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Effect of Different Organic Sources on Physical, Chemical and Biological Properties of Soil in Inceptisols of Varanasi

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Authors' contributions

This work was carried out in collaboration among all authors. Author JY designed the study and helped in manuscript writing. Author SS helped in laboratory analysis and manuscript writing. All authors read and approved the final manuscript.

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ABSTRACT

After the green revolution excessive use of inorganic fertilizers increased, which resulted in affecting the activities of soil microflora and macrofauna, thus posing an environmental risk and decreasing crop production. The use of organic sources which include biochar, carpet waste, FYM (Farmyard manure) and PGPR (Plant growth promoting rhizobacteria) may act as an important tool to sustainably increase soil organic matter, crop yield and improve soil health on a long-term basis. The results of application of biochar, carpet waste, farm yard manure (FYM) and PGPR showed that the combined application of biochar, carpet waste and PGPR significantly improved soil properties such as organic carbon, nitrogen(N), phosphorus(P), potassium(K), dehydrogenase, alkaline phosphatase activity and microbial population. The enzymatic activity of soil was highly positively correlated with the physicochemical properties of soil. Therefore, it can be concluded that the combination of biochar, carpet waste, FYM and PGPR may increase and sustain the soil properties and crop productivity over time.

Keywords: Biochar; carpet waste; FYM; PGPR; dehydrogenase; alkaline phosphatase.

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1. INTRODUCTION

The intensification of rice cultivation is necessary to encounter the food demand of the growing human population, especially in India, where approximately 80% of rice has grown and consumed [1,2]. Excessive use of inorganic fertilizers deteriorates soil, affecting both the soil biota and biochemical processes, thus posing an environmental risk and decreasing crop production [3]. Nayak et al. [4] reported that the organic sources such as green manure, animal waste and farmyard manure are traditionally applied to rice soil to maintain the soil organic matter status, to increase the levels of plant nutrients and to improve overall status of the soil, which directly and indirectly affects soil fertility. Recently, the use of organic materials as fertilizers for crop production has received attention for sustainable crop productivity. In recent times the inadequate availability of organic fertilizers like FYM (Farmyard manure) and compost etc. offers a choice of alternate use of carpet waste and biochar as a source of organic fertilizer.

Sohi et al. [5] stated that the biochar is a carbon-rich material got from thermochemical change (slow, intermediate, and quick pyrolysis or gasification) of biomass in an oxygen-restricted condition. It tends to be produced from a wide variety of feedstocks, including forest and farm residues, for example, straw, nutshells, rice hull, wood chips/pellets, tree covering, and switchgrass. Thies and Rillig, [6] mentioned that the biochar has beneficial impact on plant productivity and soil microbial population, which is linked to the improvement of specific surface area, cation exchange capacity, bulk density, pH, water, and nutrients within the soil matrix. Biochar is a catalytic agent of soil microbial activity but not a compost material, which augments soil chemical properties and enhances soil water storage capacity to increase crop productivity [7,8,9]. Currently, waste biomass is widely utilized for the production of biochar because of its low-cost value and food security advantages [10].

Wool carpets have the potential for closed-loop recycling, involving returning the used carpet to the soil as a fertilizer. McNeil et al. [11] reported that nitrogen in carpet waste ranging 5.5 – 17%, sulfur 1.2-3.5% and calcium 10.8%. Behera et al. [12] stated that the wool carpets are largely biodegradable and contain plant nutrients as well as possess physical properties to provide weed suppression, moisture retention, moderation of soil temperature and soil stabilization, thus opening the opportunity for environmentally friendly disposal options as alternatives to landfilling and incineration [12]. PGPR increased the availability of nutrient concentration in the rhizosphere by fixing nutrients, thus preventing them from leaching out. As in the case of nitrogen, which is required for the synthesis of amino acids and proteins, is the most limiting nutrient for plants. The mechanisms by which atmospheric nitrogen is added into organic forms that can be assimilated by plants are exclusive to prokaryotes [13,14]. Fageria et al. [15] stated that the farmyard manure is an important source of nutrient supply on small farm holdings. Watts et al. [16] mentioned that the addition of manure might increase the biodiversity of the soil, thereby causing changes in composition, size, activity of soil microorganisms and enzyme activities.

Rice (*Oryza sativa L.*) is a major staple crop as well as an important cereal crop that assists greater than three billion people globally by comprising 50% to 80% of their daily calorie intake (FAO STAT.2019).In 2017, more than759.6Mt of rice was produced globally [17]. Approximately 90% of the annual production of rice is grown and consumed in Asia. In India, rice covers an area of about 43.79 mha, production 117.47 million tonnes and productivity 2659 kg/ha [18]. Accordingly, rice production currently depends on the large-scale use of chemical fertilizers, which pose an environmental hazard for rice-producing areas. We hypothesized that the use of PGPR (Plant growth promoting rhizobacteria) along with FYM, biochar and carpet waste significantly improve the organic carbon N (nitrogen), P (phosphorus), K (potassium), enzymatic activity and microbial population in rice under the organic farming system, which further improved soil health in long term.

