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Microbial Inoculants and Split Application of Vermicompost Enhance Nutrient Content and Economics of Wheat (*Triticum aestivum* L.) on typic Haplustepts of Rajasthan

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ABSTRACT: The assumption underlying this study has been that application of microbial inoculants and vermicompost can help to meet requirement of plant nutrients. This experiment was validating in field experiment carried out on clay loam soil in *Rabi* seasons on same site during 2017-18 and 2018-19 at the Agronomy Farm of RCA, Udaipur, Rajasthan. Two factors were included in this experiment *i.e.* five levels of microbial inoculants and four levels of vermicompost. In this study nutrient content in grain and straw of wheat were evaluated. The results show that highest nutrients (N, P, K, Fe, Mn, Zn and Cu) content in grain and straw of wheat were recorded with *Azotobacter* +PSB + KMB + ZnSB. The application of treatment *Azotobacter* + PSB + KMB + ZnSB produced the highest net returns 62362.6 ₹ ha^{-1} and 72695.5 ₹ ha^{-1} of wheat. In case of vermicompost, nutrients contents (N, P, K, Fe, Mn, Zn and Cu) in grain and straw of wheat were significantly higher under the treatment receiving 50% VC at sowing + 50% VC at tillering. Further results observed that split application of vermicompost as V_3 significantly improved net returns 62218.0 ₹ ha^{-1} and 72685.1 ₹ ha^{-1} of wheat over rest of the treatments except V_4. The lowest values of all the parameters were recorded under control. According to research results, *Azotobacter* + PSB + KMB + ZnSB had the most positive effect on the measured characteristics. Also the using of vermicompost was increased nutrient content and economics of wheat.

Keywords: Microbial inoculants, PSB, vermicompost, wheat, yield.

INTRODUCTION

Wheat is the second most important food grain crop of the family Poaceae in India ranking next to rice contributing about 35% of the food grain production in India. Various agricultural soils globally are deficient in plant nutrients. Inorganic fertilizers are quite expensive and increase cost of crop production. Besides, inorganic fertilizers lead to soil deterioration and causes health issues to both human and animals (Alori and Babalola, 2018). It is for that reason necessary to improve soil fertility, although at the same time checking linked harmful environmental effects of inorganic fertilizers. Microbial inoculants are of rising attention for their latent role in enhancing soil fertility and improve in production and their nutrient uptakes. Microbial inoculants are the helpful microorganism's formulations that play a vital role in every agro ecosystem. To coverage the future food security and sustainability needs, food production build substantially while agriculture's environmental effect must contract dramatically at the same time (Foley *et al*., 2011). When microbial inoculants applied to soil, seeds or seedlings increased the nutrient availability directly or indirectly to the host plant and enhance plant growth (Verma *et al.*, 2010). They hold a huge secure to increased crop yield (Isfahani and Besharati 2012). Biofertilizers are being promoted to gather the naturally available and biological system of nutrient availability to the plant in the soil (Venkatashwarlu, 2008). In the current agricultural techniques, there are a group of helpful microbial strains used as inoculants. They are included *Azotobacter*, *Pseudomonas*, *Azospirillum*, and *Phosphobacterium* along with others microbes (Toyota and Watanabe, 2013). Biofertilizers have immense potential for supplying nutrients, eco-friendly and low cost inputs, especially N and P and can reduce the chemical fertilizer dose by 25-50% (Rana *et al.*, 2012). Vermicompost is the product of organic residues and wastes decomposition process through activity of the earthworm to convert organic matters which contain higher organic carbon, organic matter, total and available macronutrients and micronutrients, enzyme and microbial activities (Parthasarathi *et al.*, 2007). All nutrients in vermicompost are in a readily available form, thereby enhancing nutrient content in plants (Banik and Sharma 2009). Split doses of vermicompost gave the in maximum nutrient use efficiency in rice even if only vermicompost was applied at basal application or without vermicpmpost (Bejbaruah *et al.*, 2013). The available literature on the combined application of biofertilizers and vermicompost is very meager. There is no published information on split application of vermicompost in wheat production and scanty on other crops. Keeping the above consideration, an experiment of microbial inoculation and vermicompost on nutrient content and economics of wheat was conducted.

