), while the lowest pH (7.26) was observed with the application of poultry manure @ 2.5 t ha^{-1} combined with *Rhizobium* and phosphate-solubilizing bacteria (B_4). The slight reduction in soil pH under bio-organic treatments may be attributed to the production of organic acids during the decomposition of organic residues and enhanced microbial activity.

Electrical Conductivity

The highest EC (0.23 dSm^{-1}) was recorded under 40 kg P_2O_5 ha^{-1} (P_2), followed by 20 kg P_2O_5 ha^{-1} (P_1) with 0.22 dSm^{-1}, whereas the lowest value (0.20 dSm^{-1}) was observed with the control (P_0). The highest EC (0.27 dSm^{-1}) was recorded in the control treatment (B_0), whereas the lowest EC (0.17 dSm^{-1}) was observed with poultry manure @ 2.5 t ha^{-1} + *Rhizobium* + PSB (B_4). Treatments receiving vermicompost and poultry manure in combination with microbial inoculants also recorded comparatively lower EC values than the control.

Soil Organic Carbon

Application of @ with 40 kg P_2O_5 ha^{-1} (P_2) non-significantly higher SOC in soil (0.59%) followed by @ 20 kg P_2O_5 ha^{-1} (P_1) (0.50%) compared to control (P_0) (0.39%). Application of 40 kg P_2O_5 ha^{-1} increased SOC by 28.21% over the control. Application of bio-organic amendments also significantly improved soil organic carbon content. The highest SOC (0.56%) was recorded under poultry manure @ 2.5 t ha^{-1} + *Rhizobium* + PSB (B_4), which was statistically at par with vermicompost @ 2.5 t ha^{-1} + *Rhizobium* + PSB (B_2), recording 0.55% SOC. The control treatment (B_0) recorded the lowest SOC (0.40%). Our results align with those of Meena et al. (2013), Meena and Meena (2013), Meena, R. (2017), Sharma et al. (2022) and Indoria et al. (2025).

Available Nitrogen

Among the phosphorus levels, the highest available nitrogen (201.19 kg ha^{-1}) was recorded with the application of 40 kg P_2O_5 ha^{-1} (P_2), followed by 20 kg P_2O_5 ha^{-1} (P_1), which recorded 188.73 kg ha^{-1} compared to control (P_0) (174.41 kg ha^{-1}). Application of 40 kg P_2O_5 ha^{-1} increased the available nitrogen content by 15.35%, whereas 20 kg P_2O_5 ha^{-1} resulted in an increase of 8.21% over the control. The highest available nitrogen (196.35 kg ha^{-1}) was recorded under poultry manure @ 2.5 t ha^{-1} + *Rhizobium* + phosphate-solubilizing bacteria (B_4), followed by vermicompost @ 2.5 t ha^{-1} + *Rhizobium* + PSB (B_2), which recorded 194.95 kg ha^{-1}. Both treatments were statistically at par with each other and significantly superior to the control (177.64 kg ha^{-1}). Earlier reported by Lal et al. (2012), Meena and Meena (2013), Meena, R. (2017) and Sharma et al. (2022).

Available Phosphorus

Among the phosphorus levels, the highest available phosphorus (18.39 kg ha^{-1}) was recorded with the application of 40 kg P_2O_5 ha^{-1} (P_2), followed by 20 kg P_2O_5 ha^{-1} (P_1) with 15.61 kg ha^{-1}. The lowest available phosphorus (13.40 kg ha^{-1}) was observed under the control treatment (P_0). Application of 40 kg P_2O_5 ha^{-1} increased the available phosphorus content by 37.24%, whereas 20 kg P_2O_5 ha^{-1} increased it by 16.49% over the control. Among the bio-organic treatments, the highest available phosphorus (17.48 kg ha^{-1}) was recorded with poultry manure @ 2.5 t ha^{-1} + *Rhizobium* + PSB (B_4), followed by vermicompost

Table 1: Effect of phosphorus and bio-organism levels on soil properties an Inceptisol of Varanasi

Treatments	pH	EC (dSm^{-1})	OC (%)	Nitrogen(kg ha^{-1})	Phosphorus(kg ha^{-1})	Potash(kg ha^{-1})
Phosphorus levels						
P_0	7.33	0.20	0.39	174.41	13.40	167.75
P_1	7.33	0.22	0.50	188.73	15.61	170.92
P_2	7.38	0.23	0.59	201.19	18.39	172.63
CD (P=0.05)	NS	NS	NS	2.09	0.42	2.15
Bio-Organics levels						
B_0	7.44	0.27	0.40	177.64	13.90	168.31
B_1	7.38	0.24	0.47	184.78	15.15	170.14
B_2	7.31	0.20	0.55	194.95	17.01	171.28
B_3	7.34	0.22	0.49	186.85	15.45	170.28
B_4	7.26	0.17	0.56	196.35	17.48	172.16
CD (P=0.05)	NS	0.05	0.02	2.70	0.54	NS

@ 2.5 t ha^{-1} + *Rhizobium* + PSB (B_2) with 17.01 kg ha^{-1}. These treatments were significantly superior to the control (13.90 kg ha^{-1}). The application of poultry manures together with *Rhizobium* and PSB increased the available phosphorus content by 25.76%, while vermicompost combined with *Rhizobium* and PSB increased it by 22.37% over the control. Earlier reported by Meena et al. (2012), Meena et al. (2013), Sharma et al. (2022), Indoria et al. (2025) and Sharma et al. (2020).

Available Potassium

The highest available potassium (172.63 kg ha^{-1}) was recorded under 40 kg P_2O_5 ha^{-1} (P_2), followed by 20 kg P_2O_5 ha^{-1} (P_1) with 170.92 kg ha^{-1}, whereas the lowest value (167.75 kg ha^{-1}) was observed in the control (P_0). Application of 40 kg P_2O_5 ha^{-1} increased the available potassium content by 2.91%, while 20 kg P_2O_5 ha^{-1} increased it by 1.89% over the control. However, numerically higher potassium values were observed under poultry manure @ 2.5 t ha^{-1} + *Rhizobium* + PSB (172.16 kg ha^{-1}) and vermicompost @ 2.5 t ha^{-1} + *Rhizobium* + PSB (171.28 kg ha^{-1}) compared with the control (168.31 kg ha^{-1}). Our results align with those of Meena, et al. (2012), Meena et al. (2013) and Sharma et al. (2022).

Conclusion

The findings of the present study suggest that the application of 40 kg P_2O_5 ha^{-1} with poultry manure @ 2.5 t ha^{-1}, *Rhizobium* and PSB is an effective nutrient management strategy for improving soil fertility and sustaining crop production in the Inceptisols of Varanasi. Use of this integrated nutrient management practice can enhance nutrient-use efficiency, improve soil quality, and contribute to sustainable agricultural production.

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