Indian Journal of Agricultural Sciences **91** (11): 1670–4, November 2021/Article
https://doi.org/10.56093/ijas.v91i11.118582

Soil biological properties as influenced by organic nutrient management in soybean (*Glycine max*)

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Received: 02 March 2021; Accepted: 08 April 2021

ABSTRACT

The present investigation was carried out to study the soil microbial dynamics and enzyme activities as influenced by organic nutrients management in soybean [*Glycine max* (L.) Merr.] under Typic Haplustepts soil of Rajasthan. The experiment comprised 12 treatment combinations of organic source of nutrients, i. e. control (T_1), 100% RDF (T_2), 100% FYM (T_3), 100% vermicompost (T_4), 100% compost (T_5), 100% green-leaf manure (T_6), 50% FYM + 50% vermicompost (T_7), 50% FYM + 50% compost (T_8), 50% FYM + 50% green-leaf manure (T_9), 50% vermicompost + 50% compost (T_{10}), 50% vermicompost + 50% green leaf manure (T_{11}) and 50% compost + 50% green-leaf manure (T_{12}). The experiment was laid out in a randomized block design with four replications. The soil microbial population (bacterial, fungal, actinomycetes) at 30 DAS, 60 DAS, dehydrogenase activity and alkaline phosphatase activity of soil significantly influenced due to organic nutrient fertilization, viz. 100% vermicompost treatment (T_4) in pooled analysis. However, the application of 100% vermicompost (T_4) on bacterial population, fungal population, actinomycetes population of soil at 30 DAS and 60 DAS was found statistically at par with the application of 50% FYM + 50% vermicompost (T_7), 50% FYM + 50% compost (T_8), 50% vermicompost + 50% compost (T_{10}) and 50% vermicompost + 50% green-leaf manure (T_{11}) in pooled analysis.

Keywords: Microbial properties, Organic fractions, Organic sources, Soybean

Soybean [*Glycine max* (L.) Merr.] is the most important oilseed and grain legume crop in the world in terms of its use in human foods and livestock feeds. In India it is cultivated in 11.39 million ha with the production of 13.51 million tonnes having the productivity of 1185 kg/ha. In Rajasthan, it is cultivated in 10.60 lakh ha with the production of 66.85 metric tonnes having the productivity of 1150 kg/ha (Anonymous 2019). Chemical fertilizers play an important role to meet nutrient requirement of the crop but their continuous use on lands will have deleterious effects on physical, chemical and biological properties of soil, which in turn reflects on yield (Sarkar *et al*. 1997). Judicious application of nutrient especially organic manures not only improves the crop productivity but also maintain soil health (Tiwari *et al*. 2002). Soil-organic matter is the single most important constituent that influences the soil fertility, soil formation, soil biology, physical and chemical properties of soil which in turn reflects in to crop yield (Walker *et al*. 2004). High content of soil organic matter (SOM) can increase supply of nutrients and improve physical and biological characteristics of soil (Guo *et al*. 2012), therefore maintaining soil organic matter is important for preserving the productivity of agro-ecosystems.

Various microbial communities are responsible for specific functions in decomposition of organic mass. Bacteria dominate in initial phases of decomposition of plant residues, whereas fungi prevail in later phases (Marscner *et al*. 2011). Saprophytic fungi are an important source of soil oxidation enzymes (Cusack *et al*. 2011). Soil extra cellular enzymes are synthesized and secreted by soil microorganisms, and they are agents for creation and decomposition of organic material (Burns *et al*. 2013). Soil enzymes are dominantly hydrolases, which help to acquire carbon, nitrogen, and phosphorus for support of primary metabolism; or oxido-reductases, which contribute to decomposition of organic compounds (Tiemann and Billings 2011). Measured activities of such enzymes reflect the intensity and direction of various biochemical processes in soil environment and can be used for evaluation of microbial demands for nutrients and for expressing the response of ecosystem, which reflects changes in the environment as such (Wang *et al*. 2015).

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Keeping in view the key role played by organic source of nutrients in biological and chemical properties of soil, the present investigation was carried out in Typic Haplustepts soil of Rajasthan to study the effect of organic sources of nutrients on microbial properties, enzyme activities and organic fractions of soil in soybean.