MATERIALS AND METHOD

A 2 years field trial was conducted at Agronomy Farm, Rajasthan College of Agriculture, Udaipur. The trial comes under Sub-Humid Southern Plain and Aravalli Hills (agro-climatic zone IVA) of Rajasthan and located at 24^o.35' N Latitude and 74^o.42' E Longitude with the altitude of 579.5 m above mean sea level. The soil is a clay loam texture, available nitrogen (250 kg/ha), phosphorus (18.65 kg/ha) and potassium (444.65 kg/ha).To determine soil properties of the experimental trial, soil samples were drawn from different spots of field up to 0-15 cm depth and a representative composite sample were mixed and analysis soil properties using standard analysis methods. Study was selected five treatments of microbial inoculants [Control (B_1), *Azotobacter* (B_2), *Azotobacter* + PSB (B_3), *Azotobacter* + PSB + KMB (B_4) and *Azotobacter* + PSB + KMB + ZnSB (B_5)] and four treatments of vermicompost [Control (V_1), 100% at sowing (V_2), 50% at sowing + 50% at tillering (V_3) and 75 % at sowing + 25 % at tillering (V_4)], making twenty treatments combination and replicated thrice in randomized block design (RBD). The seeds were thoroughly mixed with liquid microbial inoculants in such a way that all the seeds were uniformly coated with inoculums as per the treatments using each of 5 ml kg^{-1} and then allowed to dry in the shade before the sowing of crop. The application of vermicompost @ 4 t ha^{-1} will be applied in the field as per treatments mixed at the time of sowing (Basal application) and tillering stage (40 DAS) of the crop. Nutrients composition of vermicompost applied in the experiment is given in Table 1. The field trials were conducted as same field for two years to verify the same soil properties. The field trial was prepared after harvesting of succeeding crop with tractor drawn disc plough by ploughing (0-15 cm), cross harrowing and planking to get the soil in to good physical conditions.

The crop was irrigated at the critical stages, weeding were done at 25 and 45 days after sowing, use chemicals to control and check pest infestation and other operation carried out follow the farmers practice.

Table 1: Nutrient composition of the vermicompost used in the experiment.

Sr. No	Components	% on oven dry weight basis
1.	Nitrogen (N)	1.14
2.	Phosphorus (P_2O_5)	1.28
3.	Potassium (K_2O)	1.06
4.	Zn (ppm)	26.5
5.	Fe (ppm)	172.2
6.	Mn (ppm)	96.8
7.	Cu (ppm)	4.78
8.	pH	7.0-7.5

After the physiological maturity crop was harvested, the grain and straw were keep for air dried and weight for further procedure. The biomass of wheat was harvest from each net plot area and threshed, winnowed, cleaned and dried wheat grains in sun light therefore grains were weighed in terms of kg/plot. To determine the content of macro and micronutrients, representative grain and straw samples were drawn from each plot at harvest. The samples were shade dried for two to three days, subsequently oven dried for 24 hours at 60ºC then the samples were powdered by Willey grinder for further estimation. Dry plants were ground and composite sample was used for the determination of N, P_2O_5, K_2O, Fe, Mn, Zn and Cu content in the grain and straw of wheat using standard procedures. The experimental data were statistically analyzed using F-test analysis of variance (ANOVA) as valid in randomized block design and least significant difference (LSD) at P = 0.05 was applied to analysis the variation between individual treatments means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

A. Performance of biofertilizers and vermicompost on nutrient content of wheat

The results regarding nutrient content in grain and straw of wheat are described in Table 2 and 3. Results indicated that seed inoculation with microbial inoculants were found significant ($p<0.05$) for nitrogen, phosphorus and potassium content in grain and straw of wheat compared to control (Table 2). Under the influence of microbial inoculants, the maximum nitrogen (1.568 and 0.537 %), phosphorus (0.329 and 0.222 %) and potassium (0.554 and 1.485 %) content in grain and straw of wheat were recorded under treatment B_5 (*Azotobacter* + PSB + KMB + ZnSB) followed by B_4, B_3, B_2 and B_1 which was significantly higher compared to B_3, B_2 and control, however the treatment B_5 remained at par with B_4 in terms of nitrogen and potassium in grain and straw of wheat. The lowest nutrient content was recorded under control. Application of microbial inoculants were increased nitrogen (9.80 and 14.74 %), phosphorus (16.25 and 18.09 %) and potassium (12.37 and 10.24 %) content in grain and straw of wheat due to application of B_5 compared to control (B_1), respectively. Further results revealed that seed inoculation with microbial inoculants were found significant ($p<0.05$) for zinc, iron, manganese and copper content in grain and straw of wheat over to control (Table 3). Treatment B_5 were recorded significantly ($p<0.05$) higher zinc (59.91 and 40.46 ppm), iron (81.57 and 177.43 ppm), manganese (46.33 and 69.28 ppm) and copper (14.13 and 5.86 ppm) content in grain and straw of wheat compared to rest of treatments except B_4 in terms of iron and copper in grain and straw and manganese in grain of wheat. Inoculation with microbes were improved zinc (15.84 and 20.81 %), iron (14.12 and 9.38 %), manganese (12.67 and 10.23 %) and copper (18.17 and 38.86 %) content in grain and straw of wheat due to application B_5 compared to control (B_1), respectively. This might be due to inoculation with microbes which can increase activities of malic and isocitric dehydrogenase (Kurtz and Larue, 1975), enhanced activity of nitrate reductase and nitrogenase enzyme in soil by PSB (Verma *et al.* 2014) and mobilization of K from soil by KMB due to secretions of different organic acids from root exudates (Vaid *et al.*, 2013). The micro nutrient content was improved might be due to inoculation with microbes increase chelating properties and secretions of organic acids from root exudates (Ghetiya *et al.*, 2019).

