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Effect of biofertilizers and vermicompost on physico-chemical properties of soil under wheat (*Triticum aestivum*) crop

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ABSTRACT

A field experiment was conducted at the Instructional farm, Rajasthan College of Agriculture, Udaipur for two years (2017–18 and 2018–19) during the winter (*rabi*) season. The experiments were arranged in a randomized block design (RBD) manner with 3 replications. The results showed that, seed inoculation with biofertilizers (*Azotobacter* + Phosphorus solubilizing bacteria + Potash mobilizing bacteria + Zinc solubilizing bacteria) improved physico-chemical properties of soil except bulk density, particle density, *p*H, EC and showed higher availability of nutrients over control plot. Whereas in case of vermicompost (VC), physical properties such as BD, PD, porosity, WHC and chemical properties like *p*H, EC, CEC, OC and available nutrients were found distinctly enhanced under 50% VC at sowing + 50% VC at tillering in post-harvest soil over control. However, 50% VC at sowing + 50% VC at tillering significantly reduced bulk density, particle density, *p*H and EC. Furthermore, both biofertilizers and split application of vermicompost also significantly improved the productivity of wheat. It is concluded that application of biofertilizers and vermicompost could reliably be used to improve soil physico-chemical properties of wheat cultivated soils.

Keywords: Biofertilizers, PSB, Soil organic carbon, Vermicompost, Wheat

Deterioration in soil health due to indiscriminate use of chemical fertilizers necessitates us to use biological inputs like biofertilizers and vermicompost, which have been sought as one of the best option to restore the soil health apart from solving nutrition problem of soil. Biofertilizers contain living cells of microorganisms, are ecofriendly with the capacity to improve the soil fertility status and promote plant growth by converting major nutrients from unavailable to available form (Prasad *et al*. 2016). Seed inoculation with biofertilizers has immense potential to promote nitrogen fixation, solubilization of potassium and phosphate, plant nodule formation and the production of phytohormones and siderophores in plants (Sinha *et al.* 2014). Biofertilizers aid in holding the soil particles together to form stable aggregates, which reduce soil erosion and ameliorate soil structure (Wu *et al.* 2005). Vermicompost is an organic manure resulting from microbial composting through earthworm activity, which contains higher organic matter, organic carbon and available macro and micronutrients (Parthasarathi *et al*. 2007). Vermicompost is the best soil amendment or conditioner because of its higher microbial activity, water-holding capacity, drainage, aeration and high porosity. Applying vermicompost at the time of sowing resulted in increased soil fertility by improving the nutrient content, cation exchange capacity (CEC) and soil organic matter (Ganesh *et al*. 2011). The application of vermicompost significantly influenced the physico-chemical properties like *p*H, CEC, organic carbon (OC), bulk density and particle density (Sharma *et al*. 2013). Wheat (*Triticum aestivum* L.) is the staple food of about two billion people (36% of the global population) in the world. Worldwide, wheat contributes nearly 20% of the food calories and 55% of the carbohydrates consumed. Wheat occupied over 34.6 million hectare area worldwide with a production level of about 109.2 million tonnes and a productivity of 3571 kg/ha (FAO 2019–20). Sole and combined application of organic manures improved the productivity of bread wheat (Ali *et al*. 2020). Seeing all the beneficial effects of biofertilizers and vermicompost, an experiment was conducted to see the effect of biofertilizers and vermicompost on physico-chemical properties of soil.

MATERIALS AND METHODS

Field experiments were conducted at the Instructional farm, Rajasthan College of Agriculture, Udaipur (24°.35' N latitude, 74°.42' E longitude and an altitude of 579.5 m amsl) during the winter (*rabi*) seasons (December–April) of

