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Soil Biological Properties as Influenced by Long Term Application of Organic and Inorganic Inputs under Wheat-Maize Cropping System in Typic Haplustepts

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A B S T R A C T

A field study entitled Soil biological properties as influenced by long term application of organic and inorganic inputs under wheat-maize cropping system in typic haplustepts was conducted during Kharif 2016-17 and 2017-18 in the Long Term Fertilizer Experiments initiated in Kharif, 1997 at the Instructional Farm of the Rajasthan College of Agriculture, Udaipur. The results of the present investigation revealed that the significantly highest microbial population (i.e Bacteria, Fungi and Actinomycetes) were registered in FYM @ 20 t treatment followed by 100% NPK + FYM 10 t ha^{-1}. Application of inorganic fertilizer alone or combination with manure significantly improved microbial population as compared to control and 100% N treatment. However, highest *Azotobacter* population was found in 100% NPK + *Azotobacter* treatment followed by FYM @ 20 t treatment. The maximum content of soil microbial biomass carbon, soil microbial biomass nitrogen, soil microbial biomass phosphorus and soil microbial biomass sulphur were registered under application of FYM @ 20 t in LTFE soils. Application of either manure (FYM) alone or in combination with inorganic fertilization significantly improved microbial biomass as compared to inorganic fertilization alone.

Introduction

The living soil is a central part of soil fertility because the activity of soil organisms rendered available the elements in plant residues and organic debris entering the soil. Part of this material, however, remains in the soil and contributes to its stabilization by humus build up. Soil microorganisms and the processes are essential for the long-term sustainability of agricultural systems (Wardle *et al.,* 1999) and are important factors in soil formation and nutrient cycling. It has been frequently reported that soil microbial biomass and activity is an important aspect of soil quality (Schloter *et al.,* 2003). The microorganisms present in the soil carry out a wide range of activities like organic matter decomposition, nitrogen fixation and translocation of immobile elements. The microbial community structure can provide a sensitive reflection of soil quality under different land use and management practices. The productivity and stability of soil as a medium for plant growth depends greatly on the balance between living and non-living components. Energy from the sun and nutrients essential for growth stored in the fabric of crop plants, are recovered for reuse through decomposition activities of microorganisms in soil. The soil organic matter formed during this process serves both as a continuous nutrient supply and a factor stabilizing the soil physical environment (Howard, 1972). To maintain productivity, soluble nutrients removed from soil through plant growth and harvest must be replaced, either as fertilizers or through biological decomposition of organics. Soil microorganisms play a vital role in soil health but are often forgotten in farming systems. There is a growing interest in their beneficial effects, their role as soil health indicators and factors that influence their abundance and diversity. As soil microorganisms decompose the organic matter, they also assimilate a portion of the nutrients in soil to build up their body. The nutrients in soil microbial biomass are mineralized from the dead microorganisms.

Therefore, soil microbial biomass is considered as a source and sinks for nutrients and is an active pool of organic matter in soils. Because of its important role in various ecological systems, nitrogen and carbon contained in soil microbial biomass (*i.e.* SMBN and SMBC) has received much attention in recent years. Contribution of organic matter to soil from manure plant residues or root secretion usually increases the levels of SMBN, SMBC and enzyme activities. Besides this biofertilizer application seems to enhance the soil microbial activity and nutrient availability. Studies of biological activities in soils are important as they indicate the potential of soil to support biochemical processes which are essential for the maintenance of soil fertility (Dkhar and Mishra, 1983). Considering the paramount significance of soil microbial processes, as a main driving force in the decomposition of organic materials and also as an early indicators of changes in soil properties resulting from soil management and environment stresses in agricultural ecosystems, this study was designed to assess the impact of organic and inorganic fertilization on soil biological properties under wheat-maize cropping system in typic *Haplustepts.*

Materials and Methods

The present investigation was carried out at the Instructional Farm of the Rajasthan College of Agriculture, Udaipur during 2016-17 and 2017-18. The experimental site is a permanent manurial trial and its layout is on fixed site, at block B2, situated at 24°34N' latitude, 73°42E' longitude and 582.17 m about mean sea level. The area comes under sub-humid southern plain (Zone-IVa) of Rajasthan. The climate of the region is subtropical, characterized by mild winters and distinct summers associated with high relative humidity particularly during the months of July to September.

