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Household Waste Based Vermicompost and Fertilizer Effect on Soil Fertility and Functional Indicator Microbes in Pot Culture Rice

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ABSTRACT

Unbalanced use of fertilizers has deteriorated soil health and caused pollution at large scale. The different doses of household waste based vermicompost and fertilizer combination and its effect on soil fertility with microbial diversity analysis as well as its quantification was primary focus of this research with using Completely Randomized Design with two factors. Rice crop in pot culture was taken at experimental station, department of soil science, Dr RPCAU, Pusa in *kharif*, 2018. The higher dose of vermicompost and RDF fertilizer i.e., vermicompost (3.75t ha^{-1}) + 100% Recommended Dose of Fertilizer elevated the higher nutrient content in soil of pot culture with rice crop in pots. The nutrients content increased from tillering to grain filling stage and decreased from that particular stage to post harvest condition in pot culture soil and it might be due to the exhaustion of nutrients by crop plants and higher amount of organic matter present in soil provided the suitable habitat for growth and proliferation of functional indicator microbes i.e., *Azotobacter*, *Azospirillum*, *Bacillus*, *Pseudomonas*, phosphate solubilizing bacteria, starch and cellulose hydrolyzing microbes from initial crop growth to post harvest condition soil in pot culture.

Keywords Rice, Vermicompost, Fertilizer, Nutrients, Functional indicator microbes.

INTRODUCTION

Application of heavy dose of uncontrolled fertilizer and chemicals pollute the soil environment and decrease the crop yield due to different losses of nutrients and its unavailability to the crop plants. Vermicomposting is the process of conversion of waste materials with its breakdown (Alshehrei and Ameen 2021) by earthworms; stimulate microbial activities with elevation of mineralization of nutrients in soil that produces humus like organic substances called vermicompost. Different local varieties of earthworms are used in vermicomposting process (Ansari and Sukhraj 2010). Vermicomposts are the finely divided materials having rich sources of nutrients, high water

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holding capacity, high porosity, free from pathogens related to plants (Dominguez and Edwards 2011, Kumar and Prasad 2020). Vermicompost particles are having increased surface area with rich nutrient concentration that helps in growth and proliferation of microbes in soil and strong adsorption capacity helps in retention of nutrients (Ansari and Ismail 2012).

Integrated application leads to solubilization and mineralization of nutrients in soil and increase its availability to the crop plants. Soil microbial environment is enriched with minimizing soil pollution and ensuring maximum profit to the farmers in terms of yield (Najar and Khan 2013). The soil organic matter act as food source for microbial growth. The soil functional indicator microbes i.e., *Azotobacter*, *Azospirillum*, *Bacillus*, *Pseudomonas*, PSB, Starch and cellulose hydrolyzing microbes show elevated population in response to the combined application of vermicompost, organic materials with fertilizer and an ecofriendly environment is created (Lazcano and Dominguez 2011). This research focuses on reducing and converting waste to vermicompost for soil health and quality enhancement.

MATERIALS AND METHODS

A pot culture experiment was carried out at experimental station, department of soil science, Dr RPCAU, Pusa in *kharif*, 2018 with combination of different levels of vermicompost (0 t ha^{-1}, 1.25 t ha^{-1}, 2.5 t ha^{-1}, 3.7 t ha^{-1}) and RDF fertilizer (0 %, 100 %, 50 % RDF) of twelve treatments in Factorial Completely Randomized Design method and rice variety (*Rajendra Bhagawati*) in pot which are replicated thrice. The treatment details are as follows:

V_0 F_0:- No manure + No Fertilizer-Control
V_0 F_{100}:- No manure + 100% RDF
V_0 F_{50}:- No manure + 50% RDF
$V_{1.25}$ F_0:- Vermicompost (1.25t ha^{-1}) + No Fertilizer
$V_{1.25}$ F_{100}:- Vermicompost (1.25t ha^{-1}) +100% RDF
$V_{1.25}$ F_{50}:-Vermicompost (1.25t ha^{-1}) + 50% RDF
$V_{2.50}$ F_0:-Vermicompost (2.5t ha^{-1}) + No Fertilizer
$V_{2.50}F_{100}$:-Vermicompost (2.5t ha^{-1}) + 100%RDF
$V_{2.50}F_{50}$:-Vermicompost (2.5t ha^{-1}) + 50% RDF
$V_{3.75}F_0$:-Vermicompost (3.75t ha^{-1}) + No Fertilizer
$V_{3.75}F_{100}$:-Vermicompost (3.75t ha^{-1}) + 100%RDF
$V_{3.75}F_{50}$:-Vermicompost (3.75t ha^{-1}) +50% RDF

Available N

The available nitrogen in soil was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1965).

