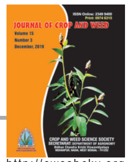
Journal of Crop and Weed, 17(3): 103-108 (2021)

ISSN- O : 2349 9400 ; P : 0974 6315



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Biological properties of soil as influenced by land use practices and soil depths in Vertisols under Mahakaushal region of Madhya Pradesh

***A. SURYAWANSHI, H.K. RAI, G.S. TAGORE AND C. MAZUMDER**

Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) India;Borlaug Institute for South Asia (BISA) Research Farm, Lakhnwara, Jabalpur (M.P) India

Received : 18.06.2021 ; Revised : 27.07.2021 ; Accepted : 07.08.2021

DOI: https://doi.org/10.22271/09746315.2021.v17.i3.1498

ABSTRACT

A study was conducted to assess the vertical variations in biological properties of soil as influenced by land use practices and soil depths in Vertisols after harvest of Kharif and Rabi seasons of 2015-16 and 2016-17. Soil samples were collected from the fields practiced with seven land use practices at Borlaug Institute for South Asia (BISA) Research Farm, Lakhnwara, Jabalpur (M.P) India. For statistical analysis of data in split-plot design, land-use practices were considered as main plot i.e. L_1: Uncultivated, L_2: rice-wheat system with CT, L_3: rice-wheat system with CA, L_4: soybean-wheat system with CT, L_5: soybean-wheat system with CA, L_6: maize-wheat system with CT and L_7: maize-wheat system with CA and soil depth i.e. 0-5, 05-15 and 15-30 cm as sub-plot treatments with three replications. It was found that highest amount of mineralizable carbon in soil was (35.68, 36.29, 37.15 and 37.82 mg kg^{-1}, respectively) obtained in rice-wheat system with CA and lowest values (28.22, 27.67, 27.61 and 27.80 mg kg^{-1}) in maize-wheat system with CT land use practices. However, the data further revealed that highest values (143.78, 153.44, 148.14 and 160.41 µg c g^{-1}) of MBC in soil were recorded in uncultivated and lowest (119.33, 114.59, 118.64 and 121.83 µg c g^{-1}) in rice-wheat system with CT treatments.Data indicated that the significantly highest (39.7, 32.3, 36.6 and 33.1ìg TPF h^{-1} g^{-1}, respectively) dehydrogenase enzyme activity was recorded in uncultivated plots as compared to land use practices.Therefore,it was also noted that mineralizable carbon, MBC and dehydrogenase activity content in soil was decreased significantly with increasing soil depth having highest value in 0-5 cm and lowest in 15-30 cm depths over the seasons and years. Whereas, interaction effects of land use practices and depth of soil was statistically not significant during both the seasons and years.

Keywords: Conservation agriculture, conventional agriculture, dehydrogenase activity, mineralizable carbon and microbial biomass carbon

Soil, being an important natural resource for any agricultural production system, contributes to enhance crop productivity and augment environmental quality within the ecosystem and land-use boundaries by direct or indirect resilience at temporal and spatial scales. A land-use system adds biomass to the soil, binds the soil through the root system, checks runoff, soil and nutrient loss, and ultimately improves the soil health. Thus maintenance of good quality soil is an important aspect to ensure food security through sustainable agricultural production (Kumar *et al.,* 2017). Management of soil approaches have always been focused on a composite set of dynamic and measurable physical, chemical and biological attributes i.e. soil quality which is affected by management and natural drivers (Franchini *et al.,* 2007; Kaur and Bhat, 2017). Organic matter (OM) is important component of soil biota which is directly involved in energy and nutrient cycling. It was well-known that rather than total or available soil organic matter (SOM) or other available soil nutrients more dynamic soil characteristics such as microbial biomass carbon (MBC), enzyme activity and respiration respond faster to changing crop management or ecological conditions (Dick, 1992; Doran *et al.,* 1996). For example, dehydrogenase enzyme activity is good indicator of microbiological activity as it reflects the total range of oxidative activity of soil microflora (Nannipieri *et al.,* 1990; Chaudhury *et al.,* 2005). Alteration soil organic carbon content due to change in physical, chemical and biological properties of soil through diversified crop rotation affects the quality of the soil (Srinivasarao *et al.,* 2013). Microbial diversity, MBC and availability of nutrient are changed by variations in the cropping system (Balota *et al.,* 2003). Agricultural practices like the choice of high biomass producing crops, crop residue retention, switching from monoculture to rotation cropping and adoption of conservation agriculture (CA) could increase C input in agro-ecosystems and change the soil properties (Nieder and Benbi, 2008) and vegetative covers protect soil from adverse conditions (Deekor *et al.,* 2012; Kaur and Bhat, 2017). Soil organic matter is the source of nutrient in soil which improves the physical and chemical properties of soil and also stimulates biological activity in soil as an indicator of soil quality which influences soil enzymes activities as well as microorganism's activities (Salazar *et al.,* 2011).

