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Soil Microbial Population and Nutrients Availability Influenced by Graded Levels of Organic Manures 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 microbial population was estimated at sowing and 45 DAS of crop. The total count of fungi, bacteria and actinomycetes and the population of beneficial microoganisms viz., Azotobactor, Azospirillum, PSB and PSF were increased with the increased levels of organic manures. The maximum population of fungi (22.00 x 10^4 g^{-1} soil), bacteria (41.00 x 10^7 g^{-1} soil), actinomycetes (32.00 x 10^6 g^{-1} soil), Azotobactor (28.00 x 10^4 g^{-1} soil), Azospirillum (26.00 x 10^4 g^{-1} soil), PSB (24.00 x 10^4 g^{-1} soil), and PSF (21.33 x 10^4 g^{-1} soil) were recorded in the treatment receiving 7.5 ton FYM ha^{-1} at 45 DAS. Increasing trends in population of all microorganisms were noticed as compared to their initial values. 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 organic C and available N, P and K contents were highest at 45 DAS and then gradually decreased at harvest of crop but values were higher than initials. The soil microbial population showed positive and significant relationship with organic carbon and available nutrients.

Keywords: *Organic farming, total microbial population, beneficial microorganisms, available nutrients, pearl millet*

1. INTRODUCTION

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 one cubic meter of soil may have many hundreds of species of bacteria, actinomycetes, algae and fungi. The numerical dominance of bacterial significance, each group has its unique contribution to the nutrients cycles and a source of useful chemicals like an enzyme. Microbial community composition can be more sensitive to soil amendments with plant residues than microbial biomass and it is possible through the addition of different forms of organic amendment such as FYM, Vermicompost etc. (Randhwa *et al.,* 2005). Microorganisms were responsible for the decomposition and mineralization of the organic materials. Addition of organic manures modify the size and activities of microbial communities and thereby soil fertility. Hence, these microorganisms are considered as biological indicator of soil fertility. Considering the paramount importance of soil biological fertility, the present investigation was carried out with an objective to know the soil microbial population dynamics as influenced by graded levels of organic manures under rainfed condition.

2. MATERIALS AND METHODS

A field experiment was conducted at pearl millet Research Farm, College of Agriculture, Dhule, Maharashtra State during *Kharif* 2011was 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 1). For this investigation, the farm yard manure and vermicompost were used as organic manures. They were analyzed for chemical and biological properties (Table 2). 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 microbial population, 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.

Table 1: 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 2: 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 (×104g-1 soil)	12	9
Bacterial count (×107g-1 soil)	22	20
Actinomycetes count (×106g-1 soil)	17	19

Physical and chemical properties of soil like mechanical analysis (Bouyoucos 1928) and field capacity (Klute and Dirksen 1986), soil pH, EC, organic C, available N (Subbiah and Asija 1956), Olsen's P and available K (NH_4OAc-extractable) were analyzed following the procedure described by Jackson (1973). The different microbial populations were estimated by using serial dilution plate method as described by Dhingra and Sinclair (1993).

The experimental data of soil and microorganisms were statistically analyzed to draw conclusion of significance by using the methods prescribed by Panse and Sukhatme (1995). The simple correlation of soil properties and microbial population were worked out for the effects which were significant.

3. 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 1).

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 2. 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 microbial population dynamics as influenced by graded levels of organic manures

The data pertaining to the total fungal, bacterial and actinomycetes populations as well as beneficial microorganisms influenced by organic manuring are presented in table 3 and 4.