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2017–18 and 2018–19. The region falls under agro-climatic zone IVA (sub-humid Southern plain and Aravalli hills) of Rajasthan. The experimental soil was clay loam in texture, with *p*H (8.0), CEC (14.01C mol (P^+)/kg), OC (0.52 %), N (253 kg/ha), P_2O_5 (18 kg/ha), K_2O (440 kg/ha), Zn (2.80 mg/kg), Fe (3.34 mg/kg), Mn (9.35 mg/kg) and Cu (1.70 mg/kg). There were 20 treatments (5 × 4) and each treatment was replicated three times with 5 levels of biofertilizers (B_1: Control, B_2: *Azotobacter*, B_3: *Azotobacter* + PSB, B_4: *Azotobacter* + PSB + KMB and B_5: *Azotobacter* + PSB + KMB + ZnSB) and 4 levels of vermicompost (V_1: Control, V_2: 100% VC at sowing, V_3: 50% VC at sowing + 50% VC at tillering and V_4: 75% VC at sowing + 25% VC at tillering). Biofertilizers, viz. *Azotobacter*, PSB, KMB and ZnSB were added in required quantity (@5 ml of each biofertilizers/kg seed). The vermicompost was collected from the dairy farm of RCA, Udaipur in November and analyzed using standard methods. It consisted of *p*H (6.71±0.02) and total C, N, P, K, Zn, Fe, Mn and Cu of 13.4±0.01%, 1.61±0.01%, 1.02±0.12%, 0.73±0.02%, 50.1±2.23 mg/kg 175±27.1 mg/kg, 98±3.01 mg/kg and 5.00±0.01 mg/kg, respectively. The vermicompost (@4 t/ha) was applied in the field during sowing (basal application) and the tillering stage (40 DAS). A starter dose of $N:P_2O_5:K_2O$ @ 60:40: 20 mg/kg was added to the soil of each plot through urea, DAP and muriate of potash, respectively. The average annual rainfall ranges from 500–750 during December–February. The crop was harvested on 8 April 2018 and 10 April 2019. Soil samples were collected near the root zone at two different times: initial (before sowing and application of vermicompost) and final (after harvesting of wheat) from each plot and analyzed for parameters. The collected soil samples were placed in plastic bags and labelled accordingly. Physical properties of the soil like bulk density, particle density, porosity were determined by specific gravity bottle method (Kanwar and Chopra 1981), water holding capacity analyzed (Piper 1966), and *p*H (1:2; soil:water), electrical conductivity (EC), cation exchange capacity (Jackson 1973), organic carbon (Walkley and Black 1934), available nitrogen (Subbiah and Asija 1956), available phosphorus (Olsen *et al*. 1954), available potassium (Jackson 1973) and DTPA extractable Zn, Fe, Cu and Mn (Lindsay and Norvell 1978) were analyzed. The experimental data on soil was subjected to fisher's method of Analysis of variance (ANOVA) as reported by (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Bulk density, particle density, porosity and water holding capacity of post-harvest soil: Data revealed that bulk density (BD), particle density (PD) and porosity of soil did not influence significantly except water holding capacity (WHC) of the soil (Table 1). The maximum water holding capacity (48.7%) was obtained under B_5 (*Azotobacter* + PSB + KMB + ZnSB) and lowest (44.0%) was obtained under control. The treatment B_5 remained at par with B_4 and significantly higher over other treatments. This has perhaps been due to application of biofertilizers to improve soil structure and supply of nutrients (Goyal *et al.* 2017). Vermicompost had significant (P<0.05) effects on bulk density, particle density, porosity and water holding capacity of soil (Table 1). Bulk density and particle density values were decreased from 1.38 and 2.58 Mg/m^3 to 1.35

Table 1 Effect of biofertilizers and vermicompost on physico-chemical properties of post-harvest soil (2 years pooled data)