Email: arpitsurya226@gmail.com

Growth of microorganism and production of enzyme thus depend on quality and quantity of organic matter in the soil because these are sources of energy (Fontaine *et al.,* 2003). During the biological oxidation of soil organic matter dehydrogenases enzyme plays a significant role in transferring hydrogen from organic substrates to inorganic acceptors (Zhang *et al.,* 2010). Production of this enzyme in the soil environment is significantly influenced by various ecological factors like temperature and moisture content of soil, availability of oxygen, soil pH, SOM, soil depth, heavy metal contamination and soil fertilization or pesticide use, etc. However, ploughing operations used in conventional tillage (CT) changes soil structure, decrease OM and microbial activity in the soil;while,CA stimulates the build-up of OM and microbial carbon in the soil. Microbial biomass is the live and active portion of the SOM and more evaluable organic matter reservoir while, soil respiration reflects disturbance and environment productivity (Islam and Weil, 2000; Aleksander *et al.,* 2018). Hitherto, the trial was conducted to assess the effect of different land use practices and soil depth on biological properties of soils.

MATERIALS AND METHODS

A field experiment was carried out during 2015-16 and 2016-17 after harvest of *kharif* and *rabi* crops at Borlaug Institute for South Asia (BISA) Research Farm, Lakhanwada, Jabalpur (M.P), India. The farm is situated under semi-humid Mahakaushal region of Madhya Pradesh. Geographically BISA farm is situated at 23^0 33' N latitude, 80^0 04' E longitude and at an altitude of 407.0 m above mean sea level. Soil of the experimental site belongs to swell-shrink type with dark greyish brown colour. Soils of the BISA farm have been classified as fine, smectitic, hyperthermic family of *Typic Haplusterts* (Vertisols) and known as medium black soil. The study was initiated with seven main plots of land use practices [L_1: Uncultivated, L_2: rice-wheat system with conventional agriculture (CT), L_3: rice-wheat system with conservation agriculture (CA), L_4: soybean-wheat system with CT, L_5: soybean-wheat system with CA, L_6: maize -wheat system with CT and L_7: maize-wheat system with CA) and three sub plots of soil depths i.e.0-05, 05-15 and 15-30 cm with three replications in split plot design. Soil samples were collected from the treatment plots with the help of posthole auger to determine the biological properties of soil following standard procedure. The soil sample thus obtained was subjected to analysis to assess the biological property of the soil.The mineralizable carbon in soil samples was determined using the method given by Keeney and Nelson (1982), MBC in soil samples through chloroform fumigation extraction method (Vance *et al.,* 1987) and dehydrogenase enzyme activity in soil was estimated using the procedure prescribed by Casida *et al.* (1964). The data on different parameters as obtained from chemical analysis were analyzed for test of significance using standard statistical procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Mineralizable carbon

