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Changes in Soil Enzymes and Nutrients under Organically Grown Rainfed Pearl Millet in Vertisol

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Abstract **– Field experiment during *Kharif* 2011was laid out with eight treatments replicated thrice in Randomized Block Design. Treatments comprising of absolute control, 2.5, 5.0 and 7.5 ton FYM ha^{-1}, 1.0, 2.0 and 3.0 ton Vermicompost ha^{-1}, and combination of 2.5 ton FYM ha^{-1} + 1.0 ton Vermicompost ha^{-1}. Soil chemical analysis was carried out at sowing, 45 days after sowing and at harvest of crop. While, soil enzymes were estimated at sowing and 45 DAS of crop. Application of organic manures significantly enhanced the microbial activities over control. The highest dehydrogenase activity (97.26 µg TPF g^{-1} soil 24 hr^{-1}) and alkaline phosphatase activity (137.43 µg P –Nitrophenol g^{-1} soil 24 hr^{-1}) were recorded in the treatment receiving 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} followed by application of 7.5 ton FYM ha^{-1} and 3.0 ton vermicompost ha^{-1}. The maximum urease activity (0.358 NH_4 -N released g^{-1} soil 24 hr^{-1}) was noted under the treatment 7.5 ton FYM ha^{-1} followed by the treatment 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1}. Increasing levels of both the manures increases the enzyme activities. However, there was less activities of these enzymes at sowing stage and further increased at 45 days after sowing. The organic carbon content and available nutrients (N, P and K) in soil were found significantly highest in the treatment receiving 7.5 ton FYM ha^{-1} followed by the application of 2.5 ton FYM ha^{-1} + 1.0 ton Vermicompost ha^{-1}. The soil fertility in terms of nutrient availability was significantly improved with the addition of organic manures over control. The soil enzymes showed positive and significant relationship with organic carbon and available nutrients.**

Keywords **– Available Nutrients, Organic Farming, Pearl Millet, Soil Enzymes.**

I. Introduction

The food grain production is decreasing day by day due to deterioration of soil health and imbalanced use of nutrients particularly secondary and micronutrients. Under such situation scientific management of land for soil fertility through organic recycling has to play key role in achieving sustainability in agriculture production [10]. The management of nutrients to maintain productivity and quality in organic farming systems is a challenge that must be met through a combination of organic amendments and management of soil organic matter. A major agriculture research priority is to sustain soil productivity and to develop better methods to monitor changes in soil physical, chemical and biological properties as influenced by the management practices. The living soil is central part of soil fertility because the activity of soil organisms rendered available the element in plant residues and organic debris entering in soil. The productivity and stability of soil as a medium for plant growth depends greatly on the balance between living and non living microorganisms. The maintenance of soil organic matter is the problem in tropical countries like India, hence, the application of organic residues is essential for the maintenance of fertility level. The production and turnover of the microbes is pivoted to our understanding of nutrients recycling. This prospectus for improved management of enzymes activities and microbial population there by improved nutrient turnover, will lead to more cost effective efficient agriculture which is more organically oriented. Soil enzymes help soil organisms in their effort to satisfy their nutritional need. Soil enzymes are participatory in and assuring the correct sequence of all biochemical cycle. Hence, it is pertinent to study the activity of soil enzyme. Soil enzymes activity may provide useful index of changes in soil quality. Dehydrogenase enzyme system has significant role in oxidation of organic matter as they transfer hydrogen from substrate to acceptors. Biological oxidation of organic compounds is generally dehydrogenase process. Urease responsible for hydrolyzed urea to ammonium carbonate in most soil and also involved in estimation of urea hydrolysis in soil. Considering the paramount importance of soil biological fertility, the present investigation was carried out with an objective to know the enzyme activities and nutrient dynamics under organic farming.

II. Materials and Methods

A field experiment was conducted at pearl millet Research Farm, College of Agriculture, Dhule, Maharashtra State during *Kharif* 2011 was laid out with eight treatments replicated thrice in Randomized Block Design using pearl millet variety GHB-558 with spacing 45 x 15 cm. Treatments were as follows, T_1-Control, T_2-2.5 ton FYM ha^{-1}, T_3-5.0 ton FYM ha^{-1}, T_4-7.5 ton FYM ha^{-1}, T_5-1.0 ton Vermicompost ha^{-1}, T_6-2.0 ton Vermicompost ha^{-1}, T_7-3.0 ton Vermicompost ha^{-1}, and T_8-2.5 ton FYM ha^{-1} + 1.0 ton Vermicompost ha^{-1}. The sowing was done by dibbling method. The required cultural practices (thinning and weeding) were done at proper time. As this was organic farming experiment, no pesticides and insecticides were used throughout the crop growth.