Available P

Soil available phosphorus was determined by using 0.5M $NaHCO^3$ (pH 8.5) solution (Olsen extractant) as suggested by Olsen *et al*. (1965).

Available S

The standard turbid metric method was followed as given by Chesnin and Yien (1951).

Functional indicator microbes

Ten gram of soil sample was taken in 100 ml water in 500ml flask and serial dilution was made up to 10^{-5}. 0.5 ml of sample was taken from 10^{-5} dilution was spread in petri plate along with different media for different microbes studies like *Bacillus*, *Pseudomonas*, *Azotobacter*, *Azospirillum*, PSB, Cellulose hydrolyzing bacteria, starch hydrolyzing microbes as described further by Schmidt and Caldwell (1967).

RESULTS AND DISCUSSION

Available-N (kg ha^{-1})

In the post-harvest soil the elevated level of available-N (Table 1) was found in the treatment receiving vermicompost-3.75 t ha^{-1}+ 100% RDF i.e., 283.33 kg ha^{-1} which was significantly superior over control (no vermicompost + no fertilizer) i.e., 217.00 kg ha^{-1}.

The availability of nitrogen gradually increased from tillering to post-harvest soil might be due to more amount of organic matter influenced the microbial activities around rhizospheric zones and mineralization of nutrients increased the nitrogen content. Similar close findings achieved by Kumar and Singh (2010).

Table 1. Effect of vermicompost and fertilizer on N availability in soil of rice crop during growth periods.

Available –N (kg ha^{-1}) Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	242.67	321.33	279.00	281.00	217.00	238.45	231.02	228.82
$V_{1.25}$	268.00	335.33	284.33	295.89	230.67	241.78	235.11	235.85
$V_{2.5}$	277.67	339.00	297.00	304.56	230.27	267.81	240.33	246.14
$V_{3.75}$	285.33	356.33	320.67	320.78	239.00	283.33	251.29	257.88
Mean	268.42	338.00	295.25		229.23	257.84	239.44	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	8.45		2.88		6.63		2.26	
Fertilizers (F)	7.32		2.49		5.74		1.96	
V X F	NS		4.99		11.49		3.91	

V_o= Vermicompost (no manure), $V_{1.25}$= Vermicompost (1.25 t ha^{-1}), $V_{2.5}$= Vermicompost (2.5 t ha^{-1}), $V_{3.75}$ = Vermicompost (3.75 t ha^{-1}), F_0= Fertilizer (no fertilizer) , F_{100}= Fertilizer (100 % fertilizer), F_{50}= Fertilizer (50 % fertilizer) and V_0F_0 = control (no vermicompost + no fertilizer).

Available-P_2O_5 (kg ha^{-1})

The integrated application of vermicompost (3.75 t ha^{-1}) + 100 % NPK showed higher available phosphorus i.e., 20.97 kg ha^{-1} and 31.96 kg ha^{-1} in soil at tillering and post-harvest, respectively over the control (Table 2). The interactions among the vermicompost and fertilizer levels were found non-significant.

Virdia and Mehta (2010) reported that the application of vermicompost with or without chemical fertilizers increased the available phosphorus content as compared to non vermicompost treatments and this might be due to mineralization of added P and the available P status in post-harvest soils of paddy markedly improved from the initial content. Sharma and Bali (2010) reported that the application of vermicompost along with inorganic P increased the availability of phosphorus.

Available-S (kg ha^{-1})

In post-harvest soil, available-S (Table 3) varied from 4.33 to 9.21 kg ha^{-1} with the application of vermicompost, irrespective of fertilizer application and ranged between 6.74 to 8.50 kg ha^{-1}, irrespective of vermicompost application. The vermicompost level of 2.5 t ha^{-1} gave significantly higher available-S over other vermicompost levels of applications and fertilizer level of 100 % RDF recorded significantly higher available-S over other fertilizer levels of applications. The integrated application of vermicompost (2.5 t ha^{-1}) + 100 % NPK showed higher available-S i.e., 10.65 kg ha^{-1} which was statistically at par with the vermicompost 3.75 t ha^{-1} + 50 % RDF i.e., 10.50 kg ha^{-1}.

