



Long-term influence of conservation tillage on soil organic carbon and microbial diversity

DHINU YADAV*, LEELA WATI, DHARAM BIR YADAV and ASHOK KUMAR

CCS Haryana Agricultural University, Hisar 125 004, India

Received: 20 September 2019; Accepted: 15 October 2019

ABSTRACT

The physico-chemical and microbiological properties of soil may be modified by long-term tillage practices and crop-rotations. The tillage system, may also affect soil properties under various climatic conditions. In present investigation, soil microbial diversity at different depths was studied in long term tillage experiment continued since 1997-98 (pearl millet-wheat), 2000-01 (sorghum-wheat) and 2015-16 (mungbean-wheat) that was carried out in sandy loam textured soil at Hisar (Haryana) during 2017-18, with 20 years of zero tillage (ZT) under sorghum-wheat, 17 years under pearl millet-wheat and 2 years under mungbean-wheat cropping system, respectively. Adoption of ZT practice positively affected soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, dehydrogenase activity and viable counts of microbes. So, indicating that ZT is an effective measure to improve the physico-chemical and microbiological properties of soil that may lead to improved soil health along with enhanced crop productivity.

Key words: Crop-rotations, Enzyme activities, Microbial biomass carbon, Microbial biomass nitrogen, Soil organic matter, Zero tillage

Soil is a critically important, fundamental and irreplaceable component of the earth's biosphere, functioning as a vital living system in the production of food and fiber, and in the maintenance of biogeochemical cycles. Soil health is most simply defined as 'the capacity of the soil to function' and it consists of the chemical, physical, and biological components of a soil and their interactions (Doran and Zeiss 2000). Soil quality is highly dependent on its structure, natural productivity and human influence; and tillage is the mechanical disturbance of the soil through plowing, cultivation or digging and has been used by the farmers since ancient time. There are number of advantages of tillage as it incorporates biomass in deeper layer of soil, optimize the bulk density; maintain soil aeration, reduce land degradation and improve organic matter accumulation (Hobbs 2007, Yildirim *et al.* 2018).

Conventional tillage (CT) practices may adversely affect long-term soil productivity due to erosion and loss of organic matter in soils. Conservation tillage is the practice in which at least 30% of crop residues are left in the field during sowing, thus reduce soil erosion (Uri 1999). Nevertheless, long-term no-tillage application increases organic carbon content, positively affecting not only soil structure, but also microbiota activity (Desanctis *et al.*, 2012). Microbial activity responds quickly to disturbances in a shorter period of time

than other parameters. The effect of tillage on soil microbial populations have generally been studied by comparing microbial numbers, soil microbial community (Klikocka *et al.* 2012), enzyme activity like dehydrogenase and microbial biomass (Gilsotres *et al.* 2005).

The aim of this research was to investigate differences in the physiological profiles of bacterial communities under ZT and CT following three crop rotations at 0-15 and 15-30 cm depths. The omission of variables, such as tillage, different crop-rotations and other factors, allowed investigation of the effect of the type of soil, its structure, and its characteristics, on the catabolic potential of the microbial community. It is hypothesized that in a good quality soil, the microbial activity and diversity would be higher.

MATERIALS AND METHODS

Collection and preparation of soil samples

To study the effect of conservational practices on various properties of soil under different cropping systems, soil samples (0-15 and 15-30 cm depths) were collected from Agronomy Research Farm, CCS Haryana Agricultural University, Hisar (latitude- 29.08°N and longitude- 75.41°E) fields after harvesting of wheat in 2017, having pearl millet-wheat, sorghum-wheat, and mung bean-wheat cropping system under continuous (20, 18 and 2 years, respectively) zero and conventional tillage. The soil samples collected were sieved through 2 mm sieve for different analysis and stored at 4±1°C. For determination of microbial biomass

*Corresponding author: dhinuyadav737@gmail.com

and microbial activities, the soil was moistened to 60 % water holding capacity (WHC) and incubated at 30^o C for 10 days to permit uniform rewetting and allow microbial activity to equilibrate after the initial disturbances. Sub-samples were air-dried and ground for chemical analysis.

Soil texture

The textural class of the soil was determined from the relative proportion of sand, silt and clay fractions in the sample using textural triangle proposed by International Society of Soil Sciences (ISSS).