Experimental soil was initially analyzed for its initial properties (Table I). For this investigation, the farm yard manure and vermicompost were used as organic manures. They were analyzed for chemical and biological properties (Table II). The organic manures viz., FYM and vermicompost were applied in field as per the treatments before ten days of sowing of crop. The respective doses of manures were applied as per treatments. For estimation of soil enzymes, the soil sampling was done at sowing and 45 days after sowing (DAS) of pearl millet. While, for organic carbon and available N, P and K, the soil samples were collected at sowing, 45 DAS and at harvest of crop.

Physical and chemical properties of soil like mechanical analysis [1] and field capacity [5], soil pH, EC, organic C, available N [14], Olsen's P and available K (NH_4OAc-extractable) were analyzed following the procedure described by Jackson [3]. Dehydrogenase activity was assessed following the method of Casida *et al.* [2]. Alkaline phosphatase activity and urease activities were analyzed following the method of Tabatabai and Bremmer [14].

The experimental data of soil were statistically analyzed to draw conclusion of significance by using the methods prescribed by Panse and Sukhatme [8]. The simple correlation of soil properties and soil enzymes were worked out for the effects which were significant.

III. Results and Discussion

The experimental soil was clay in texture with field capacity 52.13%, pH 7.8, EC 0.34 dSm^{-1} , organic carbon 6.1 g kg^{-1}, available N 186.12 kg ha^{-1}, P 16.90 kg ha^{-1} and K 352.46 kg ha^{-1} (Table I).

The locally available organic manures such as FYM and vermicompost were analyzed for the evaluation of the manurial value. The data regarding chemical and biological composition of organic manures are given in table II. The nitrogen, phosphorus, potassium and organic carbon content were highest in vermicompost. The fungal and bacterial counts were highest in FYM while higher actinomycetes count was recorded in vermicompost.

Soil enzyme activities as influenced by graded levels of organic manures

The data pertaining to the dehydrogenase, alkaline phosphatase and urease activities influenced by organic manuring are presented in table III. Result pertaining to the dehydrogenase activity revealed that the content was ranged between 52.06 to 97.26 µg TPF g^{-1} soil 24 hr^{-1}. Result indicated the enhancement in dehydrogenase activity due to addition of organic manures. Significant differences were obtained in various treatments of organic manures under this study. At sowing stage, significantly highest (87.90 µg TPF g^{-1} soil 24 hr^{-1}) dehydrogenase activity was recorded in treatment (T_8) 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} followed by the treatment (T_4) 7.5 ton FYM ha^{-1} (76.16 µg TPF g^{-1} soil 24 hr^{-1}) and (T_7) 3.0 ton vermicompost ha^{-1} (72.10 µg TPF g^{-1} soil 24 hr^{-1}). The lowest dehydrogenase activity observed in treatment T_1 (control). An increased level of organic manures also increases the activity of this enzyme. Although, at 45 DAS, the higher activity of this enzyme (97.26 µg TPF g^{-1} soil 24 hr^{-1}) was recorded with the combine application of 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} followed by the treatment (T_4) 7.5 ton FYM ha^{-1} (91.43 µg TPF g^{-1} soil 24 hr^{-1}). Similar results were also reported by Masciandaro *et al.* [7] who have studied dehydrogenase activity under the influence of organic matter and reported an increase due to organic matter amendment. Although, there was a less activity of dehydrogenase enzyme at sowing stage when compared with advanced stage of crop growth.