Table 2. Effect of vermicompost and fertilizer on P_2O_5 availability in soil of rice crop during growth periods.

Available- P_2O_5 (kg ha^{-1}) Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	15.44	17.31	16.90	16.55	27.86	29.99	27.84	28.56
$V_{1.25}$	16.71	19.89	18.50	18.37	28.52	30.60	30.26	29.80
$V_{2.5}$	17.36	20.60	19.04	19.00	30.13	31.39	30.15	30.58
$V_{3.75}$	18.66	20.97	20.14	19.92	30.36	31.96	30.96	31.09
Mean	17.04	19.69	18.64		29.22	30.99	29.81	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.497		0.169		0.524		0.178	
Fertilizers (F)	0.431		0.147		0.453		0.154	
V X F	NS		0.293		NS		0.309	

Table 3. Effect of vermicompost and fertilizer on S availability in soil of rice crop during growth periods.

Available- S (kg ha^{-1}) Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	8.82	8.90	13.45	10.39	3.72	5.25	4.01	4.33
$V_{1.25}$	26.47	28.87	7.62	20.99	7.26	10.35	8.27	8.63
$V_{2.5}$	18.59	10.03	10.21	12.94	7.80	10.65	9.19	9.21
$V_{3.75}$	11.59	22.02	9.63	14.41	8.17	7.78	10.50	8.80
Mean	16.37	17.46	10.28		6.74	8.50	7.98	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.54		0.15		0.12		0.04	
Fertilizers (F)	0.39		0.13		0.10		0.04	
V X F	0.78		0.27		0.21		0.07	

Bacillus (x 10 ^{7} c.f.u. g^{-1} dry soil)

The Table 4 showed integrated application of vermicompost (3.75 t ha^{-1}) + 100 % NPK showed significant higher amount of *Bacillus* count i.e., 15.77 x 10 ^{7} c.f.u. g^{-1} dry soil in soil 21.46 x 10 ^{7} c.f.u. g^{-1} dry soil at tillering and post-harvest soil, respectively which were both statistically at par with the vermicompost 3.75 t ha^{-1} + 50 % RDF. The higher population of *Bacillus* was due to the availability of organic matter in due course of plant growth in soil and similar close finding were given by Pradhan *et al*. (2016).

Pseudomonas (x 10 ^{7} c.f.u. g^{-1} dry soil)

In post-harvest soil, the *Pseudomonas* count (Table 5) varied with the application of levels of vermicompost from 13.44 to 19.06 x 10 ^{7} c.f.u. g^{-1} dry soils,

Table 4. Effect of vermicompost and fertilizer on *Bacillus* population in soil of rice crop during growth period.

Bacillus (x 10 ^{7} c.f.u. g^{-1} dry soil) Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	8.34	9.46	8.64	8.75	13.11	15.60	13.63	14.11
$V_{1.25}$	10.20	11.78	10.50	10.83	16.52	19.03	16.82	17.45
$V_{2.5}$	9.67	14.76	13.14	12.52	15.31	20.11	17.61	17.68
$V_{3.75}$	10.70	15.77	14.89	13.78	16.32	21.46	20.65	19.48
Mean	9.73	12.94	11.75		15.32	19.04	17.18	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.82		0.28		0.65		0.22	
Fertilizers (F)	0.71		0.24		0.56		0.19	
V X F	1.41		0.48		1.12		0.38	

Table 5. Effect of vermicompost and fertilizer on *Pseudomonas* population in soil of rice crop during growth period.

Pseudomonas (x 10 ^{7} c.f.u. g^{-1} dry soil) Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	8.64	9.76	9.41	9.27	12.53	15.16	12.65	13.44
$V_{1.25}$	10.16	11.52	10.25	10.65	14.66	17.71	16.46	16.28
$V_{2.5}$	10.51	13.15	11.92	11.86	15.27	19.84	17.59	17.57
$V_{3.75}$	12.17	13.60	12.87	12.88	15.82	21.04	20.32	19.06
Mean	10.37	12.01	11.11		14.57	18.44	16.76	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.25		0.09		0.38		0.13	
Fertilizers (F)	0.22		0.07		0.33		0.11	
V X F	0.43		0.15		0.65		0.22	

Table 6. Effect of vermicompost and fertilizer on azotobacter population in soil of rice crop during growth period.