2. MATERIALS AND METHODS

2.1 Experimental Set Up

The experiment was laid out in a randomized block design with three replications in the Agriculture Research Farm Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. Varanasi is situated in the (25°18’ N latitude 83°3’ E longitude) at an altitude of 80.7 m above the mean sea level in the Northern Gangetic Alluvial plain. It falls in a semi-arid to sub-humid climate with a moisture deficit index between 20 - 40. The mean relative

humidity is about 68%, which rise to 82% during the wet season and goes down to 30% during the dry season. The maximum and minimum temperatures varied between 26.4 – 40.1°C and 8.8- 26.6°C throughout the entire growing season of rice crop. The soil was alluvial with order Inceptisol (Typic Ustochrept). The field was ploughed thoroughly, flooded 2-3 days before transplanting for puddling and leveling. The initial experimental soil had pH 8.02, electrical conductivity 0.20dS m^{-1}, organic carbon 0.47%, available nitrogen, phosphorus and potassium were 218.02 kg ha^{-1} ,12.8 kg ha^{-1},216.7 kg ha^{-1},dehydrogenase and alkaline phosphatase were 53 µgTPF g^{-1}soilday^{-1} and 38 µg pNP g^{-1} soil h^{-1}. The 10 treatment combinations were : Control , biochar@1tha^{-1} + carpet waste@1 t ha^{-1}, biochar@2 t ha^{-1}+carpet waste@ 1t ha^{-1} ,biochar@1t ha^{-1}+carpet waste@1t ha^{-1}+FYM1t ha^{-1} , biochar@2 tha^{-1} +carpet waste@1tha^{-1} + FYM@1tha^{-1} , PGPR consortium , biochar@1tha^{-1} +carpet waste@ 1tha^{-1} + PGPR , biochar@2tha^{-1} +carpet waste@1)tha^{-1}+PGPR , biochar@1tha^{-1} +carpet waste@1tha^{-1}+ FYM@1t ha^{-1} + PGPR and biochar@2tha^{-1} +carpet waste@1tha^{-1} + FYM 1 t ha^{-1} + PGPR.

Biochar was brought from Rice Mill, district, Chandauli, Uttar Pradesh.Carpet waste was collected from the carpet factory, Bhadohi district, Uttar Pradesh. It was retained in a polybag for analyzing manorial value. FYM was collected from the dairy farm of BHU, air-dried, ground, sieved through a 2 mm sieve and retained in polybags to analyzing the nutrient content of manure. Recommended doses of biochar, FYM (Farmyard manure) and carpet waste were applied as basal doses before transplanting the rice crop. Rice seedlings were dipped in the PGPR consortium before transplanting. The PGPR consortium consists of *Azospirillum brasilensis*, *Pseudomonas aurigenosa*, *Pseudomonas fluorscences* and *Azotobacter chroococcum*, was collected from the microbiology laboratory of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, BHU. These organic sources were analyzed in the laboratory for different physico-chemical parameters which were presented in (Table 1).

2.2 Soil Analysis

Soil samples were collected after harvesting rice from each plot and the soil pH was determined with distilled water in a ratio (soil: water) of 1: 2.5 (w/v) using a pH meter [19]. Soil organic carbon was determined by taking (0.5 g soil sample) and oxidizing organic matter in soil samples with (10 mL) $K_2Cr_2O_7$ in (20 mL)concentrated sulphuric acid for 30 min followed by titration of the excess of $K_2Cr_2O_7$ with ferrous-ammonium sulphate [20], available N by 0.32% alkaline potassium permanganate followed by distillation and absorption of ammonia in boric acid mixed indicator 2% and titrated against 0.05N sulphuric acid [21], sodium bicarbonate (0.5M $NaHCO_3$, pH 8.5) extractable-P [22] by spectrophotometer at 660nm and ammonium acetate-extractable K [23] by flame photometer.

For biological analysis, soil samples were drawn at a period of 40, 80 and 120 days form rice field for dehydrogenase and alkaline phosphatase activity. Dehydrogenase activity (DHA) was determined using the assay by Casida et al. [24] as a reduction of triphenyltetrazolium chloride (TTC) to triphenylformazan (TPF). Three grams of field-moist soil were placed into 16 mL–test tubes, and 1 mL TTC was added followed by 2.5 mL distilled water; the suspension was incubated for 24 hours at 37□C. Then 50 mL methanol were added for the extraction of TPF reflecting in red coloration. Finally, the suspension was filtrated, and the intensity of reddish color was measured with the spectrophotometer at a wave-length of 485 nm using methanol as a blank. The concentration of TPF was calculated according to the calibration curve and expressed as µg TPF per 1 g dry soil matter.

Alkaline phosphatase activity was determined according to procedures of Tabatabai and Bremner [25]. One g of soil sample was incubated with 0.25ml toluene, 4 ml modified phosphate buffer (pH 11) and 1 ml of 0.025M of P- nitrophenylphosphate solution (substrate) at 37 ± 2ºC for 1 hr. After incubation alkaline phosphatase was inhibited by 1 mL of 0.5M $CaCl_2$ solution and 4mL of 0.5 M NaOH solution. Samples were swirled and soil suspension was filtered through Whatman No.42 paper. The formation of P- nitrophenol was assayed spectrophotometrically at 420 nm.

The serial dilution and plating techniques suggested by Subba Rao [26] were employed for isolation and identification of viable bacteria, actinomycetes and fungi count. Population counts of bacteria, fungi and actinomycetes was noted using dilution plate technique by employing nutrient agar (NA), potato dextrose agar medium (PDA) and Kenknight's media, respectively. The population was expressed as colony forming units (cfu/g soil).