Urease activity in present study varied from 0.091 to 0.382 mg NH_4-N released g^{-1} soil 24 hr^{-1}. Among the two stages, less activity of this enzyme was noticed at sowing as compared with advanced stage of crop. However, the highest urease activity (0.273 mg NH_4-N released g^{-1} soil 24 hr^{-1}) was observed in treatment T_4 i.e. application of 7.5 ton FYM ha^{-1} followed by T_8 (2.5 ton FYM ha^{-1} + 1.0 ton Vermicompost ha^{-1}) and T_3 (5.0 ton FYM ha^{-1}) at sowing. Increasing levels of organic manures significantly increases the urease activity over control. While, at 45 DAS, the maximum activity of this enzyme (0.382 mg NH_4-N released g^{-1} soil 24 hr^{-1}) was recorded in treatment 7.5 ton FYM ha^{-1} followed by the treatment (T_8) 2.5 ton FYM ha^{-1} + 1.0 ton Vermicompost ha^{-1} (0.358 mg NH_4-N released g^{-1} soil 24 hr^{-1}). Urease is more specific enzyme involved in the hydrolysis of urea to ammonium carbonate. This enzyme is produced by both microorganisms and plant roots and help in transformation of urea N into NH_4 form and this was the reason of high activity of this enzyme at 45 days after sowing of pearl millet crop. In general, increase in microbial growth and enzyme activities with the addition of carbon substrate was noticed by Manna *et al.* [6].

The alkaline phosphatase activity varied between 60.00 to 137.43 µg P –Nitrophenol g^{-1} soil 24 hr^{-1}. At sowing of crop, treatment receiving 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} showed the highest alkaline phosphatase activity (122.13 µg P –Nitrophenol g^{-1} soil 24 hr^{-1}) followed by the application 7.5 ton FYM ha^{-1} (116.20 µg P –Nitrophenol g^{-1} soil 24 hr^{-1}). With the increasing amount of organic manure application, the alkaline phosphatase activity was improved. All these organically manured treatments showed significant higher activity of this enzyme over absolute control. Further, it was observed that the alkaline phosphatase activity was found to be increased at 45 days after sowing as compared to at sowing stage and the maximum activity (137.43 µg P –Nitrophenol g^{-1} soil 24 hr^{-1}) was recorded with 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} followed by the treatment 7.5 ton FYM ha^{-1} (120.86 µg P –Nitrophenol g^{-1} soil 24 hr^{-1}). This kind of trend of activation of enzyme activities viz., dehydrogenase , urease, and alkaline phosphatase was due to addition of organic sources acting as the sole source of carbon and energy for the heterotrophs was also reported by Qureshi *et al.* [11]. The applied organic sources were able to get mineralized rapidly in early days, hence, there was more mineralization than immobilization which consequently provided sufficient nutrition for the proliferation of microbes and their activities in terms of soil enzymes. Since, the mineralized nutrients were highly available up to 60 days, therefore rapid increase in microbial activity was observed during this period [12].

Organic C, N, P and K

The changes in soil fertility in terms of organic carbon, available N, P and K due to addition of graded levels of organic manures were recorded at sowing, 45 days after sowing and at harvest of pearl millet (table IV). The maximum content of organic carbon (7.1 g kg^{-1}), available N (297.30 kg ha^{-1}), available P (23.71 kg ha^{-1}) and available K (596.14 kg ha^{-1}) were recorded in the treatment receiving 7.5 ton FYM ha^{-1} at 45 DAS followed by the application of 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1}. Although, it was noticed that increasing levels of both the organic manures significantly increased the nutrients availability in soil over control. Further, it was observed that the content of organic carbon and available N, P, K were increased with crop growth and gradually declined at harvest of crop indicating the higher turnover at 45 days after sowing. Similar findings were recoded by Patil and Varade [9]. In context with ongoing results, it is clear that the addition of organic manures significantly increases the microbial population their activity and thereby increasing the availability of nutrients.

Correlation

The urease (0.900**), alkaline phosphatase (0.900**) and dehydrogenase (0.921**) enzymes were found to be positive and significantly related with organic carbon content in soil (table V). The soil organic carbon had a highest influence on soil enzyme activities was reported by Klaus [4]. The significant relationship of these enzymes with available N, P and K was founds under organically grown pearl millet. The positive correlation of enzyme activities with organic carbon and available N, P and K indicate that these activities are primarily associated with soil nutrients. The results are in consonance with that of Srinivas and Raman [13].

IV. Conclusion

The application of organic sources of nutrients was found to be favourable for enzyme activities in this experiment. Application of 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} was found to be highly effective for achieving more dehydrogenase and alkaline phosphatase activities at both the stages and the activity of urease was maximum in the soil treated with 7.5 ton FYM ha^{-1}. Soil fertility in terms of organic carbon content and available N, P and K significantly influenced by the application of organic manures under pearl millet. Maximum availability was recorded with the highest doses of organic manures. However, the nutrients availability was highest at 45 DAS and it gradually declined at harvest of crop. The soil biological communities played crucial role in soil fertility formation and nutrient cycling and they could not only provide plant available nutrient, but also accumulate soil organic carbon, ultimately increased the crop production. However, there is need to conduct such experiments to enhance the soil biological fertility under organic farming systems, which received the profitable and quality crop production per unit area, ultimately fetches high prices.