The mean annual rainfall of the region varies from 650 to 750 mm, most of which is received in rainy season from July to September. The mean maximum and minimum temperature are 35.45°C and 17.41°C, respectively. At the inception of the experiment, the composite soil samples were drawn from 0-15 cm depth prior to treatment application in order to as certain initial fertility status and physico-chemical properties of the experimental soil. At the initiation of the experiment, soil of the experimental field was having pH 8.20, EC 0.48 dSm^{-1}, Organic carbon 6.80 g kg^{-1}, available Nitrogen 360 kg ha^{-1}, available phosphorus 22.4 kg ha^{-1}, available potassium 671 kg ha^{-1}, available Zn 3.76 mg kg^{-1}, available Fe 2.52 mg kg^{-1}. The 12 treatments with four replications in a randomized block design with 152 m^2 plot for each treatment were as follows: T_1-control; T_2-100% N; T_3-100% NP; T_4-100% NPK; T_5-100% NPK + Zn; T_6-100% NPK + S; T_7-100% NPK + Zn + S; T_8-100% NPK + Azotobacter; T_9-NPK 100% NPK + FYM 10 t ha^{-1}; T_{10}- FYM 10 t ha^{-1} + 100 % NPK (-NPK of FYM); T_{11}-150%; T_{12}-FYM 20 t ha^{-1}. Soil samples collected from a depth of 0–0.15 m after the harvest of maize (2016-17 and 2017-18) were used for determination of various chemical parameters.

Fresh soil samples were used for biological studies. Fungal, bacterial, actinomycetes and Azotobacter population were determined by using standard serial dilution and plate count method as described by Vance *et al.,* (1987). The SMBC was determined by chloroform fumigation method using Kc value of 2.64 (Vance *et al.,* 1987). For SMBN analysis, fumigated and unfumigated soil samples were extracted with 0.5 M potassium sulfate (K_2SO_4), and the values were determined by standard method, and biomass N was computed by the method outlined by (Vance *et al.,* 1987) using Kn value of 2.22. SMBP was calculated on the basis of Bray P1 of the fumigated and unfumigated soil samples using Kp value of 0.40 (Brookes *et al.,* 1982). SMBS was determined on the basis of Chesnin and Yien (1951) of the fumigated and unfumigated soil samples using Ks value of 0.35 method outlined by Wu *et al.,* (1994). Statistical analysis was done as outlined by Panse and Sukhatme (1985).

Results and Discussion

Bacteria

A perusal of the pooled data (Table 1) reveals that FYM 20 t ha^{-1} gave 366.11 and 103.48 per cent higher bacterial population as compare to control (7.26 cfu X 10^6) and recommended dose of fertilizer (16.63 cfu X 10^6). The highest bacterial population was recorded under FYM 20 t ha^{-1} (33.84 cfu X 10^6) which was significantly superior to rest of the treatments. Application of optimal and super optimal dose of NPK *viz;* 100 and 150% NPK increased the bacterial population by 129.06 and 165.70 per cent, respectively over the control. Bacterial population in 100% NPK (T_4) being 16.63 cfu X 10^6 was found to be significantly higher than treatment receiving 100% NP (14.17 cfu X 10^6) and 100% N (7.79 cfu X 10^6). This indicated that imbalanced application of fertilizers exerted adverse effect on bacterial population. Addition of FYM with inorganic fertilizer levels showed a profound increase in the microbial population in comparison to chemical fertilizer used alone. FYM acts as a source of the nutrients and also as a substrate for decomposition and mineralization of nutrients, thereby creating a favourable condition for the proliferation of microbes in the soil. Among the microbes, bacterial population was highest as compared to fungal and actinomycetes it may be due to their high multiplication rate. This finding is in accordance with the findings of Walia *et al.,* (2010), Ndubuisi-Nnaji *et al.,* (2011).

Fungi

It is inferred from the data (Table 1) that fungal population varied from minimum value of 5.60 and 5.52 cfu X 10^4 in control to maximum value of 18.21 and 18.95 cfu X 10^4 in FYM 20 t ha^{-1} during 2016-17 and 2017-18, respectively. The pooled analysis reveals that FYM 20 t ha^{-1} gave 234.17 and 49.11 per cent higher fungal population as compare to control (5.56 cfu X 10^4) and recommended dose of fertilizer (12.46 cfu X 10^4). The fungal population in 100% N, 100% NP and 100% NPK treatments was higher by 31.29, 68.52 and 124.10 per cent, respectively over the control. Similarly, application of 100% NPK + FYM and 100% NPK (-NPK of FYM, T_{10}) showed significant increase in the content of fungal population by 34.75 and 30.81 per cent, respectively over 100% NPK alone. Fungal population in 100% NPK being 12.46 cfu X 10^4 was found to be significantly higher than treatment receiving 100% NP (9.37 cfu X 10^4) and 100% N (7.30 cfu X 10^4). This indicated that imbalanced application of fertilizers exerted adverse effect on fungal population. It is evident from the study that in treatments receiving farm yard manure fungi population were higher compared to the no FYM applied plots and this may be attributed to more availability of carbon (Belay *et al.*, 2002). The increase in microbial population (fungi) with the incorporation of organics (FYM) might be due to application of organic manures in turn provides adequate biomass as a feed for the microbes and helps in increasing microbial population in soil (Singh *et al.*, 2012).