Treatment	BD (Mg/m^3)	PD (Mg/m^3)	Porosity (%)	WHC (%)	*p*H	EC (dS/m)	CEC (C mol (P^+)/kg)	OC (%)
Biofertilizer								
B_1	1.37	2.58	47.9	44.0	8.26	0.818	14.0	0.629
B_2	1.36	2.57	48.4	46.0	8.26	0.814	14.4	0.646
B_3	1.37	2.55	48.5	47.0	8.25	0.812	14.6	0.666
B_4	1.36	2.55	48.2	48.4	8.25	0.808	15.2	0.674
B_5	1.35	2.54	49.3	48.7	8.24	0.804	15.2	0.679
SEm±	0.004	0.010	0.35	0.15	0.008	0.002	0.04	0.002
CD (P=0.05)	NS	NS	NS	0.45	NS	NS	0.11	0.005
Vermicompost								
V_1	1.38	2.59	46.7	44.1	8.29	0.819	14.0	0.624
V_2	1.36	2.53	48.8	46.9	8.24	0.810	14.5	0.651
V_3	1.35	2.52	49.8	48.5	8.22	0.799	15.2	0.683
V_4	1.36	2.53	48.6	48.5	8.24	0.807	15.1	0.677
SEm±	0.004	0.009	0.32	0.14	0.007	0.002	0.03	0.002
CD (P=0.05)	0.010	0.025	0.91	0.40	0.020	0.006	0.10	0.005

*NS, non significant; BD, Bulk density; PD, Particle density; WHC, Water holding capacity; EC, Electrical conductivity; CEC, Cation exchange capacity; OC, Organic carbon.

Biofertilizer and vermicompost details are mentioned in Materials and Methods.

and 2.54 Mg/m^3 under vermicompost treatments. This might be due to action of gum compounds, polysaccharides and fulvic acid compound of organic matter on the soil structure (Manickam 1993). The results showed that porosity values increased up to 49.3% under V_3 (50% VC at sowing + 50% VC at tillering) but treatment V_2, V_4 and V_3 did not differ significantly with each other (Table 1). The greatest water holding capacity (48.5%) was observed in V_3 (50% VC at sowing + 50% VC at tillering) and lowest (44.1%) was observed in soil without vermicompost (V_1). However, treatment V_3 was found significantly higher over other treatments except V_4. Application of vermicompost significantly decreases bulk density and particle density and improves the water-holding capacity due to increased soil aggregation (Sheikh and Dwivedi 2018).

Soil p*H, electrical conductivity (EC), organic carbon (OC) and cation exchange capacity (CEC) of post-harvest soil*: Seed inoculation with biofertilizers reduced the pH and EC values of soil but not significantly. The results revealed that highest cation exchange capacity (15.2 C mol (P^+) / kg) was obtained under B_5 (*Azotobacter* + PSB + KMB + ZnSB) and lowest in control (Table 1). The treatment B_5 remained at par with B_4 and significantly higher over the rest treatments. Among the treatments, the highest soil organic carbon value (0.679%) was recorded under B_5 (*Azotobacter* + PSB + KMB + ZnSB) and lowest (0.629%) value was observed in control. Biofertilizers with radical hyphae and bacterial population in inoculated plot attributes to the increased organic carbon in soil (Prasad *et al*. 2016). Application of vermicompost resulted in reduced *p*H and EC in all treatment over the control (V_1). The lowest value of *p*H (8.22) and EC (0.799 dS/m) were recorded with V_3 (50% VC at sowing + 50% VC at tillering) treatment (Table 1). These results might be due to continuous production of organic acids on decomposition of organic matter resulting into lowering of soil *p*H and EC (Kansotia *et al*. 2015). Cation exchange capacity values were found to be higher in V_3 (15.2 C mol (P^+)/kg) over control and V_2. However, treatment V_3 was statistically at par with V_4. The significant increase in CEC of the soil might be due to increase in water holding capacity of the soil which further provided higher availability of water to plants and solubility of the nutrients (Epstein 1997). Significantly maximum organic carbon (0.683%) was found in treatment V_3 (50% VC at sowing + 50% VC at tillering) and minimum organic carbon (0.624%) was obtained with control (Table 1). This might be due to direct addition, continuous mineralization and biological immobilization of organic matter that applied on experimental soil (Kansotia *et al*. 2015).

