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IMPACT OF CONSERVATION TILLAGE ON ORGANIC MATTER DYNAMICS IN LOESS DRYLAND SOIL, PUNJAB, PAKISTAN

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ABSTRACT

Conservation tillage and carbon sequestration are critical issues in rain-fed farming areas of Pakistan. Conservation tillage is not extensively used in developing countries on dryland soil where marginal farming is practiced. Therefore, primary purpose of this experiment was to determine the influence of conservation tillage practices on soil organic carbon (SOC), particulate organic matter (POC), mineral associated organic carbon (MOC), microbial biomass carbon (MBC) and dehydrogenase activity (Dha) in loess dry land Pothwar, Punjab, Pakistan. The tillage practices included zero tillage (ZT), minimum tillage (MT), reduced tillage (RT) and conventional tillage (CT) with mouldboardplough as a control in main plot and fallow-wheat (*Triticumaestivum* L.) and mungbean (*Vigna radiate L.*) crop rotation in sub plot as a split plot layout. The results indicated that ZT showed higher SOC (7.90 g kg^{-1}), POC (2.35 g kg^{-1}), MOC (5.1 g kg^{-1}), MBC (359.37 $\mu g g^{-1}$) and Dha (45.12 TPF$\mu g g^{-1}$ dry weight) than CT. Among crop rotation, overall mungbean-wheat showed higher values as compared to fallow-wheat crop. The study indicated that conservation tillage practices with legume crop rotation have potential for improving soil organic carbon storage and hence carbon sequestration in soil.

Keywords: Conservation tillage; soil organic carbon; microbial biomass carbon; dehydrogenase enzyme; loess dryland; mungbean-wheat

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INTRODUCTION

Soil organic carbon (SOC) is important for climate regulation, as it stabilizes carbon and mitigates yield reduction (Lal, 2004a). Despite its importance, loss of soil SOC is occurring, causing decline in soil fertility (Yu *et al*., 2006). Soil organic carbon loss is exacerbated due to conventional tillage (CT) practices such as removal of crop residues after harvest and intensive use of mouldboard plough (MBP) that disturbs the soil (Zhang *et al*., 2015). Such intensive tillage practices also affect the rate of carbon sequestration in soil (Roldán *et al*., 2005) and increase emission of greenhouse gasses CO_2(La Scala *et al*., 2008),N_2O (Chatskikh and Olesen, 2007) and CH_4(Li *et al*., 2011). Conventional tillage practices also cause degradation of soil structure (Willekens *et al*., 2014)and erosion that result in loss of SOC (Liu *et al*., 2010). Intensive tillage practices on large scale result in reduction of soil organic matter, soil quality, and fertility in arid and semi-arid conditions (Álvaro-Fuentes *et al*. 2013; Abdullah, 2014). Thus, depletion of SOC has become a threat to agricultural production. Therefore, to reverse the trend of SOC loss, it is crucial to prioritize the adoption of practices that increase SOC such as the "4 per 1000" Initiative (https:// www.4p1000.org/) aims. This initiative aims at promoting soil management practices e.g. adoption of cover crops and reduced tillage to effectively increase SOC (Lal, 2016). Proper management of land can increase SOC (Lal, 2014, Zhang and Ni, 2017) through organic matter input and improvement of soil structure by promoting aggregates stability (Deb *et al*., 2015).

Conservation tillage practice (minimum soil disturbance, direct drilling, zero/no-tillage etc) is considered to be effective in increasing SOC and decreasing erosion in Northeast China (Zhang *et al*., 2015). Conservation agriculture with proper crop residue management practices had been shown not only to increase SOC but also improve soil quality and reduced soil degradation (Awale *et al*., 2013). Many studies have reported an increase in SOC and carbon fractions under short and long term residue management, mulching, integrated nutrient management, and fertilization (Verma *et al*., 2013; Mi *et al*., 2016). In CT, intensive ploughing leaves less than 15 percent of the crop residue, whereas, in conservation tillage, 30% of crop residue is left on soil surface (CTIC, 2015). However, the effect of zero tillage (ZT) on SOC is not always clear and consistent. In some studies, no-tillage has increased SOC as compared to CT (West and Post, 2002; Ogle *et al*., 2005; Kumar *et al*., 2012) while in other studies that was not the case (Baker *et al*., 2007; Blanco-Canqui and Lal, 2008; Powlson *et* *al*., 2014). These differences might be due to variations in soil type, duration of tillage, cropping systems and environmental conditions (Blanco-Canqui, 2013). The effect of cropping systems on SOC is crucial as it affects the characteristics and amount of crop residue input (Yang and Kay, 2001; Zuber *et al*., 2015). Crop residues differ in chemical composition that mostly determines their rate of decomposition and incorporation to the soil organic matter pool (Ogle *et al*., 2012; Poeplau *et al*., 2015). Other useful practices, for instance, conversion of fallow land to agro forestry and horticultural or cropland, could improve SOC and fractions on long term basis due to higher input (aboveground and belowground biomass) of organic matter in soil (Ramesh *et al*., 2013; Ramesh *et al*., 2015).