Azotobacter (x 10 ^{7} c.f.u. g^{-1} dry soil) Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	9.40	11.27	9.80	10.16	12.15	15.26	13.07	13.49
$V_{1.25}$	10.54	13.22	11.05	11.60	14.20	17.59	16.22	16.00
$V_{2.5}$	10.32	14.80	11.93	12.35	13.99	18.77	17.01	16.59
$V_{3.75}$	11.79	16.45	15.05	14.43	15.97	19.77	18.57	18.10
Mean	10.51	13.93	11.96		14.08	17.85	16.22	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.28		0.10		0.36		0.12	
Fertilizers (F)	0.24		0.08		0.31		0.11	
V X F	0.48		0.16		0.63		0.21	

irrespective of fertilizer levels and ranged from 14.57 to 18.44 x 10 ^{7} c.f.u. g^{-1} dry soil with respect to the different levels of fertilizer application, irrespective of vermicompost levels. The interactions among vermicompost and fertilizer levels were found significant. The higher level of vermicompost (3.75 t ha^{-1}) + 100 % RDF recorded higher *Pseudomonas* count i.e., 21.04 x 10 ^{7} c.f.u. g^{-1} dry soil over control (12.53 x 10 ^{7} c.f.u. g^{-1} dry soil) and similar close findings were given by Richard and Ogunjobi (2016).

Azotobacter (x 10 ^{7} c.f.u. g^{-1} dry soil)

The integrated application of vermicompost (3.75 t ha^{-1}) + 100 % NPK showed significantly higher azotobacter count i.e., 19.77 x 10 ^{7} c.f.u. g^{-1} dry soil in soil at post-harvest over the control (12.15 x 10 ^{7} c.f.u. g^{-1} dry soil) given in Table 6. The higher microbial activity is due to availability of more organic matter for rapid growth an proliferation of microbes and similar close finding was given by Deubel *et al*. (2002).

Azospirillum (x 10 ^{7} c.f.u. g^{-1} dry soil)

The integrated application of vermicompost (3.75 t ha^{-1}) + 100 % NPK showed significant higher amount of *Azospirillum* count (Table 7) i.e., 16.50 x 10 ^{7} c.f.u. g^{-1} dry soil in soil and 15.72 x 10 ^{7} c.f.u. g^{-1} dry soil at tillering and post-harvest soil, respectively which were both superior over controls.

Phosphate solubilizing bacteria (x 10 ^{7} c.f.u. g^{-1} dry soil)

The integrated application of vermicompost (3.75 t ha^{-1}) + 100 % NPK showed higher phosphate solubilizing bacteria count i.e., 20.58 x 10 ^{7} c.f.u. g^{-1} dry soil in soil at post-harvest over the control (13.14 x 10 ^{7} c.f.u. g^{-1} dry soil) given in Table 8.

Starch hydrolyzing microbes (x 10 ^{7} c.f.u. g^{-1} dry soil)

The integrated application of vermicompost (3.75 t

Table 7. Effect of vermicompost and fertilizer on *Azospirillum* population in soil of rice crop during growth period.

Azospirillum (x 10 ^{7} c.f.u. g^{-1} dry soil) Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	7.97	10.93	8.64	9.18	9.46	11.09	10.21	10.25
$V_{1.25}$	9.70	13.91	12.33	11.98	12.59	13.35	12.62	12.85
$V_{2.5}$	10.96	15.20	13.49	13.22	12.26	14.56	13.65	13.49
$V_{3.75}$	12.10	16.50	15.06	14.55	12.80	15.72	14.86	14.46
Mean	10.18	14.14	12.38		11.78	13.68	12.84	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.28		0.10		0.29		0.10	
Fertilizers (F)	0.24		0.08		0.29		0.08	
V X F	0.49		0.17		0.50		0.17	

Table 8. Effect of vermicompost and fertilizer on phosphate solubilizing bacteria population in soil of rice crop during growth period.