MATERIALS AND METHODS

Experimental site and soil: The two-year field experiment was conducted during *kharif* season of the year 2016–17 and 2017–18 at Instructional farm (Agronomy), Rajasthan College of Agriculture, Udaipur situated under Sub-humid Southern Plain and Aravalli Hill zone of Rajasthan. The average maximum and minimum temperatures during rainy season (July–October) ranged between 15.7–35.3^oC and 16.6–35.9^oC and the average annual rainfall is 552 and 440 mm received during the crop growing period in 2016-17 and 2017-18, respectively. Soil is clay loam in texture, alkaline in *p*H (8.23±0.16), electrical conductivity is normal (0.81±0.06 dS/m), medium in organic carbon (0.59±0.05%), low in available N (254.25±5.11 kg/ha), available P_2O_5 (12.84±0.85 kg/ha), available Fe (2.46±0.05 mg/kg), available Mn ((9.49±0.05 mg/kg), available Cu (1.67±0.03 mg/kg), high in available K_2O (450.43±6.41 kg/ha) and available zinc (2.14±0.035 mg/kg).

Experimental design and treatments: The experiment was laid out in randomized block design replicated four times in the plot size of 4.0 m × 3.6 m (14.4 m^2) with 12 treatment combinations of organic source of nutrients, i.e. control (T_1), 100% RDF (T_2), 100% FYM (T_3), 100% vermicompost (T_4), 100% compost (T_5), 100% green-leaf manure (T_6), 50% FYM + 50% vermicompost (T_7), 50% FYM + 50% compost (T_8), 50% FYM + 50% green-leaf manure (T_9), 50% vermicompost + 50% compost (T_{10}), 50% vermicompost + 50% green-leaf manure (T_{11}) and 50% compost + 50% green-leaf manure (T_{12}). The soybean var. JS 9560 was sown in lines 30 cm apart.

Application of organic and inorganic fertilizers: The application of organic manures, i.e. FYM, vermicompost, green-leaf manure and compost were thoroughly mixed and applied as per allocation of treatments in plots before 15 days prior to soybean sowing. The nitrogen @ 20 kg/ha was applied in two equal splits, the half dose of nitrogen as basal and the remaining half dose of nitrogen was top dressed at the time of first irrigation. The basal dose was applied through urea after adjusting the quantity supplied through diammonium phosphate (DAP). The phosphorus @40 kg/ha through DAP was applied as basal and drilled at the depth of 8–10 cm along basal dose of N prior to sowing.

Soil sampling, processing and analysis: The soil samples were collected at the harvest of crop from 0-15 cm depth at three randomly selected spots in each replication and composite samples were prepared. The soil was gently ground, well mixed and sieved through 2-mm mesh and utilized for laboratory analysis for chemical and biological properties. The field moist soil samples were collected for microbial dynamics, enzyme activities and organic fractions in soil and stored at 4°C. In the soil material, soil microbial populations were determined by standard serial dilution and plate-count method (Vance *et al.* 1987). Dehydrogenase activity was analyzed by anthrone extraction method (Cassida *et al*. 1964) and activity of alkaline phosphatase was determined by P-nitro phenol estimation method (Tabatabai and Bremner 1969).

Statistical analysis: The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique for a randomized block design. The results are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Soil microbial population at 30 DAS: The application of organic source of nutrients significantly influenced soil microbial population (Bacterial, fungal and actinomycetes) in soil at 30 DAS during both the years of experiment and in pooled analysis.The maximum bacterial population (65.25×10^7 cfu/g soil), fungal population (25.94 ×10^5 cfu/g soil) and actinomycetes population (27.91 × 10^6 cfu/g soil) in soil at 30 DAS was found under the application of 100% vermicompost (T_4) in pooled analysis (Table 1). However, the application of 100% vermicompost (T_4) on bacterial population in soil at 30 DAS was found statistically at par with the application of 50% FYM + 50% vermicompost (T_7), 50% FYM + 50% compost (T_8), 50% vermicompost + 50% compost (T_{10}) and 50% vermicompost + 50% green-leaf manure (T_{11}) in pooled analysis (Table 1). In case of actinomycetes population however, treatment T_4 (100% vermicompost) was found statistically at par with T_{10} (50% vermicompost + 50% compost) in pooled analysis. The data further revealed that the per cent increase in bacterial population; fungal population and actinomycetes population in soil were in order of 3.91, 21.91 and 22.03 in pooled analysis due to application of 100% vermicompost (T_4) as compared to control (T_1), respectively. It might be due to the supply of additional mineralizable and readily hydrolysable C due to organic manure application resulted in higher microbial activity and in return higher microbial biomass carbon. The addition of animal or green manures on organic farms provided a significantly greater input of organic carbon, which increased bacterial populations (Fraser *et al*. 1994).