SOC is composed of different compounds that vary from simple to complex molecules that differ in stability (Deb *et al*., 2015). SOC has three different pools/fractions: slow, passive and active (Paul and Clark 1996; Paul and Collins 1998).Soil microbial biomass carbon (MBC) and particulate organic carbon (POC) are included in the active pool that is labile and may turnover from days to years (Brady and Weil, 2008). The role of these fractions in nutrient turnover is essential. Changes caused by soil management practices are difficult to determine only through quantification of total SOC measurements (Haynes, 2005). Quantifying changes in labile carbon pool has shown help in detecting changes in soil quality (Wang *et al*., 2014; Awale *et al*., 2017). Thus, chemical, physical and biological fractions of SOC e.g. POC, MBC and mineral associated organic carbon (MOC) have received more attention as they are more sensitive to soil management practice than total SOC (Dou *et al*., 2008). MOC is that carbon fraction in soil organic matter pool, which is stabilized physically and chemically. It is considered a passive pool of carbon that takes long time for the turnover process (Marschner *et al*., 2008). The passive and slow pools show more resistance to decomposition and turnover from decades to centuries (Dumale *et al*., 2009). The bioavailability of these fractions for microbial decomposition is very low due to the long turnover time (Six *et al*., 2002; Benbi *et al*., 2014).

Enzymes are biological catalysts that speed up chemical reactions without being consumed by the reaction. These chemical reactions are essential for microbial processes in soil, organic waste decomposition, organic matter formation and soil structure stabilization (Dick *et al*., 1994).Soil enzymes are produced by plants, animals and microorganisms and may be present in dead cells and cell debris and are also adsorbed by clay or incorporated into humic substances (Allison, 2005). Soil enzymes and SOC pools especially labile pools are considered good indicators for short term impacts with soil management (Hok *et al*., 2018). Soil enzymes play a significant part in mineralization of organic matter (María *et al*., 2002). Soil enzyme activities are often used as indicators of microbial activity and nutrient cycling (Sinsabaugh *et al*., 2008).For instance, soil dehydrogenase activity (Dha) mediate soil organic matter oxidation via the transfer of electron and proton from substrates to acceptors. Soil Dha occurred intracellular in all living cells of microorganisms. Thus, it is a good indicator of microbial activity (Stępniewska and Wolińska, 2005)

Conservation tillage is practiced on 125 million hectares of land all over the world and makes up 9% of arable cropland worldwide (Kassam *et al*., 2012). North America has the most significant share at45%, followed by South America and Canada (32%), New Zealand and Australia (14%) and the rest of the world (9%) (Friedrich *et al*., 2012). In Asia, only 2.2 % of the agricultural lands are under conservation tillage (Derpsch and Friedrich, 2010). Little information exists regarding SOC pools and its sensitivity to change under different land management practices in South Asian countries such as Afghanistan and Pakistan. In Pakistan, most research on SOC is related to fertility and the amount of soil organic carbon. There is less work regarding agricultural management practices to increase the quantity and quality of SOC (Lal, 2004b).

The dryland agroecological system of Pakistan consists of Pothwar plateau (Rawalpindi, Jhelum and Attock districts), upland of Khyber Pakhtunkhwa, Balochistan plateau, and desert of Cholistan (Sharif *et al*., 2017). In these areas, dryland farming has some constraints including low rainfall, soil fertility, and weakly structured soil, degraded and low in SOC concentration. In dryland farming, farmers employ a more intensive cultivation method with MBP (traditionally, 8–10 ploughings) and commonly grow winter wheat crop and leave the land fallow for six months till the next winter crop to conserve soil moisture (Hassan *et al*., 2015).Sixty-five percent of farmers employ a wheat-maize (2-year system) rotation system where eighty percent of farmers practice summer fallow with wheat (Arif and Malik, 2009).