2.3 Statistical Analysis

The analysis of variance (ANOVA) technique was used to find out the impact of each treatment on physico-chemical, enzymatic and microbial population in soil. IBM SPSS 2019 version 26. The difference between the treatments found out using the Tukey's Honestly Significant Difference test using IBM SPSS 2019 version 26. The figures were drawn using Microsoft Office Excel 2016. The relationships between soil enzymatic activities and Physico-chemical properties of post-harvest soil were evaluated by the Pearson correlation procedure using IBM SPSS 2019 version 26.

3. RESULTS AND DISCUSSION

3.1 Impact on Physico-Chemical Properties of Post-harvest Soil

There was a significant difference observed in organic carbon, available nitrogen, available phosphorus and available potassium but no significant difference found in the soil pH and electrical conductivity which was illustrated in (Table 2). In this experiment increase in pH and electrical conductivity was not statistically significant, but there was a slight increase in pH and electrical conductivity that was observed in all other treatment compared to control. The use of rice husk biochar increased the mean pH of both fertilized and non-fertilized soil but the increase was non-significant [27]. The increase in organic carbon observed from control to other treatments. The minimum value of organic carbon observed in control i.e.0.49% and maximum value observed where biochar@2tha^{-1}+carpetwaste@1tha^{-1}+FYM@1tha^{-1}alongwithPGPR applied, which was (0.61%). This observation showed that when biochar, carpet waste, FYM alongwith PGPR applied, it increased the organic carbon level in soil compare to all the treatments. The increase in organic carbon might be due to greater biochar, carpet waste, FYM applied in the soil resulted in more buildup of carbon in the soil. In this experiment, available nitrogen content in soil ranged from 281.29 kg ha^{-1} in control to 319.56 kg ha^{-1} in biochar@2tha^{-1}+carpetwaste@1tha^{-1}+FYM@1tha^{-1}alongwithPGPR applied. Mann et al. [28] reported that the use of organic manures increased organic matter and ultimately total nitrogen in the soil. Clearly, it showed that available N content was minimum in Control to the maximum in treatment (biochar@2tha^{-1}+carpetwaste@1tha^{-1}+FYM@1tha^{-1} along with PGPR applied) followed by the next highest value observed in treatment biochar@1tha^{-1} + carpet waste@1tha^{-1} + FYM@1tha^{-1} with PGPR applied, which was 2.86% higher as compared to treatment where biochar@1tha^{-1} + carpet waste@1tha^{-1} + FYM@1tha^{-1} applied. When only PGPR was applied, available N was 1.07% higher compared to control. A similar, trend observed in the available P and K content in the soil which was found highest in treatment where biochar@2tha^{-1} +carpetwaste@1tha^{-1} + FYM@1tha^{-1} along with PGPR applied. When only PGPR applied the available phosphorus increased 19.08% over without PGPR. In some treatments, not much significant difference observed in available N, available P, available K and organic carbon which was illustrated in (Table 2).

3.2 Impact on Soil Enzyme Activity at Different Interval During a Field Experiment

There was a significant difference found in the dehydrogenase and alkaline phosphatase Activity at ($p<0.05$) illustrated in (Table 3). At 40 DAT (Days After Transplanting) maximum dehydrogenase activity was found in biochar @2tha^{-1}+carpetwaste@1tha^{-1}+ FYM@1tha^{-1} along with PGPR applied, which was 9.18% superior to control followed by biochar@2 t ha^{-1} + carpet waste@1t ha^{-1}+ FYM @1 t ha^{-1} applied and biochar@1t ha^{-1} + carpet waste@1t ha^{-1} + FYM@1t ha^{-1} + PGPR applied, which was 5.18%, 2.05% higher than control. At 80 days similar trend was observed maximum activity observed in biochar@2tha^{-1}+carpetwaste@1tha^{-1}+FYM@1tha^{-1}alongwith PGPR applied followed by biochar@1tha^{-1}+carpetwaste@1tha^{-1} +FYM@1tha^{-1}alongwith PGPR applied further detail illustrated in Table 3. At 120 DAT (Days After Transplanting) lower dehydrogenase activity was observed compared to 80 days and highest activity recorded in biochar@2tha^{-1} +carpetwaste@1tha^{-1}+FYM@1tha^{-1}alongwith PGPR applied and at par with biochar@2tha^{-1} +carpetwaste@1tha^{-1}+FYM@1tha^{-1} and biochar @1tha^{-1}+ carpetwaste@1tha^{-1}+FYM@1tha^{-1}alongwith PGPR applied. The higher dehydrogenase activity at 80 DAT resulted due to higher microbial activity that known to stimulate dehydrogenase activity [16].

These results suggest that a change in respiratory activity happened due to the increase in the available substrate. The increase in substrate resulted in more readily available C

and N pools, that was increased after addition of these organic sources in soil. After harvest decrease in enzymatic activity was due to the changes in oxidation status of the soil. Water accessibility greatly affects the soil microbial activity, community composition and consequently on enzymatic activity [29]. As soil dry, water potential decreases so the dehydrogenase activity [29].