Soil organic carbon

The organic carbon content in different soil samples was determined by the method of Kalembassa and Jenkinson (1973).

Microbial biomass carbon and nitrogen

Microbial biomass carbon was estimated by method described by Vance *et al.* (1987) and microbial biomass N was estimated by method described by Pruden *et al.* (1985).

Soil enzyme activity

Soil dehydrogenase activity was determined by the method of Casida *et al.* (1964).

Enumeration of microorganisms

Viable counts of bacteria, fungi and actinomycetes in different soil samples was determined by serial dilution making and plating on respective media.

Statistical analysis

To assess the effects of different tillage practices on the soil properties, the RBD statistical programme was used for three way analysis of variance (ANOVA). Computation and preparation of graphs were done using Microsoft Excel 2007 Program.

RESULTS AND DISCUSSION

Soil texture

The texture of different soil samples collected from conventional and conservation tillage plots was sandy loam. Mechanical composition of soil under conventional tillage was 74% sand, 3% silt and 23% clay, while under conservational tillage respective values were 70%, 8% and 22%.

Soil organic carbon and microbiological properties

Over 60 % of the world's carbon (C) is in soils (over 40 %) and the atmosphere (20 %) (Sundquist 1993; Stevenson 1994). Management systems involving high C inputs and reduced tillage should favor C storage directly by reducing aggregate breakdown and by enhancing SOM-mediated aggregation (Quintero and Comerford 2013). Biochemical characteristics of surface soils differed between tillage treatments and soil organic carbon (SOC) was higher under ZT at surface layer but lower with depth and it is an important indicator of soil health. In present study, soil organic carbon was higher in upper layer than bottom layer with the values 0.32-0.34% and 0.26-0.31% in conventional tillage at surface and subsurface layer, respectively, while respective values under ZT were 0.30-0.36 % and 0.28-0.32 % (Table 1). Individually, crop-rotation, tillage and depth affected organic carbon content significantly but interaction of tillage and depth was non-significant under all systems. Our findings are consistent with those of Naresh *et al.* (2015) and Song *et al.* (2019) that conservation tillage practices significantly influence the total soil organic carbon (SOC) content at surface (0-15 cm) layer compared to CT due to retention of residues, minimum disturbance and accumulation of organic carbon near the soil surface layer in ZT.

Soil management practices and other perturbations of soil system affect the soil microflora and microbial processes that are agriculturally and environmentally important.

Table 1 Effect of conventional and zero tillage on soil organic carbon content, MBC and MBN under different crop rotations

Crop rotation	Tillage	Organic carbon (%)		MBC (mg/kg soil)		MBN (mg/kg soil)		MBC as % of OC	
		Depth (cm)							
		0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Sorghum-wheat	CT	0.33	0.26	133	123	17.6	15.4	0.0391	0.0397
	ZT	0.30	0.28	141	129	20.3	17.2	0.0392	0.0403
Mung bean-wheat	CT	0.34	0.31	135	123	19.1	16.1	0.0409	0.0473
	ZT	0.36	0.32	152	138	23.4	19.8	0.0423	0.0486
Pearlmillet-wheat	CT	0.32	0.29	130	124	18.5	16.4	0.0406	0.0428
	ZT	0.35	0.31	148	136	20.8	19.2	0.0422	0.0445
<i>CD (P=0.05)</i>									
Factor	A (Crop rotation)	B (Tillage)	A × B		C (Depth)		A × C	B × C	A×B×C
OC	0.016	0.013	NS		0.013		NS	NS	NS
MBC	2.344	1.914	3.315		1.914		NS	NS	NS
MBN	0.347	0.283	0.491		0.283		0.491	NS	0.694

Various microbiological properties, viz. microbial biomass carbon and nitrogen of soil under conventional and zero-tillage systems adopting different crop rotations at different locations were determined.

Microbial biomass carbon and nitrogen

The impact of tillage practices on microbial biomass carbon (MBC) and nitrogen in different soil samples shown in Table 1 indicated that under all the crop rotations, microbial biomass carbon and nitrogen was higher in 0-15 cm layer under CT as well as ZT. Under conventional systems, microbial biomass carbon varied between 130 to 135 and 123 to 124 mg/kg soil at surface and subsurface soil, respectively; and 141 to 152 and 129 to 138 mg/kg soil at surface and subsurface soil, respectively, under zero tillage practice. Microbial biomass carbon as % of organic carbon was relatively higher under mungbean-wheat cropping pattern under conservational tillage practices at subsurface layer as compared to conventional tillage followed by various crop rotations (Table 1).