Available nitrogen, phosphorus and potassium of post-harvest soil: According to the results there was significant ($P<0.05$) increase in the available nitrogen, phosphorus and potassium under the biofertilizers inoculated plots over the control (Table 2). The application of treatment B_5 (*Azotobacter* + PSB + KMB + ZnSB) resulted in significantly higher available nitrogen (306 kg/ha), phosphorus (26.6 kg/ha) and potassium (539 kg/ha) content in soil compared to control. Present study revealed that available nitrogen, phosphorus and potassium were increased up to 19.53, 31.46 and 18.72% respectively with the application of B_5 to control. Increased availability of macro nutrients might be due to soil community which is able to influence soil fertility through processes, viz. decomposition, mineralization, and release of nutrients and combined application of biofertilizers is found to have beneficial effect on enhancing N, P and K nutrients (Prasad *et al*. 2016). Application of vermicompost showed

Table 2 Effect of biofertilizers and vermicompost on available macro and micro-nutrients of post-harvest soil (2 years pooled data)

Treatment	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Biofertilizer							
B_1	256	20.2	454	2.82	3.37	9.3	1.75
B_2	281	23.6	484	3.10	3.65	10.0	2.04
B_3	291	25.2	511	3.29	3.79	10.7	2.13
B_4	301	25.9	531	3.38	3.91	11.4	2.33
B_5	306	26.6	539	3.63	3.99	11.6	2.39
SEm±	1.54	0.11	2.20	0.03	0.02	0.11	0.01
CD (P=0.05)	4.38	0.31	6.25	0.08	0.05	0.32	0.04
Vermicompost							
V_1	255	20.3	454	2.83	3.36	9.4	1.68
V_2	286	24.4	509	3.17	3.67	10.1	2.08
V_3	304	26.4	533	3.50	4.01	11.5	2.40
V_4	302	26.0	530	3.48	3.92	11.4	2.35
SEm±	1.38	0.09	1.97	0.03	0.01	0.10	0.01
CD (P=0.05)	3.92	0.27	5.59	0.07	0.05	0.29	0.03

Biofertilizer and vermicompost details are mentioned in Materials and Methods.