Actinomycetes

A perusal of the pooled data (Table 1) reveals that the highest content of actinomycetes population was recorded under FYM 20 t ha^{-1} (19.83 cfu X 10^6) which was significantly superior to rest of the treatments. Application of FYM 20 t ha^{-1} gave 229.40 and 54.92 per cent higher actinomycetes population as compare to control (6.02 cfu X 10^6) and recommended dose of fertilizer (12.80 cfu X 10^6). Application of optimal and super optimal dose of NPK *viz;* 100 and 150% NPK increased the actinomycetes population by 112.62 and 144.18 per cent, respectively over the control. The actinomycetes population in 100 per cent N, 100 per cent NP and 100 per cent NPK treatments was higher by 12.62, 62.45 and 112.62 per cent, respectively over the control. Application of 100% NPK + FYM and 100 per cent NPK (-NPK of FYM, T_{10}) showed significant increase in the content of actinomycetes population by 37.65 and 35.85 per cent, respectively over 100% NPK alone (T_4). However T_4, T_5, T_6 and T_8, treatments with values of 12.80, 13.27, 13.46 and 12.87 cfu x 10^6, respectively were statistically at par with each other.

Azotobacter

It is inferred from the pooled data (Table 1) reveals that the highest *Azotobacter* population was recorded under FYM 20 t ha^{-1} (244.37 cfu X 10^4) which was significantly superior to rest of the treatments. Application of FYM 20 t ha^{-1} gave 102.83 and 65.09 per cent higher *Azotobacter* population as compare to control (120.48 cfu X 10^4) and recommended dose of fertilizer (148.02 cfu X 10^4). The *Azotobacter* population in 100% N, 100% NP and 100% NPK treatments was higher by 10.28, 13.80 and 22.85 per cent, respectively over the control. *Azotobacter* population in 100% NPK (T_4) being 148.02 cfu X 10^4 was found to be significantly higher than treatment receiving 100% NP (137.11 cfu X 10^4) and 100% N (132.87 cfu X 10^4). This indicated that imbalanced application of fertilizers exerted adverse effect on *Azotobacter* population. Maximum counts of *Azotobacter* were observed in 100 per cent NPK + Azotobacter treatment followed by FYM in addition to mineral fertilizers was applied. It may be due to large amount of C source provided by FYM which is required for proliferation of *Azotobacter*.

Table.1 Effect of organic and inorganic fertilization on population of bacteria (cfu X 10^6), fungi (cfu X 10^4) actinomycetes (cfu X 10^6) and *Azotobacter* (cfu X 10^4) of soil after harvest of maize under wheat-maize cropping sequence

Treatments	Bacteria			Fungi			Actinomycetes			*Azotobacter*		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T1 = Control	7.30	7.22	7.26	5.60	5.52	5.56	6.10	5.94	6.02	120.82	120.14	120.48
T2 = 100% N	7.80	7.77	7.79	7.35	7.24	7.30	6.85	6.70	6.78	132.10	133.65	132.87
T3 = 100% NP	14.15	14.18	14.17	9.35	9.38	9.37	9.75	9.80	9.78	135.50	138.71	137.11
T4 = 100% NPK	16.55	16.70	16.63	12.32	12.60	12.46	12.64	12.95	12.80	145.62	150.41	148.02
T5 = 100% NPK + Zn	18.67	18.83	18.75	12.61	12.84	12.72	13.10	13.45	13.27	148.43	153.34	150.88
T6 = 100% NPK+ S	18.90	19.03	18.97	13.17	13.45	13.31	13.35	13.57	13.46	145.64	150.31	147.98
T7 = 100% NPK+ Zn + S	20.70	20.87	20.79	13.40	13.73	13.57	13.65	13.78	13.72	149.51	154.43	151.97
T8 = 100% NPK + Azotobactor	23.15	23.33	23.24	12.28	12.41	12.35	12.80	12.94	12.87	260.41	268.51	264.46
T9 = 100% NPK + FYM 10 t ha-1	30.70	30.98	30.84	16.63	16.95	16.79	17.42	17.82	17.62	210.54	216.14	213.34
T10 = FYM 10 t ha-1 + 100% NPK (-NPK of FYM)	28.80	28.94	28.87	16.16	16.43	16.30	17.15	17.63	17.39	205.63	209.54	207.59
T11 = 150% NPK	19.17	19.40	19.29	14.42	14.65	14.54	14.60	14.80	14.70	160.41	163.42	161.92
T12 = FYM 20 t ha-1	33.72	33.95	33.84	18.21	18.95	18.58	19.70	19.95	19.83	240.43	248.31	244.37
S.Em.±	0.51	0.52	0.36	0.30	0.31	0.22	0.32	0.33	0.23	4.32	4.40	3.08
C.D. (P = 0.05)	1.48	1.49	1.03	0.88	0.89	0.61	0.92	0.94	0.65	12.45	12.67	8.71