Data pertaining to effects of land use practices and depth of soil on mineralizable carbon of soil after harvest of *kharif* and *rabi* season crops during 2015-16 and 2016-17 are given in Table 1. The mineralizable carbon of soils under different land use practices ranged from 28.22 to 35.68, 27.67 to 36.29, 27.61 to 37.15 and 27.80 to 37.82 mg kg^{-1}, respectively. The highest amount of mineralizable carbon (35.68, 36.29, 37.15 and 37.82 mg kg^{-1}, respectively) was obtained in L_3 (R-W system with CA) followed by L_5 (S-W system with CA) and lowest values (28.22, 27.67, 27.61 and 27.80 mg kg^{-1}) in L_6 (M-W system with CT) treatment. Data also showed that in all the cropping systems mineralizable carbon content in CA was higher than that of CT but the difference was statistically non-significant. However, among the cropping systems, values of mineralizable carbon in soil under rice-wheat rotation was highest followed by soybean-wheat and lowest in maize-wheat rotations. Data further revealed that values of mineralizable carbon in soil at 0-05, 05-15 and 15-30 cm varied from 32.57 to 33.95, 31.08 to 31.89 and 29.07 to 30.97 mg kg^{-1}, respectively. However, that mineralizable carbon content of soil was decreased with depth and highest values (33.95, 32.57, 33.36 and 33.30 mg kg^{-1}, respectively) were obtained in soil at 0-05 cm depth followed by 05-15 cm and lowest (29.07, 29.72, 30.40 and 30.97 mg kg^{-1}, respectively) in 15-30 cm soil depth. Mineralizable carbon content at 0-05 cm soil depth was significantly higher than those obtained in 15-30 cm but statistically at par with 05-15 cm depth. Whereas, interaction effects of land use practices and depth of soil was found non-significant. Results also showed that mineralizable carbon in surface soil was significantly higher than sub-surface soil with highest in 0-5 cm and lowest in 15-30 cm soil depth. It may be because of higher SOC content and microbial activity in surface soil as compared to sub-surface soil. Similar findings were also stated by Schnurer *et al.* (1985), Sayre *et al.,* (2005) and Majumder *et al.* (2008). It was also found that irrespective of cropping systems the mineralizable carbon in soil was more in CA as compared to CT which may be justified by surface retention of residue under CA practice which provided more SOC for mineralization. Van *et al.,*(1991), Huang *et al.* (2012) and Gill *et al.* (2017) also reported that biomass content and SOC exhibits close relationship that directly regulates the amount of mineralizable carbon in soil.

Table 1: Effect of land use practices and soil depth on mineralizable carbon in soil

Main Plot (Land use practices)	Mineralizable carbon (mg kg^{-1})			
	2015-16		2016-17	
	After *kharif* season crops	After *rabi* season crops	After *kharif* season crops	After *rabi* season crops
L_1:Uncultivated	28.47	28.59	29.51	29.63
L_2:R-W system-CT	32.99	31.58	31.52	30.73
L_3:R-W system-CA	35.68	36.29	37.15	37.82
L_4:S-W system-CT	33.36	31.58	31.65	31.28
L_5:S-W system-CA	33.91	32.81	33.85	34.70
L_6:M-W system-CT	28.22	27.67	27.61	27.80
L_7:M-W system-CA	28.83	29.32	30.42	31.34
SEm (±)	**1.711**	**1.403**	**1.161**	**0.889**
LSD (0.05)	**5.098**	**4.184**	**3.314**	**2.572**
Sub-Plot (Soil depth)				
D_1: 0-05 cm	33.95	32.57	33.36	33.30
D_2: 05-15 cm	31.89	31.08	31.26	31.42
D_3: 15-30 cm	29.07	29.72	30.40	30.97
SEm (±)	**1.189**	**0.756**	**0.612**	**0.607**
LSD (0.05)	**3.414**	**2.211**	**1.780**	**1.756**
Main x Sub treatment	**NS**	**NS**	**NS**	**NS**

Table 2: Effect of land use practices and soil depth on microbial biomass carbon (MBC) in soil

