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Soil quality indicators and microbial biomass of soil influenced by long term use of organic and inorganic inputs under wheat-maize cropping system in typic Haplustepts

Dharmendra Singh, Priyanka Pannu and Dr. Anil Mawalia

Abstract
A field study entitled "Soil microbial biomass and soil quality indicators 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 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. Application of 20 t ha^{-1} FYM significantly increased CEC of soil followed by 100% NPK+ FYM 10 t ha^{-1} application. Application of FYM alone recorded highest soil organic carbon and total organic carbon content of soil. Application of FYM @ 20 t ha^{-1} gave lowest bulk density and significantly maximum total porosity, water holding capacity and hydraulic conductivity of soil followed by FYM 10 t ha^{-1} + 100% NPK treatment.

Keywords: Farmyard manure, soil microbial biomass carbon, soil microbial biomass nitrogen, soil microbial biomass phosphorus, soil microbial biomass sulphur

Introduction
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. 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) [18]. The microorganisms present in the soil carry out a wide range of activities like organic matter decomposition, nitrogen fixation and translocation of immobile elements. 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) [6].
Single or short-term fertilizer experiments, however, only give a partial picture of yield sustainability and crop responses to the use of various inputs. Therefore, the adoption of integrated nutrient management and continuous cropping system has become the need of hour for enhancing soil quality and crop productivity from food security point of view in Indian agriculture. The long-term field experiments (LTFE) on the other hand, provide means to evaluate sustainability and environmental impact of subsistence soil quality. 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. The SMBC was determined by chloroform fumigation method using Kc value of 2.64 (Vance *et al.* 1987) [23]. 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) [23] 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) [3]. SMBS was determined on the basis of Chesnin and Yien (1951) [5] of the fumigated and unfumigated soil samples using Ks value of 0.35 method outlined by Wu *et al*. (1994) [27]. Statistical analysis was done as outlined by Panse and Sukhatme (1985) [16].

Results and Discussion

Soil microbial biomass carbon (SMBC)

It is apparent from the data (Table 1) 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) [13, 11, 10] 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 1) 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) [13], Kundu *et al.* (2016) [11], Khan *et al*. (2017) [10] and li *et al.* (2018).

Soil microbial biomass phosphorus (SMBP)

The pooled analysis (Table 1) 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) [25] and Tripura *et al.* (2018) [22]. 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 1) 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) [1]. These results are in accordance with the findings of Mishra *et al.* (2008) [15] and Meena and Sharma (2016) [13].

Table 1: 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

Bulk Density

Data presented in the Table 2 revealed that the bulk density varies from 1.30 to 1.45 Mg m^{-3} and 1.29 to 1.44 Mg m^{-3} during 2016-17 and 2017-18 under different treatments. The pooled data revealed that application of FYM 20 t ha^{-1} gave lowest bulk density *i.e.* 1.30 Mg m^{-3} and at par with 100% NPK + FYM 10 t ha^{-1} treatment. This treatment gave 11.53 and 7.69 per cent less bulk density as compare to control (1.45 Mg m^{-3}) and recommended dose of fertilizer (1.40 Mg m^{-3}). Application of balanced fertilizers alone or in combination with organics decreased bulk density of soil significantly over control and the extent of reduction was more when FYM were applied alone in both maize and wheat crops which may be due to the addition of organic matter that resulted in increase in pore space and good soil aggregation (Singh *et al.* 2012) [19]. Comparison of different fertilizer treatments with control revealed that there was a general decrease in the bulk density of soil.

Porosity

A deep insight into the data (Table 2) revealed that the porosity varies from 49.61 to 44.66 per cent and 50.00 to 45.04 per cent during 2016-17 and 2017-18 under different treatments. The porosity significantly decreased 49.61 and 50.00 per cent during 2016-17 and 2017-18, under FYM 20 t ha^{-1} application. The pooled data revealed that application of FYM 20 t ha^{-1} gave highest porosity *i.e.* 49.81 per cent and at par with T_9 and T_{10}. This treatment gave 9.95 and 7.34 per cent high porosity as compare to control (44.85%) and 100 per cent NPK treated plot (46.15%).

Water holding capacity

Data presented in the (Table 2) revealed that the application of different treatments differed significantly with respect to water holding capacity of the experimental soil during both the years and pooled basis. The significantly maximum water holding capacity was recorded (49.00%) with the application of FYM 20 t ha^{-1} and at par with T_9 and T_{10} during both the years 2016-17, 2017-18 and in pooled. Increasing SOM content characteristically leads to a decrease in bulk density and surface crusting and an increase in water holding capacity and macroporosity. The beneficial effect of soil organic matter in increasing the water holding capacity of the soil has been reported by several workers (Vennila and Muthuvel, 1998 and Choudhary *et al.* 2017) [24].