Phosphate solubilizing bacteria (x 10 ^{7} c.f.u. g^{-1} dry soil)								
Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	12.30	14.34	13.62	13.42	13.14	15.78	13.50	14.14
$V_{1.25}$	14.22	16.38	15.30	15.30	15.42	18.12	16.68	16.74
$V_{2.5}$	14.94	17.10	16.08	16.04	15.54	19.26	17.82	17.54
$V_{3.75}$	15.48	18.90	17.04	17.14	16.56	20.58	19.86	19.00
Mean	14.24	16.68	15.51		15.17	18.44	16.97	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.59		0.20		1.13		0.39	
Fertilizers(F)	0.51		0.17		0.98		0.34	
V X F	NS		0.35		NS		0.68	

ha^{-1}) + 100 % NPK showed significant higher amount of starch hydrolyzing microbes i.e. 17.30 x 10 ^{7} c.f.u. g^{-1} dry soil and 17.46 x 10 ^{7} c.f.u. g^{-1} dry soil in soil at tillering and post-harvest soil, respectively where both were significantly superior over controls as in Table 9 and similar close findings were given by Kumar *et al*. (2012).

Cellulose hydrolyzing bacteria (x 10 ^{7} c.f.u. g^{-1} dry soil)

The interactions (Table 10) among vermicompost and fertilizer levels were found significant. The higher level of vermicompost (3.75 t ha^{-1}) + 100 % RDF recorded significantly higher cellulose hydro-

Table 9. Effect of vermicompost and fertilizer on starch hydrolyzing microbes in soil of rice crop during growth period.

Starch hydrolyzing microbes (x 10 ^{7} c.f.u. g^{-1} dry soil)								
Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	8.07	10.47	8.57	9.04	11.06	13.52	11.62	12.07
$V_{1.25}$	9.80	14.23	12.41	12.15	12.79	15.03	14.36	14.06
$V_{2.5}$	12.00	16.21	13.58	13.93	13.56	16.24	15.10	14.97
$V_{3.75}$	13.03	17.30	15.53	15.29	14.33	17.46	15.84	15.88
Mean	10.73	14.56	12.52		12.94	15.56	14.23	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.29		0.10		0.32		0.11	
Fertilizers (F)	0.25		0.09		0.28		0.10	
V X F	0.50		0.17		0.56		0.19	

Table 10. Effect of vermicompost and fertilizer on cellulose hydrolyzing bacteria population in soil of rice crop during growth period.

Cellulose hydrolyzing bacteria (x 10 7 c.f.u. g^{-1} dry soil)								
Treatments	Tillering stage				Post-harvest stage			
	F_0	F_{100}	F_{50}	Mean	F_0	F_{100}	F_{50}	Mean
V_0	8.97	11.29	9.71	9.99	8.60	11.63	9.54	9.92
$V_{1.25}$	10.43	14.33	13.30	12.66	10.74	13.45	12.62	12.27
$V_{2.5}$	11.96	15.88	14.23	14.02	11.87	15.66	14.02	13.85
$V_{3.75}$	13.33	18.82	15.95	15.70	13.95	16.66	15.88	15.50
Mean	11.17	14.81	13.30		11.29	14.35	13.01	
Factors	CD (5%)		SEm(±)		CD (5%)		SEm(±)	
Vermicompost (V)	0.30		0.10		0.29		0.10	
Fertilizers (F)	0.26		0.09		0.25		0.09	
V X F	0.52		0.18		0.51		0.17	

V_o= Vermicompost (no manure), $V_{1.25}$= Vermicompost (1.25 t ha^{-1}), $V_{2.5}$= Vermicompost (2.5 t ha^{-1}), $V_{3.75}$ = Vermicompost (3.75 t ha^{-1}), F_0= Fertilizer (no fertilizer) , F_{100}= Fertilizer (100% RDF), F_{50}= Fertilizer (50 % RDF) and V_0F_0 = control (no vermicompost + no fertilizer).

lyzing bacteria count i.e., 16.66 x 10^7 c.f.u. g^{-1} dry soil over control (8.60 x 10^7 c.f.u. g^{-1} dry soil) and similar finding supported by Lakshmi *et al*. (2014) as higher amount of organic substrate availability favored higher growth.

CONCLUSION

The application of vermicompost enriched with nutrients improves the soil health and soil properties. Vermicompost when applied with fertilizer elevate the nutrient content in soil due to mineralization and solubilization of nutrients in soil. Higher amount of organic matter addition in soil elevates the soil fertility status and provide substrate for microbial growth and proliferation. The higher amount of vermicompost and fertilizer RDF i.e., 3.75 t ha^{-1} with 100 % RDF provided better nutrient concentration to the soil and also supported enhanced microbial population in soil, thus soil health improved with higher crop yield.

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