Soil microbial population at 60 DAS: Results from the pooled data basis of two-year study indicated that the application of organic source of nutrients significantly increased the soil microbial population (Bacterial, fungal and actinomycetes) in soil at 60 DAS during both the years as well as in pooled analysis. The maximum bacterial population (55.71×10^7cfu/g soil), fungal population (22.30 × 10^5 cfu/g soil) and actinomycetes population (23.97 × 10^6 cfu/g soil) in soil at 60 DAS was found under the application of 100% vermicompost (T_4) in pooled analysis (Table 1). However, the application of 100% vermicompost (T_4) on bacterial population in soil at 60 DAS was found statistically at par with the application of 50% FYM + 50%

Table 1 Effect of organic sources of nutrients on soil microbial population at 30 DAS and 60 DAS

Treatment	Bacteria (No. × 10^7 cfu/g soil)			Fungi (No. × 10^5 cfu/g soil)			Actinomycetes (No. × 10^6 cfu/g soil)			Bacteria (No. × 10^7 cfu/g soil)			Fungi (No. × 10^5 cfu/g soil)			Actinomycetes (No. × 10^6 cfu/g soil)		
	30 DAS									60 DAS								
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Control (T_1)	62.70	63.12	62.91	21.18	21.16	21.17	22.75	22.98	22.87	53.22	53.69	53.46	18.25	18.29	18.27	19.77	19.75	19.76
100% RDF (T_2)	62.94	63.02	62.98	21.34	21.38	21.36	23.18	23.20	23.19	53.75	53.81	53.78	18.39	18.42	18.41	19.95	19.97	19.96
100% FYM (T_3)	63.28	63.36	63.32	21.56	21.60	21.58	23.89	23.91	23.90	54.04	54.10	54.07	18.58	18.61	18.60	20.56	20.57	20.57
100% vermicompost (T_4)	65.21	65.29	65.25	25.92	25.96	25.94	27.90	27.92	27.91	55.68	55.74	55.71	22.28	22.32	22.30	23.96	23.98	23.97
100% compost (T_5)	63.46	63.52	63.49	21.45	21.49	21.47	24.30	24.32	24.31	54.18	54.25	54.22	18.48	18.52	18.50	20.91	20.92	20.92
100% green-leaf manure (T_6)	63.17	63.25	63.21	21.38	21.42	21.40	23.58	23.60	23.59	53.94	54.00	53.97	18.42	18.46	18.44	20.29	20.31	20.30
50% FYM + 50% vermicompost (T_7)	64.98	65.07	65.02	23.70	23.49	23.60	26.60	26.62	26.61	55.49	55.55	55.52	20.18	20.22	20.20	22.86	22.88	22.87
50% FYM + 50% compost (T_8)	64.90	64.98	64.94	23.06	22.72	22.89	25.47	25.49	25.48	55.42	55.48	55.45	19.53	19.56	19.55	21.90	21.92	21.91
50% FYM + 50% green-leaf manure (T_9)	64.08	64.16	64.12	22.10	21.98	22.04	24.76	24.78	24.77	54.73	54.78	54.76	18.90	18.93	18.92	21.30	21.31	21.31
50% vermicompost + 50% compost (T_{10})	65.10	65.18	65.14	24.77	24.62	24.70	27.18	27.20	27.19	55.60	55.65	55.63	21.14	21.18	21.16	23.35	23.37	23.36
50% vermicompost + 50% green-leaf manure (T_{11})	64.96	65.04	65.00	23.07	23.00	23.04	25.70	25.72	25.71	55.47	55.53	55.50	19.77	19.80	19.79	22.10	22.11	22.11
50% compost + 50% green-leaf manure (T_{12})	64.20	64.28	64.24	22.83	22.50	22.67	25.09	25.12	25.11	54.82	54.89	41.14	19.34	19.37	14.52	21.59	21.60	16.20
SEm±	0.532	0.219	0.288	0.495	0.333	0.298	0.480	0.564	0.370	0.337	0.501	0.302	0.373	0.329	0.249	0.398	0.414	0.287
CD (P=0.05)	1.560	0.643	0.820	1.453	0.976	0.850	1.409	1.654	1.056	0.988	1.469	0.860	1.094	0.966	0.709	1.167	1.213	0.818