Alkaline phosphatase significantly differed among the days after transplanting of rice. Alkaline phosphatase was found more at 80 DAT (Table.3). Alkaline phosphatase enzyme activity was found in the order of 80 DAT > 120 DAT > 40 DAT. At 40 Days After Transplanting the lowest alkaline phosphatase enzyme activity was observed in the control (50.15 µg PNP produced g^{-1} soil hr^{-1}) and highest activity observed in treatment where biochar@2tha^{-1} + carpet waste @1tha^{-1}+FYM@1tha^{-1}alongwith PGPR applied, which was (83.45 µg PNP produced g^{-1} soil hr^{-1}) followed by biochar@1tha^{-1} + carpet waste@1tha^{-1} + FYM @1tha^{-1}+ PGPR and biochar @2 tha^{-1}+carpet waste@1tha^{-1} +FYM @1tha^{-1} respectively. At 40DAT, there was no significant difference found in some treatment, which was illustrated in Table 3. At 80 DAT, the maximum phosphatase activity observed in treatment where biochar@2tha^{-1}+carpet waste@1tha^{-1}+FYM@1tha^{-1}alongwith PGPR applied followed by biochar@2tha^{-1} +carpet waste @1tha^{-1}+FYM@1tha^{-1} and biochar@1tha^{-1}+carpet waste@1tha^{-1} +FYM@1tha^{-1}along with PGPR respectively. Behera et al. [12] reported that the application of biochar, carpet waste, FYM and PGPR significantly increased the alkaline phosphatase activity after 80days due to greater microbial population and organic matter in the soil. At 120 DAT, there was a decrease in enzymatic activity and there was no significant difference found in some treatment, which was presented in (Table 3).

3.3 Impact on Microbial Population at Different Interval During Field Experiment

There was significant increase in the population of bacteria in treatment where biochar@2tha%$^{-1}$+carpetwaste@1tha^{-1}+FYM@1tha^{-1}alongwithPGPRapplied,corresponding increase was 29.16%, 44.11% and 57.48% compared to control at 40 days, 80 days and 120 days after transplanting of rice. The highest bacterial population was found after 80 days after transplanting of rice and lowest observed in 40 days after transplanting of rice. The next highest population found in treatment where biochar@1t ha^{-1} + carpet waste@1t ha^{-1} + FYM@1t ha^{-1} + PGPR applied, increase was 25%,35.29% and 46.23% over control at 40 days, 80 days and 120 days after transplanting of rice. But there was decrease in bacterial population after harvesting of rice, it had happened due to less availability of organic carbon as substrate [16]. No difference was found in treatment which was illustrated in (Fig. 1).

Similarly, in case of actinomycetes at 80 days after transplanting of rice highest population (27 x 10^4 cfu g^{-1}soil) was observed in treatment where biochar@2tha%$^{-1}$+carpetwaste@1tha^{-1}+FYM@1tha^{-1}alongwithPGPR applied and minimum in control, it was illustrated in (Fig. 2). Similar trend followed after 40 days and 120 days after transplanting of rice. Behera et al. [12] reported that in the initial period the decomposition of added treatment was minimum, due to which the availability of organic carbon is limited. But in intermediate stage the rate of decomposition is high which was due to high population of microbes and after harvesting decreased due to limited availability of substrate. Zak et al. (2011) also reported similar finding that the actinomycetes population decreased after 80 days, due to decrease in organic matter content of soil.

Table1. Physico-chemical properties of organic sources

Properties	Biochar	Carpet Waste	FYM
Electrical Conductivity (dsm^{-1})	2.45**	0.19**	0.34**
pH	8.4**	7.30**	7.9**
Total N (%)	6**	11.50**	0.79**
Total P (%)	1.4**	0.05**	0.45**
Total K (%)	1.1**	0.06**	0.70**
Organic Carbon (%)	46.4**	56.55*	59.8*

**Significance at p < 0.05 level and **Significance at p < 0.01 level*

Table 2. Effect of biochar, carpet waste, FYM and PGPR on Physico-Chemical Properties of post harvest

Treatment		pH	EC(dS/m)	Organic carbon (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})
T_1	Control	8.11	0.20	0.49^{EF}	281.29^{F}	14.43^{D}	224.62^{G}
T_2	Biochar + carpet waste (1+ 1 t) ha^{-1}	8.08	0.24	0.53^{DE}	286.75^{GF}	16.25^{CD}	226.69^{EFG}
T_3	Biochar + carpet waste (2+ 1 t) ha^{-1}	8.05	0.36	0.59^{ABC}	290.18^{EF}	18.27^{BCD}	231.21^{DE}
T_4	Biochar + carpet waste + FYM (1+1+1 t) ha^{-1}	8.16	0.21	0.56^{BCD}	304.04^{C}	19.81^{BCD}	237.46^{BC}
T_5	Biochar + carpet waste + FYM (2+1+1 t) ha^{-1}	8.11	0.22	0.60^{AB}	308.54^{BC}	20.55^{BC}	241.89^{AB}
T_6	PGPR consortium	8.18	0.18	0.46^{F}	284.32^{GH}	16.89^{CD}	225.31^{FG}
T_7	Biochar + carpet waste (1+ 1 t) ha^{-1}+ PGPR	8.17	0.25	0.54^{CDE}	294.19^{DE}	18.67^{BC}	229.81^{DEF}
T_8	Biochar + carpet waste (2+ 1 t) ha^{-1} + PGPR	8.26	0.26	0.55^{BCD}	296.09^{D}	19.08^{BC}	232.64^{CD}
T_9	Biochar + carpet waste + FYM (1+1+1 t) ha^{-1}+ PGPR	8.07	0.22	0.58^{ABCD}	312.76^{B}	20.04^{AB}	242.36^{AB}
T_{10}	Biochar + carpet waste + FYM (2+1+1 t) ha^{-1} + PGPR	8.12	0.23	0.61^{A}	319.57^{A}	22.10^{A}	244.08^{A}
	LSD @ 5%	NS	NS	0.03	2.75	1.72	3.06