Table 3: Fungal, bacterial and actinomycetes population influenced by graded levels of organic manures

Treatments	Total fungi (x 104 g-1 soil)		Total bacteria (x 107 g-1 soil)		Total actinomycetes (x 106 g-1 soil)	
	At sowing	At 45 DAS	At sowing	At 45 DAS	At sowing	At 45 DAS
T1	5.0	7.00	12.00	15.00	9.00	11.00
T2	11.67	15.00	24.00	30.00	18.00	24.00
T3	14.00	18.00	28.00	35.00	23.00	29.00
T4	16.00	22.00	34.00	41.00	28.00	32.00
T5	8.00	11.00	14.33	20.00	11.00	20.00
T6	10.00	14.00	19.00	25.00	16.00	21.00
T7	12.00	17.00	22.00	29.00	20.00	25.00
T8	15.00	20.00	33.00	40.00	27.00	30.66
CD (P=0.05)	2.40	4.05	3.66	5.51	3.99	5.66

Table 4: Azotobactor, Azospirillum, PSB and PSF population influenced by graded levels of organic manures

Treatments	Azotobactor (x 104 g-1 soil)	Azospirillum (x 104 g-1 soil)	PSB (x 104 g-1 soil)	PSF (x 104 g-1 soil)

	At sowing	At 45 DAS	At sowing	At 45 DAS	At sowing	At 45 DAS	At sowing	At 45 DAS
T1	9.00	12.00	8.70	12.00	9.0	10.4	6.33	11.66
T2	15.66	18.70	13.40	17.40	14.4	15.0	11.66	14.66
T3	22.00	21.70	17.00	22.40	19.0	20.4	15.66	17.00
T4	25.67	28.00	20.40	26.00	22.0	24.0	19.66	21.33
T5	13.40	17.00	10.70	15.40	10.7	14.7	8.66	10.66
T6	15.00	18.70	13.00	17.70	12.7	15.4	10.66	13.66
T7	18.00	22.70	17.40	22.00	14.4	18.0	13.33	15.66
T8	22.00	25.70	22.00	25.70	21.7	23.0	18.66	20.66
CD (P=0.05)	1.97	2.09	2.14	2.18	1.22	1.41	1.17	3.57

PSB: Phosphate solubilizing bacteria; *PSF*: Phosphate solubilizing fungi

Table 5: 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
T1	6.06	6.26	6.16	188.30	195.60	190.45	16.90	18.09	17.61	352.71	358.64	348.21
T2	6.30	6.70	6.50	202.94	230.17	210.88	17.68	21.67	19.67	371.24	410.45	388.15
T3	6.36	6.76	6.46	205.15	248.30	226.37	17.86	22.32	19.94	382.07	425.70	397.18
T4	6.40	7.10	6.70	215.26	278.47	243.28	18.36	23.71	20.72	393.72	495.22	435.40
T5	6.16	6.46	6.36	189.20	210.37	194.85	17.21	20.34	18.42	360.62	375.86	364.38
T6	6.23	6.50	6.40	196.35	221.45	205.92	17.40	20.85	18.92	364.50	390.46	372.27
T7	6.26	6.56	6.50	202.47	229.73	209.63	17.62	21.26	19.19	370.12	412.75	387.12
T8	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 6: Correlation of soil biological properties with soil nutrients at 45 DAS

Soil biological properties	Organic carbon	Available N	Available P	Available K
Fungi	0.836**	0.899**	0.886**	0.884**
Bacteria	0.895**	0.887**	0.940**	0.949**
Actinomycetes	0.821**	0.833**	0.890**	0.861**