Table.2 Effect of organic and inorganic fertilization on SMBC (mg kg^{-1}), SMBN (mg kg^{-1}), SMBP (mg kg^{-1}) and SMBS (mg kg^{-1}) of soil after harvest of maize under wheat-maize cropping sequence

Treatments	SMBC			SMBN			SMBP			SMBS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1 = Control	156.00	150.00	153.00	23.45	23.30	23.38	3.18	3.15	3.17	4.45	4.42	4.44
T2 = 100% N	195.00	193.00	194.00	25.76	25.70	25.73	3.29	3.25	3.27	5.80	5.77	5.79
T3 = 100% NP	204.00	206.00	205.00	28.20	28.35	28.28	3.77	3.81	3.79	6.62	6.64	6.63
T4 = 100% NPK	259.00	268.00	263.50	36.72	36.95	36.84	4.29	4.34	4.32	7.29	7.35	7.32
T5 = 100% NPK + Zn	261.99	270.99	266.49	36.25	36.80	36.52	4.65	4.70	4.67	7.33	7.38	7.35
T6 = 100% NPK+ S	260.00	269.00	264.50	36.28	36.84	36.56	4.72	4.74	4.73	7.90	7.97	7.94
T7 = 100% NPK+ Zn + S	264.00	273.00	268.50	36.75	36.93	36.84	4.74	4.76	4.75	7.95	8.03	7.99
T8 = 100% NPK + *Azotobacter*	261.00	271.00	266.00	37.92	38.20	38.06	4.90	4.95	4.93	7.91	7.98	7.95
T9 = 100% NPK + FYM 10 t ha^{-1}	346.00	365.00	355.50	42.56	42.89	42.73	5.24	5.30	5.27	11.67	11.77	11.72
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	340.00	359.00	349.50	40.69	41.10	40.90	5.10	5.16	5.13	11.42	11.52	11.47
T11 = 150% NPK	290.00	317.00	303.50	38.14	38.74	38.44	4.82	4.88	4.85	7.66	7.72	7.69
T12 = FYM 20 t ha^{-1}	380.00	405.00	392.50	43.69	43.95	43.82	5.93	6.02	5.98	12.30	12.50	12.40
S.Em.±	6.57	6.85	4.75	0.84	0.85	0.60	0.11	0.11	0.08	0.21	0.21	0.15
C.D. (P = 0.05)	18.90	19.73	13.41	2.42	2.44	1.69	0.31	0.31	0.22	0.60	0.61	0.42

Higher population of various groups of microorganisms under the influence of chemical fertilizers, organics and integrated nutrient management have also been reported by Chang *et al.,* (2013), Khan *et al.,* (2017), Gowda *et al.,* (2017) and Sheoran *et al.,* (2018) results are in line with these reports.

Soil microbial biomass carbon (SMBC)

It is apparent from the data (Table 2) revealed that SMBC varied from minimum value of 156.0 and 150.0 mg kg^{-1} in control to maximum value of 380.0 and 405.0 mg kg^{-1} in FYM 20 t ha^{-1} during 2016-17 and 2017-18, respectively. The pooled analysis reveals that FYM 20 t ha^{-1} gave 156.53 and 49.23 per cent higher SMBC as compare to control (153.0 mg kg^{-1}) and recommended dose of fertilizer (263.5 mg kg^{-1}). Use of FYM alone or in combination with chemical fertilizers significantly increased soil microbial biomass carbon (SMBC). The supply of additional mineralizable and readily hydrolysable carbon due to organic manure application might have resulted in higher microbial activity in return higher soil microbial biomass carbon. Many other workers (Meena and Sharma., 2016; Kundu *et al.,* 2016 and Khan *et al.,* 2017) have also shown marked build up in microbial biomass carbon in soil receiving manure. Application of 100% NPK + FYM and 100% NPK (-NPK of FYM, T_{10}) showed significant increase in the content of SMBC by 34.91 and 32.63 per cent, respectively over 100% NPK alone. However T_4, T_5, T_6, T_7 and T_8, treatments with values of 263.5, 266.49, 264.5, 268.5 and 266.0 mg kg^{-1}, respectively were statistically at par with each other.