Table 2: Effect of microbial inoculants and vermicompost on nutrient content in grain and straw of wheat (Mean data of 2017-18 and 2018-19).

Treatments	N content (%)		P content (%)		K content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
Microbial inoculants						
B_1	1.428	0.468	0.283	0.188	0.493	1.347
B_2	1.475	0.487	0.299	0.199	0.511	1.381
B_3	1.515	0.506	0.311	0.208	0.526	1.417
B_4	1.563	0.530	0.325	0.218	0.551	1.470
B_5	1.568	0.537	0.329	0.222	0.554	1.485
SEm±	0.007	0.003	0.002	0.001	0.002	0.006
C.D. (P = 0.05)	0.021	0.009	0.004	0.003	0.007	0.016
Vermicompost						
V_1	1.433	0.469	0.285	0.191	0.491	1.354
V_2	1.469	0.494	0.300	0.202	0.519	1.397
V_3	1.572	0.535	0.328	0.220	0.555	1.476
V_4	1.565	0.524	0.321	0.214	0.543	1.452
SEm±	0.007	0.003	0.001	0.001	0.002	0.006
C.D. (P = 0.05)	0.019	0.008	0.004	0.002	0.006	0.018

Table 3: Effect of microbial inoculants and vermicompost on nutrient content in grain and straw of wheat (Mean data of 2017-18 and 2018-19).

Treatments	Zn content (ppm)		Fe content (ppm)		Mn content (ppm)		Cu content (ppm)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Microbial inoculants								
B_1	51.72	33.49	71.48	162.21	41.12	62.85	12.11	4.22
B_2	53.03	34.29	75.90	165.34	42.67	64.38	12.84	4.68
B_3	57.56	36.60	78.00	169.95	44.06	66.23	13.94	5.44
B_4	58.15	37.13	81.53	177.08	46.19	68.88	14.26	5.83
B_5	59.91	40.46	81.57	177.43	46.33	69.28	14.31	5.86
SEm±	0.20	0.13	0.20	0.20	0.06	0.09	0.03	0.01
C.D. (P = 0.05)	0.57	0.38	0.58	0.56	0.17	0.26	0.09	0.04
Vermicompost								
V_1	52.64	32.73	72.22	164.91	40.81	63.71	11.77	4.33
V_2	56.20	36.80	76.95	169.52	43.81	65.93	12.91	5.21
V_3	57.98	38.28	80.90	173.72	45.88	67.97	14.66	5.66
V_4	57.48	37.76	80.71	173.45	45.80	67.68	14.62	5.63
SEm±	0.18	0.11	0.18	0.17	0.05	0.08	0.03	0.01
C.D. (P = 0.05)	0.51	0.32	0.52	0.50	0.15	0.23	0.08	0.04

The pertaining to effect of vermicompost on nutrient content of nitrogen, phosphorus and potassium were obtained significant ($p<0.05$) over control treatment (Table 2). Results showed that the maximum nitrogen (1.572 and 0.535 %), phosphorus (0.328 and 0.220 %) and potassium (0.555 and 1.476 %) content in grain and straw of wheat were achieved under the treatment V_3 (50% VC at sowing + 50% VC at tillering) followed by V_4, V_2 and V_1 which was significantly higher as compared to control as well as basal application (100% VC at sowing), however the treatment V_3 remained at par with V_4 in respect of nitrogen content in straw. With the application of vermicompost nutrient content were increased up to 9.70 and 14.07 % (nitrogen), 15.09 and 15.18 % (phosphorus), 13.03 and 9.01 % (potassium) in grain and straw of wheat due to application of V_3 compared to control (without vermicompost). Experimental results further revealed that among the vermicompost treatments, maximum micronutrients content *viz.* Zn, Fe, Mn and Cu were recorded with V_3 that were (57.98 and 38.28 ppm), (80.90 and 173.72 ppm), (45.88 and 67.97 ppm) and (14.66 and 5.66 ppm) followed by V_4, V_2 and V_1 in both grain and straw of wheat but the difference among other vermicompost treatments recorded significant ($p<0.05$) except V_4 in terms of zinc content in grain, manganese and copper in both grain and straw of wheat (Table 3). Lowest value of micronutrients *viz.* Zn, Fe, Mn and Cu were recorded under control treatment. The percent increments in micronutrient content (Zn, Fe, Mn and Cu) were up to (10.14 and 16.69), (12.02 and 5.34), (12.42 and 6.69) and (24.55 and 30.72) in both grain and straw of wheat due to V_3 treatment, respectively. The positive influence of vermicompost on nutrient content might be due to adequate supply of nutrients in root zone and plant system, increased availability of these nutrients in the root zone coupled with increased metabolic activity at cellular levels have synthesized more nutrients and their accumulation in various plant parts (Hadis *et al.,* 2018). Application of vermicompost improves nitrogen, phosphorus, potassium and micronutrients content in both grain and straw over control in wheat crop (Sheoran *et al.,* 2015).