Like microbial biomass carbon the microbial biomass nitrogen (MBN) was also lower in sub-surface layer under all systems. The MBN in different systems ranged between 17.6-19.1 and 15.4-16.4 mg/kg soil, respectively, at surface and subsurface soil in conventional tillage and 20.3-24.4 and 17.2-19.8 mg/kg soil at surface and subsurface layers, respectively, with the adoption of zero tillage practices. Individually, the effect of tillage and depth on MBC and MBN was significant and also the interaction between crop-rotations and tillage on MBC and MBN was significant.

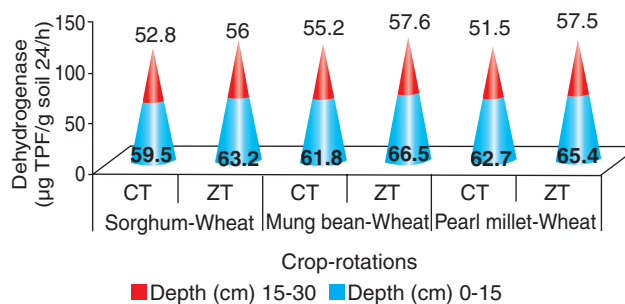
Results of our study are consistent with the findings of Kabiri *et al.* (2015 and 2016) found that higher microbial biomass carbon and nitrogen contents under NT due to the increased SOM (C and N) level probably improved soil aggregation and higher microbial biomass content. In contrary, Zuber *et al.* (2018) found that rotation did not affect microbial biomass C and N (MBC, MBN) while conventional tillage reduced MBN at 10–20 cm compared to NT might be due to dispersion of N fertilizers throughout the soil and MBN was greater in NT than CT because of accumulation of SOM under no-tillage.

Enzyme activity

Soil management practices influences population of microorganisms and enzymatic activities (Saikia and Sharma 2017). Soil microbial processes are governed by various enzymes and are affected by several physical, chemical and environmental factors.

Dehydrogenase activity

In present study, DHA was affected with different tillage practices under different cropping systems at 0-15 and 15-30 cm depth. DHA activity of different soil samples ranged between 59.5 to 62.7 and 51.5 to 55.2 µg TPF/g soil 24/h under the conventional tillage system and increased in a range from 63.2 to 66.5 and 56.0 to 57.6 µg TPF/g soil 24/h at surface and subsurface soil in zero-tillage system,



Enzymatic activity	Factors						
	CD (P=0.05)						
	A (Crop rotation)	B (Tillage)	A×B	C (Depth)	A×C	B×C	A×B×C
Dehydrogenase	0.51	0.416	0.721	0.416	0.721	NS	1.02

Fig 1 Effect of conventional and zero tillage on soil enzymatic activity under different crop rotations.

respectively (Fig 1). Our results are in agreement with the findings of Majchrzak *et al.* (2016) and Bhaduri *et al.* (2017) reported significant impact of tillage systems on DHA that was significantly higher under NT due to accumulation of organic matter and nutrients at the surface soil layer under no-tillage.

Microbial count

Microorganisms in the soil strongly influence soil processes (Garbeva *et al.* 2004), fulfill key roles in the decomposition of organic matter, the cycling of carbon and nitrogen, and the formation and stabilization of soil structure (Loranger-Merciris *et al.* 2006). Therefore, the constituents of soil microorganisms, such as microbial community, have often been identified as sensitive indicators of biological indices for maintaining soil health and quality.

In this study, the microbial population increased by adoption of zero-tillage as compared to conventional tillage and was higher in surface soil under both tillage systems. The effect of tillage practices on total bacterial population presented in Table 2 revealed that total bacterial count in different soil samples ranged from 7.68 to 8.36 ×10⁶ and 6.42 to 7.06×10⁶ cfu/g soil at 0-15 and 15-30 cm depths, respectively, under conventional system which increased to 8.35 to 8.80×10⁶ and 6.98 to 7.55 ×10⁶ cfu/g soil at 0-15 and 15-30 cm depths, respectively, under zero-tillage.