Soil microbial biomass nitrogen (SMBN)

It is inferred from the pooled data (Table 2) reveals that FYM 20 t ha^{-1} gave 87.42 and 18.94 per cent higher SMBN as compare to control (23.38 mg kg^{-1}) and recommended dose of fertilizer (36.84 mg kg^{-1}). The highest SMBN was recorded under FYM 20 t ha^{-1} (43.82 mg kg^{-1}) which was statistically at par with 100% NPK + FYM and significantly superior to rest of the treatments. Graded doses of fertilizers (100 and 150% NPK) consistently increased the SMBN. It may be due to the better plant growth, root biomass and higher rhizosphere activity, which might be responsible for high mineralization rate of N. SMBN in 100% NPK being 36.84 mg kg^{-1} was found to be significantly higher than treatment receiving 100% NP (28.28 mg kg^{-1}) and 100% N (25.73 mg kg^{-1}). Application of 100% NPK + FYM and 100% NPK (-NPK of FYM, T_{10}) showed significant increase SMBN by 15.98 and 11.02 per cent, respectively over 100% NPK alone. However T_4, T_5, T_6, T_7 and T_8, treatments with values of 36.84, 36.52, 36.56, 36.84 and 38.06 mg kg^{-1}, respectively were statistically at par with each other. These results corroborate the findings of Meena and Sharma (2016), Kundu *et al.,* (2016), Khan *et al.,* (2017) and li *et al.,* (2018).

Soil microbial biomass phosphorus (SMBP)

The pooled analysis (Table 2) reveals that FYM 20 t ha^{-1} gave 88.64 and 38.42 per cent higher SMBP as compare to control (3.17 mg kg^{-1}) and recommended dose of fertilizer (4.32 mg kg^{-1}). The highest SMBP was recorded under FYM 20 t ha^{-1} (5.98 mg kg^{-1}) which was significantly superior to rest of the treatments. Application of optimal and super optimal dose of NPK *viz;* 100 and 150% NPK increased the SMBP by 36.27 and 52.99 per cent, respectively over the control. The addition of higher levels of phosphorus through external source might have influenced the metabolism of microorganisms, which is probably responsible for higher levels of SMBP. Similar elevation in SMBP with the application of super-optimal dose of NPK and the rise in content of SMBP were also reported by Verma and Mathur (2009) and Tripura *et* *al.*, (2018). The SMBP in 100% N, 100% NP and 100% NPK treatments was higher by 3.15, 19.55 and 36.27 per cent, respectively over the control. SMBP in 100% NPK being 4.32 mg kg^{-1} was found to be significantly higher than treatment receiving 100% NP (3.79 mg kg^{-1}) and 100% N (3.27 mg kg^{-1}). The treatment receiving 100% NP alone was significantly increased SMBP as compared to the 100% N treated plots.

Soil microbial biomass sulphur (SMBS)

It is inferred from the pooled data (Table 2) reveals that the highest SMBS was recorded under FYM 20 t ha^{-1} (12.40 mg kg^{-1}) which was significantly superior than other INM treatments. Application of 100% NPK + FYM and 100% NPK (-NPK of FYM, T_{10}) showed significant increase in the SMBS by 60.10 and 56.69 per cent, respectively over 100% NPK alone. However application of 100% NPK and 100% NPK + Zn with values of 7.32 and 7.35 mg kg^{-1}, respectively were statistically alike.

The high content of SMBS in 100 per cent NPK + Zn + S treatment might be due to addition of sulphur over the years. Application of balanced dose of chemical fertilizers (100% NPK) either alone or combination with FYM resulted in significantly increased SMBS as compared to the control.

Application of FYM along with inorganic fertilization gives extra benefit than only continuous inorganic fertilization and imbalanced fertilization had adverse effect on microbial activity of soil. This could be due to high crop productivity and hence, high microbial activity which probably is responsible for transformations and rapid mineralization of sulphur as has also been documented by Brady and Weil (2002). These results are in accordance with the findings of Mishra *et al.,* (2008) and Meena and Sharma (2016).

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