Different letters for each parameter show significant difference at p < 0.05

Table 3. Effect of biochar, carpet waste, FYM and PGPR on soil enzyme activity at different interval during field experiment

Treatments		Dehydrogenase (µg TPF produced g^{-1} soil day^{-1}) Days after transplanting Days after transplanting			Alkaline Phosphatase (µg pNP produced g^{-1} soil hr^{-1}) Days after transplanting Days after transplanting		
		40	80	120	40	80	120
T_1	Control	145.34^{BC}	110.63^{E}	96.46^{G}	50.19^{F}	77.32^{H}	63.29^{E}
T_2	Biochar + carpet waste (1+ 1 t) ha^{-1}	128.08^{G}	185.16^{D}	102.61^{FG}	54.33^{EF}	80.26^{FGH}	66.00^{DE}
T_3	Biochar + carpet waste (2+ 1 t) ha^{-1}	132.60^{FG}	188.06^{D}	105.27^{EF}	59.31^{DE}	83.42^{EFG}	68.26^{DE}
T_4	Biochar + carpet waste + FYM (1+1+1 t) ha^{-1}	138.12^{DE}	201.23^{C}	111.44^{DE}	64.50^{CD}	89.34^{DE}	79.34^{C}
T_5	Biochar + carpet waste + FYM (2+1+1 t) ha^{-1}	153.79^{A}	221.02^{B}	126.08^{A}	74.40^{B}	102.00^{B}	89.59^{B}
T_6	PGPR consortium	134.07^{EF}	184.38^{D}	110.36^{DE}	51.41^{F}	79.38^{GH}	66.18^{DE}
T_7	Biochar + carpet waste (1+ 1 t) ha^{-1}+ PGPR	140.27^{CD}	202.97^{C}	112.58^{CD}	58.62^{E}	85.32^{EF}	69.87^{D}
T_8	Biochar + carpet waste (2+ 1 t) ha^{-1}+ PGPR	145.29^{BC}	218.58^{B}	118.34^{BC}	65.21^{C}	92.29^{CD}	71.53^{D}
T_9	Biochar + carpet waste + FYM (1+1+1 t) ha^{-1}+ PGPR	148.32^{B}	230.12^{A}	122.31^{AB}	71.52^{B}	95.62^{C}	82.43^{C}
T_{10}	Biochar + carpet waste + FYM (2+1+1 t) ha^{-1}+ PGPR	157.25^{A}	233.09^{A}	127.32^{A}	83.45^{A}	109.38^{A}	98.46^{A}
	LSD@ 5 %	0.947	1.744	2.02	3.50	3.57	3.55