Table 2 Effect of organic sources of nutrients on enzyme activities

Treatment	Dehydrogenase activity (μg TPF/g soil/ha)			Alkaline phosphatase activity (μg PNP/g soil/ha)		
	2016	2017	Pooled	2016	2017	Pooled
Control (T_1)	8.90	9.12	9.01	9.14	9.18	9.16
100% RDF (T_2)	9.40	9.49	9.45	9.47	9.53	9.50
100% FYM (T_3)	9.76	9.87	9.81	9.83	9.89	9.86
100% vermicompost (T_4)	12.40	12.52	12.46	12.49	12.57	12.53
100% compost (T_5)	9.96	10.06	10.01	10.03	10.09	10.06
100% green-leaf manure (T_6)	9.66	9.76	9.71	9.80	9.79	9.79
50% FYM + 50% vermicompost (T_7)	11.48	11.59	11.54	11.75	11.63	11.69
50% FYM + 50% compost (T_8)	10.95	11.06	11.00	11.21	11.10	11.16
50% FYM + 50% green-leaf manure (T_9)	10.15	10.25	10.20	10.27	10.29	10.28
50% vermicompost + 50% compost (T_{10})	11.85	11.97	11.91	12.06	12.01	12.03
50% vermicompost + 50% green-leaf manure (T_{11})	11.17	11.28	11.22	11.34	11.32	11.33
50% compost + 50% green-leaf manure (T_{12})	10.78	10.91	10.84	10.86	10.93	10.90
SEm±	0.193	0.211	0.143	0.174	0.190	0.129
CD (P=0.05)	0.565	0.619	0.407	0.511	0.559	0.368

vermicompost (T_7), 50% FYM + 50% compost (T_8), 50% vermicompost + 50% compost (T_{10}) and 50% vermicompost + 50% green-leaf manure (T_{11}) in pooled analysis (Table 1). In case of actinomycetes population however, treatment T_4 (100% vermicompost) was found statistically at par with T_{10} (50% vermicompost + 50% compost) in pooled analysis.The data further revealed that the per cent increase in bacterial population; fungal population and actinomycetes population in soil were in order of 4.20, 22.05 and 21.31 in pooled analysis due to application of 100% vermicompost (T_4) as compared to control (T_1), respectively.The increased microbial population may be due to the fact that organic manure provided necessary food and micro environment for their quicker multiplication and growth (Kumari and Kumari 2002). Soil enzymatic activities increased as the soil microbes degrade organic matter through the production of diverse extracellular enzymes, after the application of vermicompost to soils (Tejada and Gonzalez 2008). This may be attributed to higher amount of growth promoting substances, vitamins and enzymes which in turn increased the microbial population and root-biomass production. Ingle *et al*. (2014) also reported an increase in fungal population with addition of organics since most of these organisms are chemoheterotrophs, which require organic source of carbon as food and oxidation of organic substances provides energy, thereby increasing their population.

Enzyme activities: The application of organic source of nutrients significantly influenced dehydrogenase and alkaline phosphatase activity of soil after harvest of crop during both the years of experiment and in pooled analysis. The maximum dehydrogenase activity (12.46 μg TPF/g soil/ha) and alkaline phosphatase activity (12.53 μg PNP/g soil/ha) in soil after harvest of crop was found under the application of 100% vermicompost (T_4) followed by 50% FYM + 50% vermicompost (T_7) and 50% vermicompost + 50% green-leaf manure (T_{11}) treatments as compared to control (T_1) in pooled analysis, respectively (Table 2). The data further revealed that the per cent increase in dehydrogenase activity and alkaline phosphatase activity in soil were in order of 38.29 and 36.79 in pooled analysis due to application of 100% vermicompost (T_4) as compared to control (T_1), respectively. This might be due to higher organic manure application which would have favoured more microbial populations ultimately more enzyme activity. In addition to soil microorganisms, soil microflora, plants roots and plan residues undergoing varying degree of decay also contribute to this pool. Soil enzyme originate from soil microorganisms (Briggs and Spedding 1963) and soil enzyme help soil organisms in their efforts to satisfy their nutritional needs and in their function of degrading and humifying added organic material, mainly originating from plant polymers present in soil (Kiss *et al*. 1986). The enzyme activities in the soil are closely related to organic matter content and greater activities of dehydrogenase, in this treatment may also be due to enhanced microbial activity. Application of balanced amount of nutrients and manure improve the microbial biomass carbon status of soil which corresponds to higher enzyme activity (Mandal *et al*. 2007). Increase in dehydrogenase activity has also been observed by Moharana *et al*. (2014), with the addition of organic manures.

Based on the present study it can be concluded that the use of organic manures was significantly improve the soil health. Application of 100% vermicompost showed highest microbial population, dehydrogenase activity and phosphatase activity in soil. Therefore, organic nutrient sources play a key role in sustainable agriculture by increasing the microbial activity in soil which may favourable to sustain soil productivity and maintain soil health.

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