In dryland areas of Pakistan, most studies on conservation tillage are related to yield improvement, and less information is available in relation to soil organic carbon fractions (Niaz *et al*., 2017). Therefore, more information is needed on the relationship among conservation tillage practices, SOC and soil quality in these areas. In view of this scenario, our study was conducted to evaluate the impact of conservation tillage practices on SOC and its fractions and soil Dha activity in crop rotation (wheat and mungbean). It was hypothesized that organic C, carbon fractions and soil enzyme activity improve with conservation tillage practices.

MATERIALS AND METHODS

Description of Study Location: A two-year conservation tillage field study was established in 2016 at the research farm of Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, Pakistan (latitude 33°36'0" N, longitude 73°02'0" E) in a sandy clay loam soil. The experimental site is located in semi-arid dryland Pothwar (elevated 517 m from sea level) in the northern Punjab area (Fig.1). The area of Pothwar is 28488.9 sq Km. The major crops in Pothwar include wheat, millet, gram, barley, groundnut, and maize. The fallow-wheat (FW) system and intensive MBP tillage are common practices in this area. In summer, the temperature is very hot (range from 36ºC to 42ºC) and can get as high as 48 ºC in the extreme case (Nizami *et al*., 2004). In winter, temperature ranges between 4 ºC and 25 ºC but can drop below freezing point (Hussain *et al*., 2003). Seventy percent of the annual precipitation (750-950 mm) occurs during the summer or monsoon season (June to August). These heavy rain events cause soil erosion (Shaheen *et al*., 2010). In this area, dryland farming (6% irrigated and 94% rain-fed) has been a common practice for centuries. The soil pH and ECwere7.89 and 0.60 dS m^{-1}, respectively. The soil has 55.2% sand, 23.4% silt, 21.4% clay and 5.5 g/kg SOC.

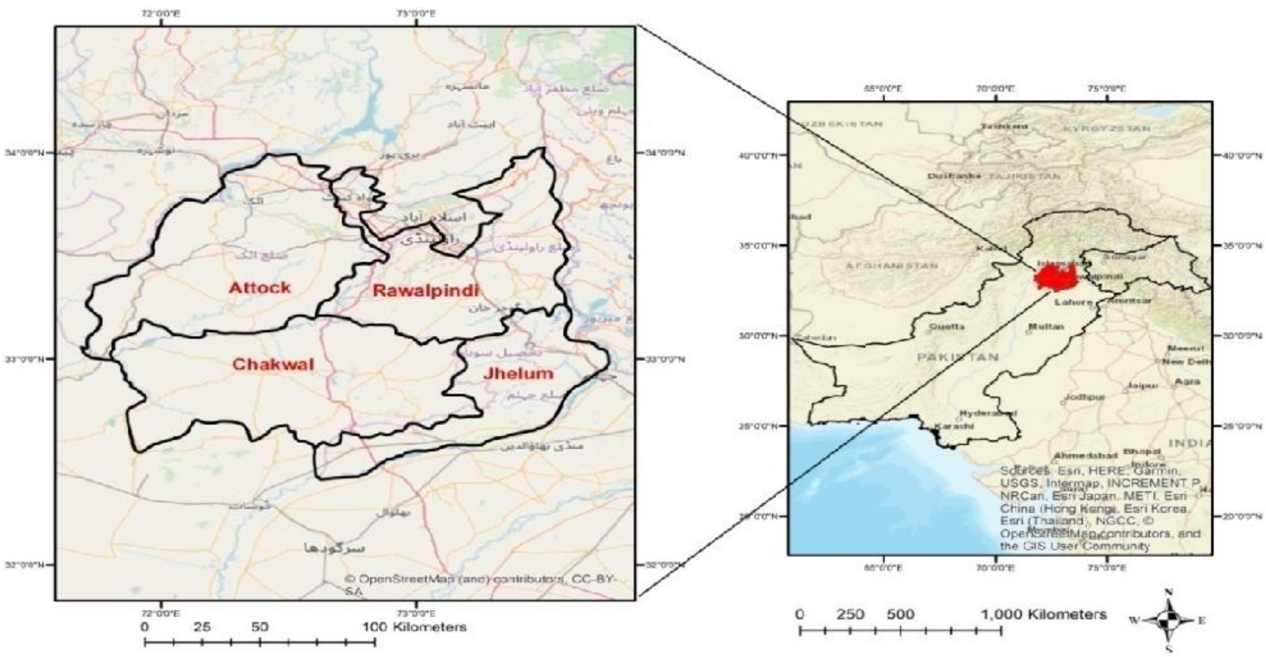

Figure1. Location of study sites in thepothwar plateau, Punjab.