B. Performance of biofertilizers and vermicompost on economics of wheat

Seed inoculation with microbial inoculants was obtained significantly ($P<0.05$) higher economics of wheat as comparison to control during the both years (Table 4). Among the treatment, treatment B_5 (*Azotobacter*+PSB+KMB+ZnSB) was recorded higher gross return (Rs 94762.6 and 105195.5 ₹/ha, respectively) in the both year over the control and single inoculation. Highest net returns (62362.6 and 72695.5 ₹/ha, respectively) and B:C ratio (1.92 and 2.24, respectively) of wheat were obtained under *Azotobacter* + PSB + KMB + ZnSB and it was significantly ($P<0.05$) higher than B_3 (*Azotobacter* + PSB), B_2 (*Azotobacter*) and B_1 (control) and remained at par with B_4 (*Azotobacter* + PSB + KMB). Seed treatment with efficient strains of microbial inoculants are low cost agricultural inputs, environment friendly that have an key role in improving nutrient provide to crops but also decreased production cost. These results also collaborate with Kumar, (2013).

Data further revealed that application of vermicompost had positive effect on economics of wheat crop (Table 4). Application of treatment V_3 (50% at sowing+50% at tillering) was obtained higher gross return (95218.0 and 105785.1 ₹/ha, respectively) during the both years over control and single inoculation. Maximum net returns (62218.0 and 72685.1₹/ha, respectively) and B:C ratio (1.88 and 2.19, respectively) of wheat were recorded under 50% at sowing+50% at tillering over to control and basal dose of vermicompost and it was significantly higher than V_2 (100% at sowing) and V_1 (control) except V_4 (75% at sowing+25% at tillering). These finding also supported by Verma *et al.,* (2014); Kaushik *et al*. (2012).

Table 4: Effect of microbial inoculants and split application of vermicompost on economics of wheat.

Treatments	Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio	
	2017-2018	2018-2019	2017-2018	2018-2019	2017-2018	2018-2019
Microbial inoculants						
B_1	75149.6	83474.6	43549.6	51774.6	1.37	1.63
B_2	81899.3	90942.8	50099.3	59042.8	1.57	1.85
B_3	89261.9	99136.3	57261.9	67036.3	1.79	2.09
B_4	92936.0	103201.3	60736.0	70901.3	1.88	2.19
B_5	94762.6	105195.5	62362.6	72695.5	1.92	2.24
SEm±	1284.1	1294.4	1284.1	1294.4	0.04	0.04
C.D. (P=0.05)	3676.4	3705.8	3676.4	3705.8	0.11	0.11
Vermicompost						
V_1	75543.3	83926.0	46543.3	54826.0	1.60	1.88
V_2	82527.1	91663.0	49527.1	58563.0	1.50	1.77
V_3	95218.0	105785.1	62218.0	72685.1	1.88	2.19
V_4	93919.1	104186.4	60919.1	71086.4	1.84	2.15
SEm±	1148.6	1157.8	1148.6	1157.8	0.03	0.04
C.D. (P=0.05)	3288.3	3314.6	3288.3	3314.6	0.10	0.10

CONCLUSIONS

It may be concluded that application of microbial inoculants *Azotobacter* + PSB + KMB + ZnSB along with vermicompost as 50 % at sowing + 50 % at tillering find out significance on nutrient content and economics of wheat. From the current study it was obtained that microbial inoculants (*Azotobacter*+PSB+KMB+ZnSB) + two split dose of vermicompost (50 % at sowing+50% at tillering) give the best result.

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Conflict of Interests. None.

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