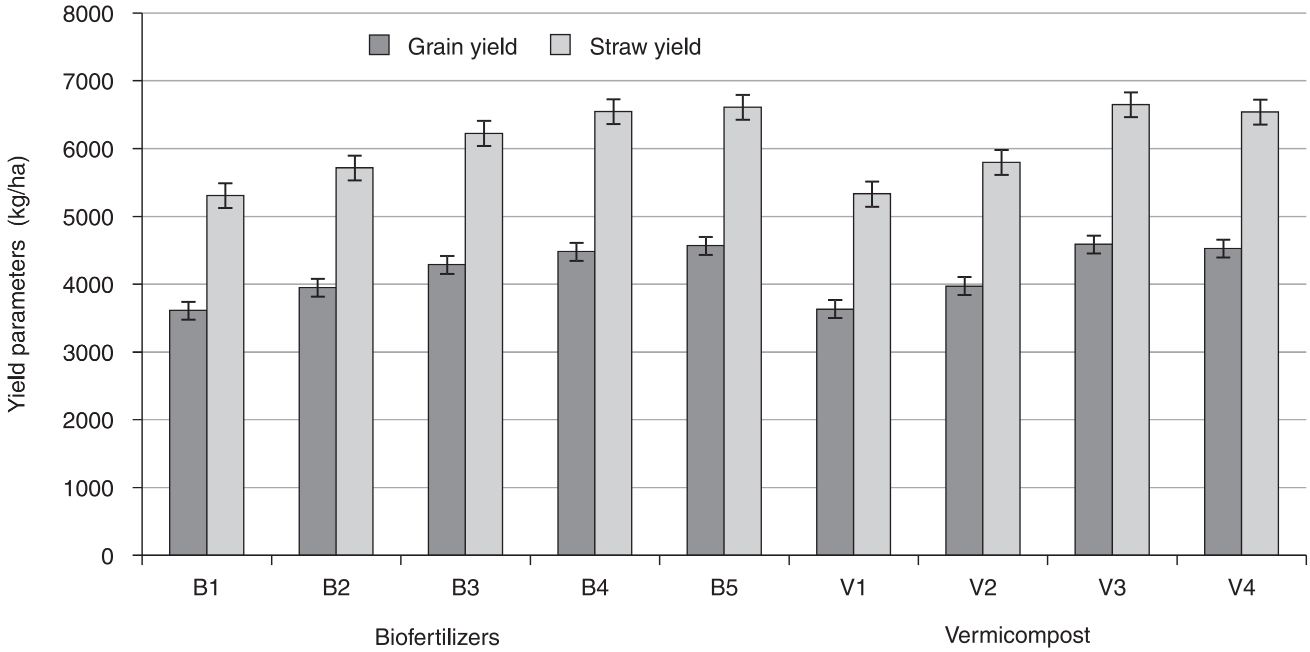

Fig 1 Effect of biofertilizers and vermicompost on grain and straw yield of wheat (pooled data of two years).

significantly ($P<0.05$) positive effects on macronutrient content in post-harvest soil of wheat (Table 2). The highest amount of available N (304 kg/ha), P_2O_5 (26.4 kg/ha) and K_2O (533 kg/ha) were found with treatment V_3 (50% VC at sowing + 50% VC at tillering) which were 19.21, 30.31 and 17.40% respectively higher over control. However, the treatments V_3 and V_4 remained at par with each other in terms of available nitrogen and potassium. Mineralization of vermicompost played a major role by creating favourable conditions throughout the wheat growing period which further improved the available nutrient pool of the soil (Ganesh *et al*. 2011).

DTPA extractable micronutrient of post-harvest soil: The seed inoculation with biofertilizers significantly ($P<0.05$) increased DTPA extractable micronutrients (Zn, Fe, Mn and Cu) than control in post-harvest soil (Table 2). According to the results, highest available Zn (3.63 mg/kg), Fe (3.99 mg/kg), Mn (11.6 mg/kg) and Cu (2.39 mg/kg) were recorded under B_5 (*Azotobacter* + PSB + KMB + ZnSB) and lowest values were observed under control, respectively. The treatments B_5 and B_4 remained at par with each other in terms of available soil Manganese. Inoculation with biofertilizers might have contributed towards enhanced chelating agents and increased availability of micronutrients (Fe, Zn, Cu and Mn) (Prasad *et al*. 2016). Present findings revealed that the application of vermicompost significantly ($P<0.05$) increased the availability of micronutrients (Zn, Fe, Mn and Cu) over the control in post-harvest soil (Table 2). Highest available Zn (3.50 mg/kg), Fe (4.01 mg/kg), Mn (11.53 mg/kg) and Cu (2.40 mg/kg) were recorded under treatment V_3 (50 % VC at sowing + 50% VC at tillering) which were respectively high over control. However the treatments V_3 and V_4 remained at par with each other in terms of available Zinc and Manganese. Higher availability of nutrients under vermicompost might have resulted from inherent capacity to increase organic carbon content in soil, which consequently leads to improved mineralization of organically bound macro and micro-nutrients and formation of organic chelates (Sheikh and Dwivedi 2018).

Grain and straw yield of wheat: The data revealed that maximum mean grain (4564.7 kg/ha) and straw yields (6606.7 kg/ha) were recorded with *Azotobacter* + PSB + KMB + ZnSB (B_5) and it was statistically at par with *Azotobacter* + PSB + KMB (B_4) (Fig 1). This increase in yield might have resulted from the growth regulating substances produced by biofertilizers besides fixation of additional nitrogen solubilisation and mobilisation of sparingly soluble nutrients in soil. These findings are in line with Meena and Maurya (2017). Results further revealed that maximum mean grain (4587.2 kg/ha) and straw yield (6648.5 kg/ha) were recorded under 50% VC at sowing + 50% VC at tillering(V_3) which was significantly higher over the control and basal application (V_2) and it remained at par with V_4. The improvement in grain and straw yield with the application of vermicompost was owing to the beneficial effect of vermicompost on nutrient availability (Patidar *et al.* 2019).

Based on results, it can be concluded that biofertilizers (*Azotobacter* + PSB + KMB + ZnSB) combined with split application of vermicompost (50% VC at sowing + 50% VC at tillering) are a good source of plant nutrients to improve physico-chemical properties and also in enhancing crop productivity.

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