Different letters for each parameter show significant difference at p < 0.05

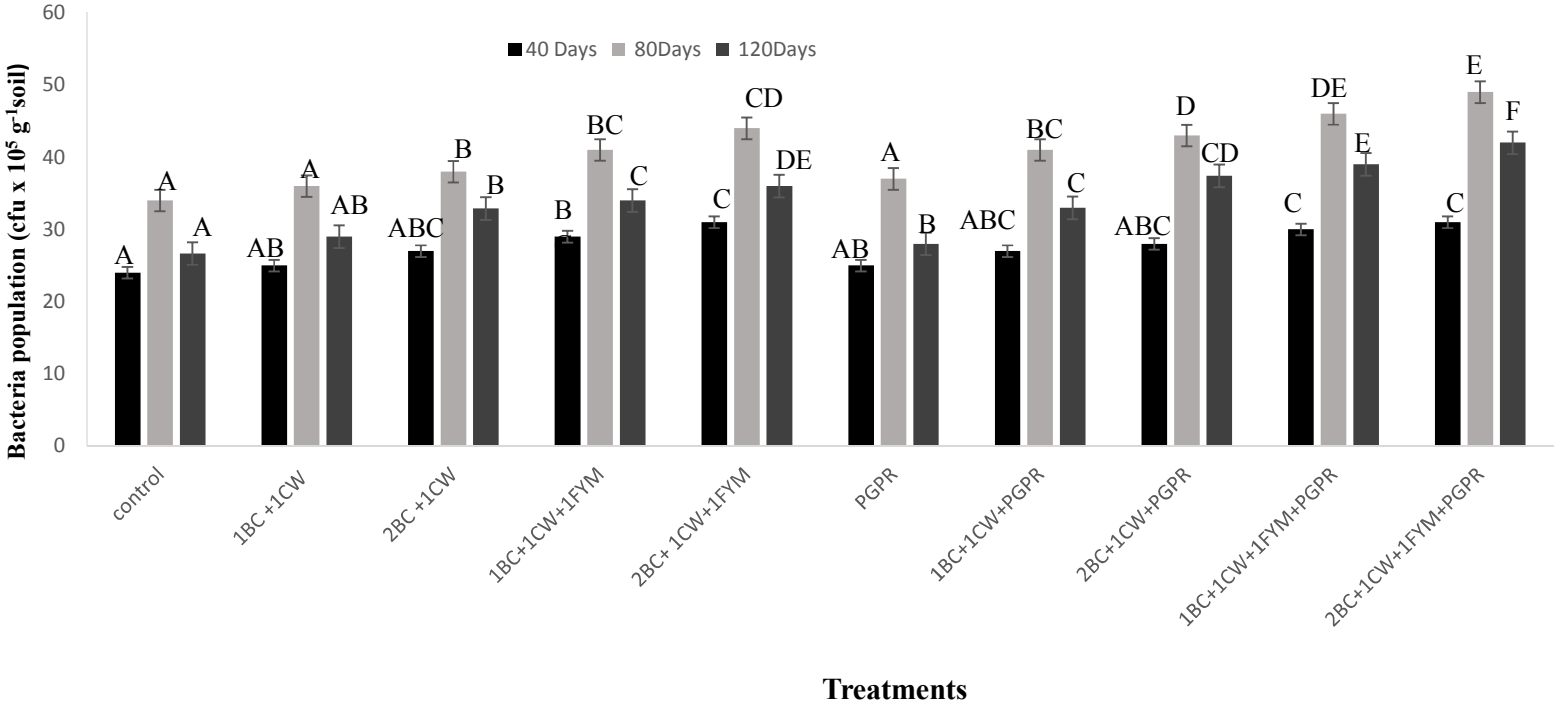

Fig. 1. Effect of biochar, carpet waste, FYM and PGPR on bacterial population in soil. Different letters for each parameter show significant difference at $p < 0.05$

Treatments: Control, 1BC +1CW – biochar@1 t ha^{-1} + carpet waste@1 t ha^{-1}, 2BC + 1C W – biochar@2 t ha^{-1} +carpet waste @1tha^{-1},1BC +1CW +1FYM- biochar@1t ha^{-1} +carpet waste@1tha^{-1} +FYM@1tha^{-1},2BC +1CW+1FYM-biochar@2tha^{-1}+carpetwaste@1tha^{-1} +FYM@1tha^{-1} ,PGPR – PGPR consortium , 1BC +1CW+1PGPR-biochar@1tha^{-1}+carpet waste@1tha^{-1}+PGPR ,2BC+1CW+ PGPR- biochar@2tha^{-1}+carpet waste@1 t ha^{-1} + PGPR ,1BC + 1CW +1FYM +PGPR -biochar@1tha^{-1} +carpet waste@1tha^{-1}+FYM@1tha^{-1} + PGPR,2BC + 1CW +1FYM +PGPR – biochar@2tha^{1} +carpet waste@1tha^{-1}+FYM @1 tha^{-1} + PGPR

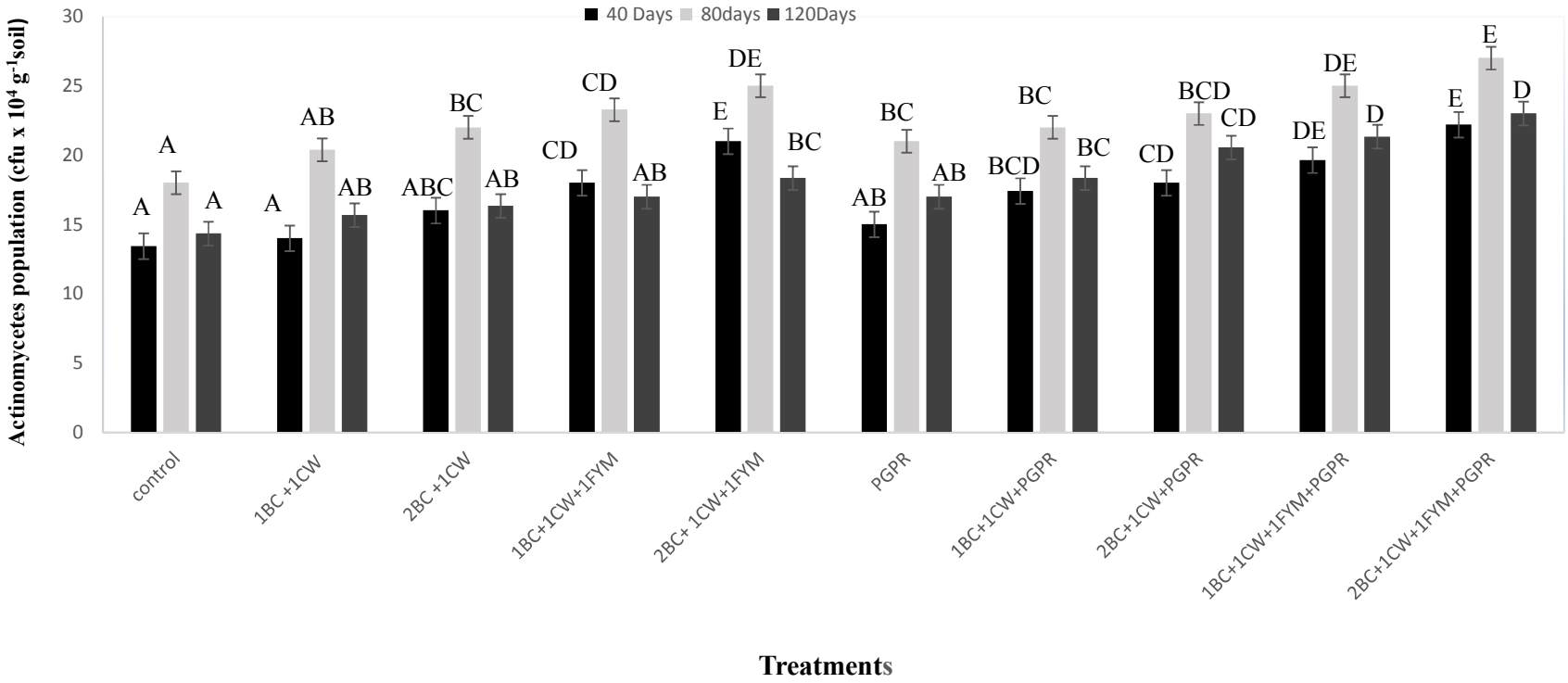

Fig. 2. Effect of biochar, carpet waste, FYM and PGPR on actinomycetes population in soil. Different letters for each parameter show significant difference at p < 0.05