** Significant at 1%

Total Fungal, bacterial and actinomycetes population

Fungal population under different treatments of organic manures was in the range between 5.0 to 22.00 × 10^4 g^{-1} soil. At sowing stage, the higher count of fungi (16 × 10^4 g^{-1} soil) was recorded in treatment (T_4) 7.5 ton FYM ha^{-1} followed by the treatment (T_8) 2.5 ton FYM +1 ton Vermicompost ha^{-1} (15 ×10^4 g^{-1} soil). Rest of the organic treatments also increases the population over control. While, at 45 days after sowing, the maximum fungal population was observed in the Treatment (T_4) receiving 7.5 ton FYM ha^{-1} i.e 22 × 10^4 g^{-1} soil followed by treatment (T_8) 2.5 ton FYM +1 ton Vermicompost ha^{-1} (20 ×10^4 g^{-1} soil). This indicated that the fungal activity increased with the higher availability of organic substrate. The treatment T_8 was found at par with treatment T_4 at both the stages. However, increasing level of FYM (2.5, 5.0 and 7.5 ton ha^{-1}) and vermicompost (1.0, 2.0 and 3.0 ton ha^{-1}) significantly increased fungal population over control. Beneficial effect of FYM and vermicompost on fungal population was noticed by Kumar *et al.* (2010). This data was closely confirmative with the recent result reported by Nakhro and Dkhar (2010) who stated that the fungi population increased in organically amended plot compared to controlled plots which may be due to addition of organic amendments that might have large impact on size and activity of fungal population.

Similarly, bacterial population was ranges in 12 to 41 x 10^7 g^{-1} soil. At sowing stage, the treatment receiving 7.5 ton FYM ha^{-1} (T_4) recorded the maximum population (34 x 10^7 g^{-1} soil). Further, the application of 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} (T_8) significantly increased the population (33 x 10^7 g^{-1} soil) over control. At 45 DAS, among all the treatments, application of 7.5 ton FYM ha^{-1} (T_4) showed significantly higher bacterial population (41 x 10^7 g^{-1} soil) over its lower doses and control treatments. The higher bacterial population (40 x 10^7 g^{-1} soil) was also noticed with combined use of 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} (T_8) and this treatments was found at par with T_4. However, it was noticed that, increase in graded levels of organic substrate, significantly increased the bacterial population. While, comparing the two organic manures viz., FYM and vermicompost, the higher values were noticed under FYM application. Parham *et al.* (2003) reported that the Farm yard manure application promoted the growth of bacteria when compared with controlled soil. The input of organic carbon through organic manures under organic farming significantly increased the bacterial population was also noticed by Fraster *et al.* (1994).

The actinomycetes population in pearl millet field under different treatments also exhibited similar trend with higher values and minimum values recorded in the organic and control plots, respectively at both the stages. The data presented revealed that the actinomycetes population under organic manures was in range between 9 to 32 x 10^6 g^{-1} soil. Among all treatments, treatment (T_4) 7.5 ton FYM ha^{-1} was significantly recorded the highest actinomycetes count (28 x 10^6 g^{-1} soil) followed by treatments 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} (T_8) and 5.0 ton FYM ha^{-1} (T_3) at sowing stage. All these treatments were found at par with each other. While, at 45 DAS, the maximum count (32 x 10^6 g^{-1} soil) was noted with the application of 7.5 ton FYM ha^{-1} followed by combined application of 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} (30.66 x 10^6 g^{-1} soil). Overall scrutiny of the result indicated that bacteria at any stage were more than that of actinomycetes and fungi. Nanda *et al.* (1988) revealed persistence of dominant bacterial flora followed by actinomycetes and fungi. The microbial population viz., bacteria, fungi, and actinomycetes conspicuously increased with application of organic sources than control. Among the organic sources, application of FYM registered maximum population of these microorganisms.

Beneficial microorganisms

Role of organic manures in altering the population of beneficial microorganisms in soil is further evidenced by spectacular effect of FYM and vermicompost addition. The data revealed that the *Azotobactor* population under different organic manures treatments was in the range between 9.0 to 28 x 10^4 g^{-1} of soil. The highest *Azotobactor* population (28 x 10^4 g^{-1} of soil) was recorded in the treatment where maximum carbon substrate was added i.e. treatment (T_4) receiving 7.5 ton FYM $ha^{-1.}$ However, the higher population (25.7 x 10^4 g^{-1} of soil) was also noticed with the combined use of FYM and vermicompost. Further, it was observed that increase in the levels of organic manures also increase the *Azotobactor* population. The *Azotobactor* count was found to be less at sowing stage and then it was increased at 45 days after sowing of pearl millet. Although, the addition of organic manures significantly increased the *Azotobactor* population over control at both the stages.