Table 2: Effect of organic and inorganic fertilization on BD (Mg m^{-3}), porosity (%),WHC (%) and hydraulic conductivity (cm hr^{-1}) of soil after harvest of maize under wheat-maize cropping sequence

Treatments	BD			Porosity			WHC			Hydraulic conductivity		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1 = Control	1.45	1.44	1.45	44.66	45.04	44.85	39.92	39.80	39.86	4.40	4.50	4.45
T2 = 100% N	1.41	1.40	1.41	45.98	46.56	46.27	44.86	44.88	44.87	4.80	5.00	4.90
T3 = 100% NP	1.39	1.37	1.38	46.95	47.51	47.23	45.96	46.26	46.11	6.90	7.20	7.05

T4 = 100% NPK	1.41	1.39	1.40	45.77	46.54	46.15	46.88	47.05	46.97	10.20	10.60	10.40
T5 = 100% NPK + Zn	1.41	1.40	1.40	45.77	46.15	45.96	44.36	44.60	44.48	10.60	10.80	10.70
T6 = 100% NPK+ S	1.40	1.38	1.39	46.36	46.92	46.64	47.62	47.94	47.78	10.30	10.50	10.40
T7 = 100% NPK+ Zn + S	1.40	1.38	1.39	46.15	47.13	46.64	43.48	43.71	43.60	10.50	10.60	10.55
T8 = 100% NPK + *Azotobacter*	1.42	1.40	1.41	45.38	46.15	45.77	45.23	45.40	45.32	10.40	10.50	10.45
T9 = 100% NPK + FYM 10 t ha^{-1}	1.33	1.31	1.32	48.65	49.22	48.94	48.92	49.20	49.06	16.80	17.40	17.10
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	1.34	1.32	1.33	48.26	49.03	48.65	48.56	48.66	48.61	16.40	17.10	16.75
T11 = 150% NPK	1.39	1.38	1.39	46.54	46.92	46.73	47.38	47.58	47.48	10.70	10.90	10.80
T12 = FYM 20 t ha^{-1}	1.30	1.29	1.30	49.61	50.00	49.81	49.00	49.10	49.05	18.20	18.80	18.50
S.Em.±	0.03	0.03	0.02	1.14	1.15	0.81	1.11	1.11	0.78	0.29	0.30	0.21
C.D. (P = 0.05)	0.08	0.08	0.07	2.90	2.92	2.29	3.19	3.20	2.22	0.83	0.86	0.58

Hydraulic conductivity

Data presented in the (Table 2) revealed that the hydraulic conductivity varies from 4.40 to 18.20 cm hr^{-1} and 4.50 to 18.80 cm hr^{-1} during 2016-17 and 2017-18 under different treatments. Application of FYM 20 t ha^{-1} recorded maximum hydraulic conductivity (18.20, 18.80 and 18.50 cm hr^{-1}) during both the years 2016-17, 2017-18 and in pooled, respectively and significantly higher as compared to all other treatments. The pooled data revealed that application of FYM 20 t ha^{-1} gave 75.94 and 43.78 percent higher hydraulic conductivity as compare to control (4.45 cm hr^{-1}) and 100 percent NPK treated plot (10.40 cm hr^{-1}). Increasing SOM content characteristically leads to a decrease in bulk density and surface crusting and an increase in macroporosity, and hydraulic conductivity. The beneficial effect of soil organic matter in increasing the hydraulic conductivity of the soil has been reported by several workers (Choudhary *et al.* 2017 and Meena *et al.* 2018) [14].

pH of soil

It is evident in data presented in (Table 3) that application of different treatments significantly influences the pH among different treatments. pH values varies from 8.18 to 8.32 during 2016-17 and 8.17 to 8.35 during 2017-18. However the differences were found statistically not significant.

EC of soil

Data pertaining to the effect of different treatments on EC presented in (Table 3). It is evident from the data, the application of 150% NPK in treatment T_{11} significantly increases to 0.92 as compared to 0.86 under control plot. Application of 20 t ha^{-1} FYM lowers the EC values significantly as compared to control plot. Same trend was observed during both years of experimentation.

CEC of soil

The values of cation exchange capacity in the present study (Table 3) varied from lowest value of 9.20 and 9.19 c mol (p$^+$) kg^{-1} in control to the highest value of 12.80 and 13.10 c mol (p$^+$) kg^{-1} in T_{12} treatment which received 20 t ha^{-1} FYM in 2016-17 and 2017-18, respectively. The pooled data revealed that application of FYM 20 t ha^{-1} gave highest CEC *i.e.* 12.95 c mol (p$^+$) kg^{-1} and at par with T_9. This treatment gave 40.76 and 23.33 per cent high CEC as compare to control {9.20 c mol (p$^+$) kg^{-1}} and recommended dose of fertilizer {10.50 c mol (p$^+$) kg^{-1} }. The value of CEC was higher in FYM 20 t ha^{-1} and followed by 100% NPK + FYM treated plots which might be attributed to higher organic colloids in these plots. Moreover, FYM additions increase the CEC of the soils due to increase in root biomass and crop residues production and their incorporation in the soil. Similar findings were reported by Prasad *et al.*, 1996, Jagdeshwari *et al.*, 2001 [17, 7].