Treatments: Control, 1BC +1CW – biochar@1 t ha^{-1} + carpet waste@1 t ha^{-1}, 2BC + 1C W – biochar@2 t ha^{-1} +carpet waste @1tha^{-1},1BC +1CW +1FYM- biochar@1t ha^{-1} +carpet waste@1tha^{-1} +FYM@1tha^{-1},2BC +1CW+1FYM-biochar@2tha^{-1}+carpetwaste@1tha^{-1} +FYM@1tha^{-1} ,PGPR – PGPR consortium , 1BC +1CW+1PGPR-biochar@1tha^{-1}+carpet waste@1tha^{-1}+PGPR ,2BC+1CW+ PGPR- biochar@2tha^{-1}+carpet waste@1 t ha^{-1} + PGPR ,1BC + 1CW +1FYM +PGPR -biochar@1tha^{-1} +carpet waste@1tha^{-1}+FYM@1tha^{-1} + PGPR,2BC + 1CW +1FYM +PGPR – biochar@2tha^{1} +carpet waste@1tha^{-1}+FYM @1 tha^{-1} + PGPR

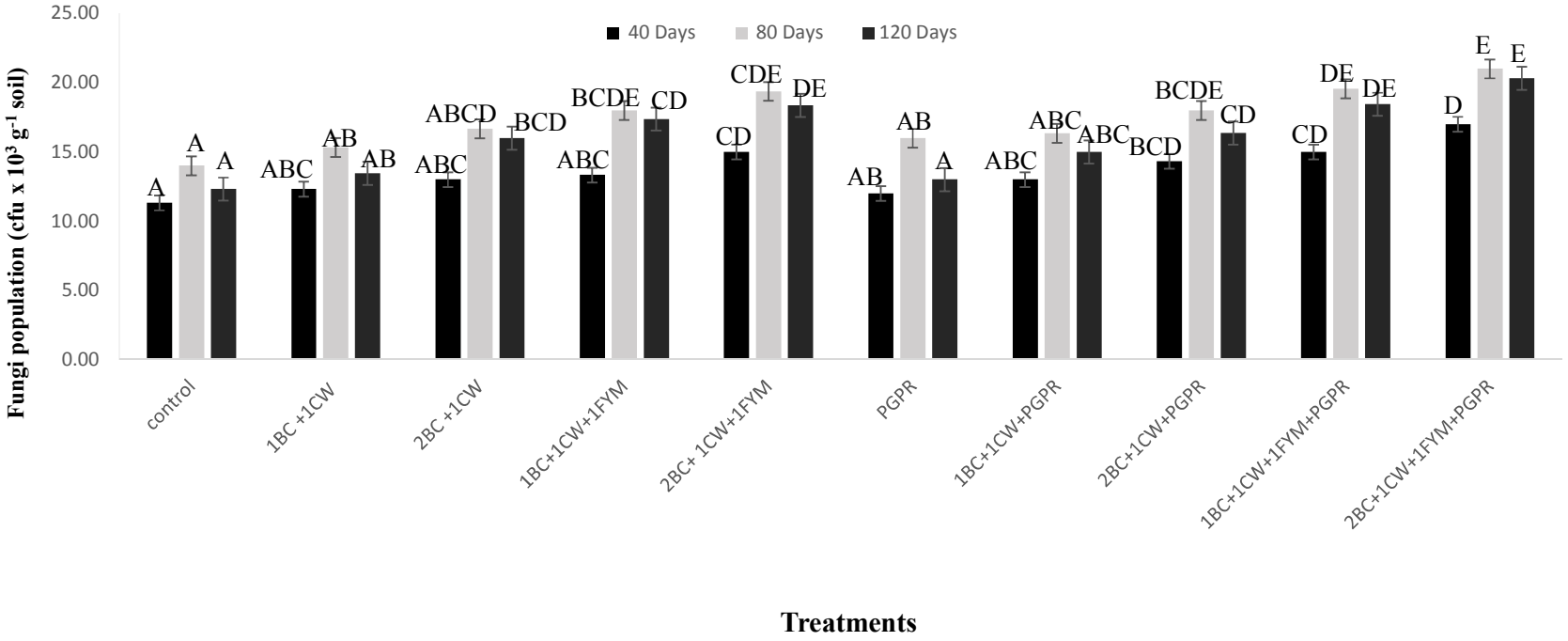

Fig. 3. Effect of biochar, carpet waste, FYM and PGPR on fungi population in soil. Different letters for each parameter show significant difference at $p < 0.05$