Fungal population in surface and subsurface soil samples varied between 10.4 to 12.8×10³ and 8.9 to 9.2×10³ cfu/g soil under conventional tillage practices which increased in a range from 13.5 to 14.8×10³ and 9.5 to 10.4×10³ cfu/g soil under zero-tillage system (Table 2).

Actinomycetes population also increased with zero tillage system (Table 2). The actinomycetes population at 0-15 and 15-30 cm depths found in a range from 3.18 to 3.27 ×10⁴ and 2.43 to 2.50×10⁴ cfu/g soil in conventional-tillage system which increased in a range from 3.56 to 3.80×10⁴

Table 2 Effect of conventional and zero tillage on viable count of different microbial groups under different crop rotations

Crop rotation	Tillage	Bacteria (CFU/g soil × 10 ⁶)		Fungi (CFU/g soil × 10 ³)		Actinomycetes (CFU/g soil × 10 ⁴)	
		Depth (cm)					
		0-15	15-30	0-15	15-30	0-15	15-30
Sorghum-wheat	CT	8.04	6.90	10.4	8.9	3.18	2.43
	ZT	8.78	7.12	13.5	9.5	3.56	2.93
Mung bean-wheat	CT	8.36	7.06	12.8	9.2	3.27	2.50
	ZT	8.80	7.55	14.8	10.4	3.80	3.37
Pearlmillet-wheat	CT	7.68	6.42	11.9	9.1	3.23	2.46
	ZT	8.35	6.98	13.5	10.2	3.69	2.83

CD (P=0.05)

Factors

Viable count	A (Crop rotation)	B (Tillage)	A × B	C (Depth)	A × C	B × C	A × B × C
Bacteria	0.137	0.112	NS	0.112	NS	NS	NS
Fungi	0.304	0.248	0.429	0.248	0.429	0.35	NS
Actinomycetes	0.027	0.022	0.039	0.022	0.039	0.032	0.055

and 2.83 to 3.37 × 10⁴ cfu/g soil at both depths with different crop rotations under zero-tillage system.

These results are consistent with the findings of Dongre *et al.* (2017) attributed relatively higher bacterial, actinomycetes and fungal count at 0-15 cm depth under conservation agriculture system to submerged conditions in deeper layer. Schmidt *et al.* (2018) recorded higher total bacterial number in cover cropped plots at different depths, while no-till treatments showed higher number at surface layer compared to standard tillage because farming practices and depths favored distinctly different microbial life strategies.

Conclusion

Based on present study, it might be concluded that the zero tillage system influences the physico-chemical and microbiological properties of soil under different crop rotations. The organic matter accumulation, viable count of microbes, and dehydrogenase activity was relatively higher at surface layer under different cropping systems in general, and pearl millet-wheat, sorghum-wheat and mungbean-wheat cropping systems in particular, by adopting zero tillage practices, because crop-residues as source of organic carbon in soil help in N fixation.

REFERENCES

- Bhaduri D, Purakayastha T J, Patra A K, Singh M and Wilson B R. 2017. Biological indicators of soil quality in a long-term rice-wheat system on the Indo-Gangetic plain: combined effect of tillage-water-nutrient management. *Environmental Earth Science* **76**(5): 1-14.
- Casida L E, Klein D A and Santoro R. 1964. Soil dehydrogenase activity. *Soil Science* **98**: 371-376.
- Desanctis G, Roggero P P, Seddaiu G, Orsini R, Porter C H and Jones J W. 2012. Long-term no tillage increased soil organic carbon content of rain-fed cereal systems in a Mediterranean area. *European Journal of Agronomy* **40**:18-27.
- Doran J W and Zeiss M R. 2000. Soil health and sustainability; managing the biotic component of soil quality. *Applied Soil Ecology* **15**: 2-11.
- Dongre K, Sachidanand B and Porte S S. 2017. Assessment of different microbial population in the rhizosphere of main kharif crop under conventional and conservation agriculture system. *International Journal of Current Microbiology and Applied Sciences* **6**(9): 813-819.
- Garbeva P, Van Veen J A and Van Elsas J D. 2004. Microbial diversity in soil: selection of microbial populations by plant and soil type and implications for disease suppressiveness. *Annual Review of Phytopathology* **42**: 243-270.
- Gil-sotres F, Trasar-cepeda C, Leiros M C and Seoane S. 2005. Different approaches to evaluating soil quality using biochemical properties. *Soil Biology and Biochemistry* **37** (5): 877-887.
- Hobbs P R. 2007. Conservation agriculture: What is it and why is it important for future sustainable food production? *Journal of Agricultural Science-Cambridge* **145**(2): 127-137.
- Kabiri V, Raiesi F and Ghazavi M A. 2015. Six years of different tillage systems affected aggregate-associated SOM in a semi-arid loam soil from Central Iran. *Soil and Tillage Research* **154**: 114-125.
- Kabiri V, Raiesi F and Ghazavi M A. 2016. Tillage effects on soil microbial biomass, SOM mineralization and enzyme activity in a semi-arid Calcixerepts. *Agriculture, Ecosystems and Environment* **232**: 73-84.
- Kalembassa S J and Jenkinson D S. 1973. A comparative study of titrimetric and gravimetric methods for the determination of organic carbon in soil. *Journal of the Science of Food and Agriculture* **24**: 1089-1090.
- Klikocka H, Narolski B, Klikock O, Głowack A, Juszczak D, Onuch J, Gaj R, Michałkiewicz G, Cybulska M and Stepaniuk S. 2012. Fertilization on microbiological parameters of soil on which spring triticale is grown. *Polish Journal of Environmental Studies* **21**(6): 1675-1685.
- Loranger-Merciris G, Barthes L, Gastine A and Leadley P. 2006.