Soil organic carbon

Soil organic carbon (SOC) contents after harvest of maize crop under wheat-maize cropping sequence influenced significantly during both years of experimentation (Table 3). The pooled data revealed that the SOC contents in 100% NPK treated plot was statistically at par with T_5, T_6, T_7, and T_8. A critical perusal of data indicates that the highest soil organic carbon 9.50 and 9.90 g kg^{-1} was obtained during 2016-17 and 2017-18, respectively with application of FYM 20 t ha^{-1}. Application of FYM alone or in combination with chemical fertilizers increased soil organic carbon content after harvest of maize crop. Reason attributed is the direct incorporation of organic matter, better root growth and more plant residues addition after harvest of crops. These findings are in agreement with the observations of Katyal *et al.*, 2003 [9], Kannan *et al.*, 2013 [8] and Brar *et al.*, 2015 [2].

Table 3: Effect of organic and inorganic fertilization on pH, EC (dS m^{-1}), CEC {c mol (p$^+$) kg^{-1}}, SOC (g kg^{-1}) and TOC (g kg^{-1}) of soil after harvest of maize under wheat-maize cropping sequence

Treatments	pH			EC			CEC			SOC			TOC		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1 = Control	8.29	8.28	8.29	0.86	0.86	0.86	9.20	9.19	9.20	5.40	5.10	5.25	7.80	7.56	7.68
T2 = 100% N	8.34	8.35	8.32	0.84	0.85	0.85	9.60	9.70	9.65	6.60	6.50	6.55	9.75	9.70	9.73
T3 = 100% NP	8.29	8.26	8.28	0.89	0.89	0.89	10.00	10.10	10.05	6.90	7.00	6.95	10.24	10.35	10.30
T4 = 100% NPK	8.29	8.25	8.27	0.85	0.87	0.86	10.50	10.50	10.50	7.40	7.60	7.50	11.28	11.47	11.38
T5 = 100% NPK + Zn	8.22	8.24	8.23	0.86	0.90	0.88	10.60	10.70	10.65	7.50	7.70	7.60	11.40	11.55	11.47
T6 = 100% NPK+ S	8.20	8.22	8.21	0.86	0.87	0.86	10.40	10.60	10.50	7.40	7.60	7.50	11.30	11.42	11.36
T7 = 100% NPK+ Zn + S	8.23	8.25	8.24	0.87	0.92	0.90	10.50	10.50	10.50	7.60	7.70	7.65	11.70	11.74	11.72
T8 = 100% NPK + *Azotobacter*	8.26	8.24	8.25	0.87	0.88	0.87	10.60	10.70	10.65	7.50	7.80	7.65	11.35	11.43	11.39
T9 = 100% NPK + FYM 10 t ha^{-1}	8.19	8.20	8.19	0.85	0.86	0.86	12.40	12.60	12.50	8.90	9.40	9.15	13.68	13.95	13.82
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	8.25	8.26	8.26	0.86	0.86	0.86	12.20	12.30	12.25	8.80	9.20	9.00	13.60	13.92	13.76

T11 = 150% NPK	8.30	8.27	8.29	0.89	0.95	0.92	10.50	10.60	10.55	7.80	8.10	7.95	12.10	12.40	12.25
T12 = FYM 20 t ha^{-1}	8.18	8.17	8.18	0.82	0.81	0.82	12.80	13.10	12.95	9.50	9.90	9.70	14.86	15.45	15.16
S.Em.±	0.20	0.20	0.14	0.02	0.02	0.01	0.26	0.27	0.19	0.18	0.19	0.13	0.28	0.28	0.20
C.D. (P = 0.05)	NS	NS	NS	0.034	0.035	0.030	0.76	0.77	0.53	0.53	0.54	0.37	0.80	0.81	0.56

Total organic carbon

The pooled data (Table 3) revealed that application of FYM 20 t ha^{-1} gave highest TOC *i.e.* 15.16 g kg^{-1} and significantly higher as compared to all other treatments. This treatment gave 97.39 and 33.21 per cent high TOC as compare to control plot (7.68 g kg^{-1}) and 100% NPK treated plot (11.38 g kg^{-1}). The marked increase in total carbon content with the application of FYM 20 t ha^{-1} and 100% NPK + FYM can be ascribed to direct addition of organic carbon through FYM and root biomass and root exudates during last twenty one years. Similar effects of FYM and inorganic fertilizer applications on soil organic carbon has also been reported by Singh *et al.*, 2017 [20]; Swati *et al.*, 2018 [21] and Tripura *et al.*, 2018 [22].

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