Main Plot (Land use practices)	MBC (µg C g^{-1} of soil)			
	2015-16		2016-17	
	After *kharif* season crops	After *rabi* season crops	After *kharif* season crops	After *rabi* season crops
L_1:Uncultivated	143.78	153.44	148.14	160.41
L_2:R-W system-CT	119.33	114.59	118.64	121.83
L_3:R-W system-CA	130.89	123.26	129.29	130.69
L_4:S-W system-CT	124.33	140.50	127.30	145.17
L_5:S-W system-CA	134.22	149.10	135.73	153.89
L_6:M-W system-CT	122.33	127.44	120.82	128.63
L_7:M-W system-CA	128.89	143.33	127.80	148.24
SEm(±)	**1.505**	**1.961**	**2.210**	**1.215**
LSD (0.05)	**4.639**	**6.045**	**6.814**	**3.747**
Sub-Plot (Soil depth)				
D_1: 0-05 cm	173.62	179.96	174.52	182.58
D_2: 05-15 cm	114.71	123.97	120.35	131.79
D_3: 15-30 cm	99.00	103.93	94.14	109.43
SEm (±)	**0.939**	**0.815**	**0.773**	**0.859**
LSD (0.05)	**2.722**	**2.363**	**2.240**	**2.492**
Main x Sub treatment	**NS**	**NS**	**NS**	**NS**

Table 3: Effect of land use practices and soil depths on dehydrogenase enzyme activity in soil

Main Plot (Land use practices)	Dehydrogenase enzyme activity (ì g TPF h^{-1} g^{-1})			
	2015-16		2016-17	
	After *kharif* season crops	After *rabi* season crops	After *kharif* season crops	After *rabi* season crops
L_1:Uncultivated	39.7	32.3	36.6	33.1
L_2:R-W system-CT	29.9	24.0	27.3	23.2
L_3:R-W system-CA	36.4	29.8	33.7	30.4
L_4:S-W system-CT	33.1	26.7	30.5	27.1
L_5:S-W system-CA	37.9	30.6	35.0	31.1
L_6:M-W system-CT	31.4	25.5	29.0	25.7
L_7:M-W system-CA	36.6	29.9	33.8	30.8
SEm(±)	**1.13**	**0.86**	**1.06**	**1.02**
LSD (0.05)	**3.36**	**2.56**	**3.08**	**2.91**
Sub-Plot (Soil depth)				
D_1: 0-05 cm	54.8	44.8	51.5	46.1
D_2: 05-15 cm	29.8	22.8	27.0	24.1
D_3: 15-30 cm	20.1	17.0	18.1	15.7
SEm(±)	**0.43**	**0.31**	**0.41**	**0.37**
LSD (0.05)	**1.21**	**0.89**	**1.12**	**1.00**
Main x Sub treatment	**NS**	**NS**	**NS**	**NS**

Microbial biomass carbon (MBC)

Data presented in Table 2 clearly showed that effect of land use practices and soil depth on MBC in soil after harvest of *kharif* and *rabi* season crops during 2015-16 and 2016-17. The MBC in soil was significantly affected by land use practices and soil depth. It is also evident from the data that highest values (143.78, 153.44, 148.14 and 160.41 µg c g^{-1}) of microbial biomass carbon were recorded in L_1 (uncultivated) followed by L_5 (S-W system with CA) and L_3 (R-W system with CA), while lowest (119.33, 114.59, 118.64 and 121.83 µg c g^{-1}) in L_2 (R-W system with CT) treatments, respectively. Further it was found that MBC in CA was significantly higher than those in CT under all cropping systems, while among the cropping systems highest values of microbial biomass carbon was obtained in soybean-wheat rotation and lowest in rice-wheat rotation.The results also shown that MBC in soil at 0-5, 05-15 and 15-30 cm depths varied from 173.62 to 182.58, 114.71 to 131.79 and 94.14 to 109.43 µg c g^{-1} of soil. The microbial biomass carbon in soil decreased significantly with depth with highest values at 0-5 cm and lowest at 15-30 cm depth. MBC functions as a labile source and acts as driving force for transformation of stable organic forms to available mineral form over longer periods. It also promotes secretion of polysaccharide, acts as cementing material in soil aggregation and increases the enzymatic activities which are responsible for nutrient cycling. More MBC in uncultivated land and CA practice may be attributed to least mechanical disturbances and more microbial population in soil. It was also found that MBC content in surface soil was significantly higher than sub-surface soil and decreased progressively with increasing soil depth up to 30 cm, may be due to less SOC content which reduced microbial population and there movement in deeper soil layers. Cui *et al.* (2013) reported 17–64% higher MBC in soil under CA as to other CT practices. Karlen *et al.* (1994), Balota *et al.* (2003), Roldan *et al.* (2005) and Kumar and Babalad (2018) also stated that intensive tillage (CT) negatively affected MBC because of breaking of water-stable macro-aggregates as it provides favourable habitat to microorganisms, while SOM that provide a substrate for microorganisms are also declined under CT. However, interaction effect of land use practices and depths of soil was non-significant during both seasons over the years.