- Rapid effects of plant species diversity and identity on soil microbial communities in experimental grassland ecosystems. *Soil Biology and Biochemistry* **38**: 2336–2343.
- Majchrzak L, Sawinska Z, Natywa M, Skrzypczak G and Głowicka-Wołoszyn R. 2016. Impact of different tillage systems on soil dehydrogenase activity and spring wheat infection. *Journal of Agriculture, Science and Technology* **18**(20): 1871–1881.
- Naresh R K, Gupta R K, Gajendra P, Dhaliwal S S and Kumar D. 2015. Tillage crop establishment strategies and soil fertility management: resource use efficiencies and soil carbon sequestration in a rice-wheat cropping system. *Ecology, Environment and Conservation* **21**: 127–134.
- Pruden G, Kalembassa S J and Jenkinson D S. 1985. Reduction of nitrate prior to Kjeldahl digestion. *Journal of the Science of Food and Agriculture* **19**: 159–164.
- Quintero M and Comerford N B. 2013. Effects of conservation tillage on total and aggregated soil organic carbon in the Andes. *Open Journal of Soil Science* **3**(8): 361–373.
- Saikia R and Sharma S. 2017. Soil enzyme activity as affected by tillage and residue management practices under diverse cropping systems. *International Journal of Current Microbiology and Applied Sciences* **6**(10): 1211–1218.
- Schmidt R, Gravuer K, Bossange A V, Mitchell J and Scow K. 2018. Long-term use of cover crops and no-till shift soil microbial community life strategies in agricultural soil. *Plos One* **13**(2): 1–19.
- Song K, Zheng X, Lv W, Qin Q, Sun L, Zhang H and Xue Y. 2019. Effects of tillage and straw return on water-stable aggregates, carbon stabilization and crop yield in an estuarine alluvial soil. *Scientific Reports* **9**(1): 1–11.
- Stevenson F J. 1994. *Humus Chemistry: Genesis, Composition, Reactions*, 2nd Edition. John Wiley and Sons Ltd, New York.
- Sundquist E T. 1993. The global carbon dioxide budget. *Science* **259**(5097): 936–961.
- Uri N D. 1999. Factors affecting the use of conservation tillage in the United States. *Water Air Soil Pollution* **116**: 621–638.
- Vance E D, Brookes P C and Jenkinson D S. 1987. An extraction method for measuring soil microbial biomass C. *Soil Biology and Biochemistry* **19**: 703–707.
- Yildirim M, Dumlupinar Z and Taner A. 2018. Effects of conventional and reduced tillage methods on some traits of wheat in cotton-wheat system. *Journal of Agriculture and Nature* **21**(5): 678–685.
- Zuber S M, Behnke G D, Nafziger E D and Villamil M B. 2018. Carbon and nitrogen content of soil organic matter and microbial biomass under long-term crop rotation and tillage in Illinois, USA. *Agriculture* **8**(3): 1–12.