Treatments: Control, 1BC +1CW – biochar@1 t ha^{-1} + carpet waste@1 t ha^{-1}, 2BC + 1C W – biochar@2 t ha^{-1} +carpet waste @1tha^{-1},1BC +1CW +1FYM- biochar@1t ha^{-1} +carpet waste@1tha^{-1} +FYM@1tha^{-1},2BC +1CW+1FYM-biochar@2tha^{-1}+carpetwaste@1tha^{-1} +FYM@1tha^{-1} ,PGPR – PGPR consortium , 1BC +1CW+1PGPR-biochar@1tha^{-1}+carpet waste@1tha^{-1}+PGPR ,2BC+1CW+ PGPR- biochar@2tha^{-1}+carpet waste@1 t ha^{-1} + PGPR ,1BC + 1CW +1FYM +PGPR -biochar@1tha^{-1} +carpet waste@1tha^{-1}+FYM@1tha^{-1} + PGPR,2BC + 1CW +1FYM +PGPR – biochar@2tha^{1} +carpet waste@1tha^{-1}+FYM @1 tha^{-1} + PGPR

Table 4. Correlation coefficients (r) of soil enzymatic activity at different interval with Physico-Chemical properties of post-harvest soil

Time enzymatic activity	organic carbon	available nitrogen	available phosphorus	available potassium
40 Days Dehydrogenase activity	0 .51	0.73**	0.61*	0.73**
Alkaline Phosphatase activity	0.84**	0.97**	0.93**	0.96**
80 Days Dehydrogenase activity	0.68*	0.80**	0.90**	0.77**
Alkaline Phosphatase activity	0.79**	0.94**	0.91**	0.93**
120 Days Dehydrogenase activity	0.72**	0.83**	0.94**	0.86**
Alkaline Phosphatase activity	0.76**	0.95**	0.89**	0.94**

***correlation is significant at (p<0.01); *correlation is significant at (p<0.05)*

Table 5. Treatment details with their code and their quantity

Treatments	Abbreviation used	Organic sources	Quantity (Tonnes/ha)
T_1	Control	-	0
T_2	BC + CW	Biochar and Carpet waste	(1+1)
T_3	BC + CW	Biochar and Carpet waste	(2+1)
T_4	BC + CW +FYM	Biochar, Carpet waste and Farm yard manure	(1+1+1)
T_5	BC + CW + FYM	Biochar, Carpet waste and Farm yard manure	(2+1+1)
T_6	PGPR consortium	-	-
T_7	BC + CW +PGPR	Biochar, Carpet waste and Plant growth promoting rhizobacteria	(1+1)
T_8	BC + CW + PGPR	Biochar, Carpet waste and Plant growth promoting rhizobacteria	(2+1)
T_9	BC + CW + FYM + PGPR	Biochar, Carpet waste, Farm yard manure and Plant growth promoting rhizobacteria	(1+1+1)
T_{10}	BC + CW + FYM + PGPR	Biochar, Carpet waste, Farm yard manure and Plant growth promoting rhizobacteria	(2+1+1)

Similarly in case of fungi at 80 days after transplanting of rice highest population (21 x 10^3 cfu g^{-1}soil) was observed in treatment where biochar@2tha%$^{-1}$ + carpetwaste @1tha^{-1}+FYM@1tha^{-1}alongwithPGPR applied and minimum in control (11.32 x10^3 cfu g^{-1}soil), it was illustrated in (Fig. 3). The next highest population found in treatment where biochar@1t ha^{-1} + carpet waste@1t ha^{-1} + FYM@1t ha^{-1} + PGPR applied. The increase in fungi population is less compared to bacteria and actinomycetes, due to slightly high pH of soil. Similar trend followed after 40 days and 120 days after transplanting of rice. But maximum fungi population observed, 80 days after transplanting of rice and minimum after harvesting of rice i.e., 120days. Behera et al. [12] reported that decrease in fungi population after harvesting of rice is due to less organic matter content and availability of nutrients. Behera et al. [12] reported that combined application of biochar @2tha%$^{-1}$+carpetwaste@1tha^{-1}+FYM@1tha^{-1} along with PGPR, resulted in greater number of microbial population (bacteria, actinomycetes and fungi) corresponds to other treatments.

3.4 Correlation Coefficients (r) of Soil Enzymatic Activity at the Different Interval with Physico-chemical Properties of Post-harvest Soil

The correlation analysis showed that the soil enzymatic activities at 40,80 and 120 days after transplanting of Rice have a positive correlation with organic carbon, available nitrogen, available phosphorus and available potassium in the soil (Table 4). This was happened due to the inclusion of biochar, carpet Waste, FYM that raised the microbial population in the soil as these source act as food for them and thus released nutrient from these sources resulted in positive correlation among them. On the other side, PGPR increased the other beneficial microorganism which also resulted in more nutrient release from the soil Sri ramachandrasekharan and Ravichandran [30] reported that the inclusion of the organic substances to the soil served as a carbon source for the microbes which enhanced the microbial biomass and phosphatase activity. The enzymes i.e. dehydrogenase and alkaline phosphatase

released by the microorganism improved the nutrient accessibility in the soil by mineralizing the N, P and K from the organic sources and the other soil minerals.

5. CONCLUSION

The present investigation result showed that use of biochar, carpet waste, FYM and PGPR had a positive impact on physico-chemical and biological properties of soil in the Inceptisol of Varanasi. Therefore, it can be inference out that the use of organic source along with PGPR gives satisfactory result in the field condition under early stage of organic farming. This approach could be an effective strategy for organic agriculture to enhance soil properties in the long term. The combined application of biochar, carpet waste, FYM (Farmyard manure) and PGPR help in enhancing the microbial population, enzymatic activities and physico-chemical properties of soil in the rice under organic farming system.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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