However, pertaining to the *Azospirillum* population, maximum population (22 x 10^4 g^{-1} of soil) was observed in the treatment 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} followed by treatment 7.5 ton FYM ha^{-1} and treatment (T_7) 3.0 ton vermicompost ha^{-1} at sowing stage. With the advancement of crop growth the population was increased and the highest *Azospirillum* population (26 x 10^4 g^{-1} of soil) was noted with the application of 7.5 ton FYM ha^{-1} (T_4) followed by the treatment (T_8) receiving combine application of FYM and vermicompost. i.e. 25.7 x 10^4 g^{-1} of soil. Both the treatments found to be at par with each other. Increase in the levels of FYM and vermicompost significantly increased the *Azospirillum* population over control.

The phosphate solubilizing bacterial population under different treatment of organic manures was in the range between 9.0 to 24 x 10^4 g^{-1} of soil. Among all the treatments, treatment T_4 showed the highest population of PSB (22.0 x 10^4 g^{-1} of soil) followed by the treatment T_8 at sowing. These treatments found at par with each other. Increasing levels of FYM from 2.5 to 7.5 ton and vermicompost from 1 to 3 ton ha^{-1} also increase the PSB count and was significantly higher over control. Similar trends were recorded at 45 DAS stage with maximum population (24.0 x 10^4 g^{-1} of soil) in the treatment 7.5 ton FYM ha^{-1} followed by treatment 2.5 ton FYM ha^{-1}+ 1.0 ton vermicompost ha^{-1} (23.0 x 10^4 g^{-1} of soil). Both these treatments were found significantly superior over control. However, less population was noticed at sowing stage as compared to 45 days after sowing. With the advancement of crop growth, the microbial population increase and then further it was declined at harvest was noticed by Thakare and Gupta (2003).

The maximum population of phosphate solubilizing fungi (19.66 x 10^4 g^{-1} of soil) at sowing stage was observed in the treatment (T_4) receiving 7.5 ton FYM ha^{-1} followed by the treatment (T_8) 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} (18.66 x 10^4 g^{-1} of soil). These treatments found at par with each other. Although, it was noticed that addition of organic manures significantly increases the PSF count over control. At 45 DAS, the highest population (21.33 x 10^4 g^{-1} of soil) was recorded with addition of 7.5 ton FYM ha^{-1} followed by 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1} (20.66 x 10^4 g^{-1} of soil). The higher population at 45 DAS than sowing stage might be due to the higher availability of decomposed organic material. Result also showed that, PSF count gradually increases with the increasing levels of FYM and vermicompost at both the stages. Soil amended with FYM showed the highest PSF population as compared to soil amendment with vermicompost. From the above result, it may aptly be inferred that application of organic sources greatly influenced the population of beneficial microorganisms.

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. 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 (2006). 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

Soil nutrients showed a significant relationship with the microbial population. Soil organic carbon had a positive and significant relationship with fungi (0.836**), bacteria (0.895**), and actinomycetes (0.821**). The data revealed that, with improvement of organic carbon status of the soil, the microbial population increased. It was also seen that available nutrient status of the soil i.e. N, P and K were significantly related with fungi, bacteria, actinomycetes population. The result suggests that microbial population improved with soil fertility and organic carbon build up and vice versa. Similar positive and significant relationship of soil nutrients and microbial population was also observed by Singh *et al.* (2009).

4. CONCLUSIONS

The significant highest population of fungi, bacteria, actinomycetes, *Azotobactor*, *Azospirillum*, PSB and PSF were recorded with the application of 7.5 ton FYM ha^{-1} followed by the treatment receiving 2.5 ton FYM ha^{-1} + 1.0 ton vermicompost ha^{-1}. The populations of these microorganisms were increased with the advancement of crop growth. 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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