Dehydrogenase enzyme activity

Data pertaining to effect of land use practices and depth of soil on dehydrogenase enzyme activity after harvest of *kharif* and *rabi season* crops during 2015-16 and 2016-17 are given in Table 3. Data indicated significantly highest (39.7, 32.3, 36.6 and 33.1ì g TPF h^{-1} g^{-1}, respectively) dehydrogenase enzyme activity in L_1 (uncultivated) as compared to those obtained in L_2, L_4 and L_6 treatments but statistically at par with L_3, L_5 and L_7 treatments. It was also found that dehydrogenase enzyme activity in soil under L_2 (rice-wheat system with

CT), L_4 (soybean-wheat system with CT) and L_6 (maize-wheat system with CT) was non-significant. After *kharif* and *rabi* season crops during 2015-16 and 2016-17, dehydrogenase enzyme activity of soil under CA was significantly higher than those in CT, while among the cropping systems, dehydrogenase enzyme activity of soil was higher in soybean-wheat rotation followed by maize-wheat and lowest in rice-wheat system. Data also revealed that dehydrogenase activity of soil at 0-5, 05-15 and 15-30 cm depth ranged from 44.8 to 54.8, 22.8 to 29.8 and 15.7 to 20.1 ì g TPF h^{-1} g^{-1}, respectively. Further it was noted that dehydrogenase activity in soil was decreased significantly with increasing soil depth having highest value in 0-05 cm and lowest in 15-30 cm depths over the seasons and years. The interaction effects of land use practices and depth of soil were statistically not significant during both the seasons and years.

Results revealed that dehydrogenase enzyme activity of soil under uncultivated field was significantly higher than those obtained in convention agricultural practice. It was also found that irrespective of cropping systems the dehydrogenase enzyme activity was higher in CA as compared to CT. Higher dehydrogenase enzyme activity under uncultivated field and CA over CT was due to less disturbances of soil and build-up of SOC. Garcia *et al.* (1997), Roldan *et al.* (2004), Green *et al.* (2007), Liu *et al.* (2014) and Chaudhary *et al.* (2017) also stated dehydrogenase enzyme activity in soil reduced with increasing tillage intensity but increased under CA with incorporation of legume crops in rotation. Results further indicated that dehydrogenase enzyme activity was significantly greater in surface soil as compared to sub-surface, while, increasing depth with decreased enzyme activity was due to less availability of SOM and microbial populations in soil.The dehydrogenase enzyme activity may be used as indicator of biological activity. It was found that oxidation of SOC by dehydrogenase is achieved by transferring protons and electrons from substrates to acceptor (Das and Verma, 2011). Similarly Madejon *et al.* (2007) and Tao *et al.* (2009) also found greater dehydrogenase enzyme activity under CA as compared to CT.

CONCLUSION

Rice-wheat system with conservation agriculture showed higher mineralizable carbon in both the year after harvesting of *kharif* and *rabi* season crops. However, MBC and dehydrogenase enzyme activity was increased under uncultivated land. Therefore, adopting conservation agriculture in different cropping systems could improve the soil biological activity and build-up of SOC to sustain soil health.

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