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Table I: Physical and chemical properties of the initial soil

Soil properties	Values
Mechanical composition (%)	
Sand	32.22
Silt	20.46
Clay	47.35
Texture	Clay
Field capacity (%)	52.13
Chemical properties	
pH	7.8
EC (dSm^{-1})	0.34
Organic carbon (g kg^{-1})	6.1
Available Nitrogen (kg ha^{-1})	186.12
Available Phosphorus (kg ha^{-1})	16.90
Available Potassium (kg ha^{-1})	352.46
Total nitrogen (%)	0.060

Table II: Chemical and biological composition of FYM and vermicompost

Parameters	FYM	Vermicompost
Total nitrogen (%)	0.61	1.2
Total phosphorous (%)	0.39	0.42
Total potassium (%)	0.79	0.99
Organic Carbon (%)	12	15
C:N Ratio	19.67	12.50
Fungal count ($\times 10^4 g^{-1}$ soil)	12	9
Bacterial count ($\times 10^7 g^{-1}$ soil)	22	20
Actinomycetes count ($\times 10^6 g^{-1}$ soil)	17	19

Table III: Soil enzyme activities influenced by graded levels of organic manures

Treatments	Dehydrogenase activity (µg TPF g^{-1} soil 24 hr^{-1})		Urease activity (mg NH_4 -N released g^{-1} soil 24 hr^{-1})		Alkaline phosphatase activity (µg P –Nitrophenol g^{-1} soil 24 hr^{-1})	
	At sowing	At 45 DAS	At sowing	At 45 DAS	At sowing	At 45 DAS
T_1	52.06	58.56	0.091	0.116	60.00	63.22
T_2	58.20	70.36	0.181	0.251	74.36	87.03
T_3	63.16	78.50	0.222	0.314	81.26	97.36
T_4	76.16	91.43	0.273	0.382	116.20	120.86
T_5	56.66	66.63	0.121	0.251	66.66	79.23
T_6	59.20	71.40	0.182	0.236	88.13	100.53
T_7	72.10	85.53	0.195	0.289	93.16	108.30
T_8	87.90	97.26	0.259	0.358	122.13	137.43
CD (P=0.05)	0.62	0.53	0.004	0.003	1.34	2.09

Table IV: Organic carbon, N, P and K influenced by graded levels of organic manures

Treatments	Organic carbon (g kg^{-1})			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	At sowing	45 DAS	At harvest	At sowing	45 DAS	At harvest	At sowing	45 DAS	At harvest	At sowing	45 DAS	At harvest
T_1	6.06	6.26	6.16	188.30	195.60	190.45	16.90	18.09	17.61	352.71	358.64	348.21
T_2	6.30	6.70	6.50	202.94	230.17	210.88	17.68	21.67	19.67	371.24	410.45	388.15
T_3	6.36	6.76	6.46	205.15	248.30	226.37	17.86	22.32	19.94	382.07	425.70	397.18
T_4	6.40	7.10	6.70	215.26	278.47	243.28	18.36	23.71	20.72	393.72	495.22	435.40
T_5	6.16	6.46	6.36	189.20	210.37	194.85	17.21	20.34	18.42	360.62	375.86	364.38
T_6	6.23	6.50	6.40	196.35	221.45	205.92	17.40	20.85	18.92	364.50	390.46	372.27
T_7	6.26	6.56	6.50	202.47	229.73	209.63	17.62	21.26	19.19	370.12	412.75	387.12
T_8	6.26	7.00	6.60	210.68	270.40	237.83	18.26	23.45	20.43	390.00	467.27	421.48
CD(P=0.05)	0.12	0.15	0.19	2.79	2.13	2.51	0.06	0.17	0.22	1.89	3.13	1.57

Table V: Correlation of soil biological properties with soil nutrients at 45 DAS

Soil biological properties	Organic carbon	Available N	Available P	Available K
Urease	0.900**	0.939**	0.971**	0.921**
Alkaline phosphatase	0.814**	0.890**	0.879**	0.869**
Dehydrogenase	0.842**	0.910**	0.888**	0.904**

** Significant at 1%