Experimental Design: Thirty-two experimental plots, each of size 29 m × 11 m, were prepared to accommodate four treatments with four replications. The basic layout of the experimental plots in the field was split-plot design under RCBD (randomized complete block design). The main plot treatments were tillage systems that include CT (conventional tillage) in which soil was ploughed with MBP followed by 8 cultivations with tine cultivator; Minimum Tillage (MT) in which field was ploughed with chisel plough at depth of 25 cm followed by 4 times cultivation with tine cultivator; Reduced Tillage (RT) in which the soil was ploughed with chisel plough one time at a depth of 45 cm and treated with roundup herbicide (Glyphosate @ 1 L $acre^{-1}$) for weed control; and ZT in which the plots were undisturbed for entire fallow period and weeds were controlled with roundup. Crop residues were retained in ZT and RT plots after crop harvest, while crop residues were removed from the MT and CT treated plots. Subplot treatments were fallow-wheat (FW) and mungbean-wheat (MW). Wheat (Chakwal-97) crop was seeded in the mid of November and harvested in May. Summer crop (Mungbean MN-11) was planted at the end of June and harvested in September.

Soil Sampling: A composite soil sample was collected from each plot of the experimental site before planting in order to analyze the basic (chemical, biological and physical) properties of soil. Plastic bags were used to preserve the soil samples then immediately shipped to laboratory for analysis. The air-dried sub-sample was ground and sieved with 2.0 mm sieve to determine the soil organic carbon and fractions. For analysis of soil dehydrogenase enzyme activity, fresh soil samples were immediately stored in a plastic bag at 4^0Cand then analysed within ten days.

Soil Physicochemical Analysis: The fractions of carbon were determined as described in (Cambardella and Elliott 1992). Soil sample (25g) was suspended in sodium hexametaphosphate solution (200ml) and transferred into the flask (500ml) and shaked for 30 min. on a mechanical shaker. The coarse fraction was separated after washing of soil suspension via >53mm sieve. The soil samples that were sieved or passed through the sieve were mineral MOC, and those that remained on the sieve were POC. The carbon fractions were transferred into an oven to dry at 60 ºC for organic carbon analysis via wet oxidation method. SOC, POC, and MOC were determined using the wet oxidation method (Walkley, 1947). Briefly, 1gm of soil was added into 500ml conical flask with 10 ml of potassium dichromate (1N) and 20 ml H_2SO_4, mixed and left it for 30 minutes. Then, distilled water (200 ml) and 10 ml concentrated H_3PO_4were added and allowed to cool it. The indicator diphenylamine (10-12 drops) was added and titrated with (0.5M) ferrous ammonium sulfate solution till color changes from violet blue to green.

Microbial biomass carbon was determined withchloroform ($CHCl_3$) fumigation extraction method. Briefly, one portion of soil (10g) was fumigated by placing in desicator with 30 ml alcohol free chloroform in another 50 ml beaker for 18-24 hours at 25 ºC and samples were extracted with 50 ml 0.5 M K_2SO_4 for 30 min at 200 revolutions per minute and filtered. The other portion of 10g soil was also extracted in the same way but without the fumigation process and extract (4 ml) was mixed with 0.0667 M potassium dichromate (1 ml) andconcentrated (5 ml) Sulphuric acid H_2SO_4. An indicator O-phenanthroline monohydrate (3-4 drop) was used and samples were titrated with ferrous ammonium sulphate solution till color changes from green/ violet to red (Anderson and Ingram, 1993). Analysis of Soil Enzymes Activity Soil Dha was determined colorimetrically as described in Alef and Nannipieri (1995). Complete procedure was done in diffused light due to light sensitivity.

Statistical Analyses: The data collected for various characteristics was subjected to analysis of variance (ANOVA) using split plot design under RCBD with Statistics® 8.1 software and means were compared at 5% level of significance by least significance difference test (Steel *et al*., 1997).

RESULTS

Soil Organic Carbon: The tillage practices and crop rotations had significantly affected SOC.SOC was the highest in ZT followed by RT with crop residues retention and MT as compared to CT. The highest amount of SOC (p =0.0001) was observed in ZT (7.90 gkg^{-1}) in MW and ZT (7.35 g kg^{-1}) in FW crop residues, followed by RT (7.21 g kg^{-1}) in MW and RT (6.86 g kg^{-1}) in FW crop residues (Table 1). The pattern of SOC among tillage treatment was in this order ZT > RT > MT > CT. Among crop rotations, MW resulted in6.85 g kg^{-1}soil SOC and FW in 6.57g kg^{-1}.

Table 1. Soil organic carbon (g kg^{-1}) changes in 0-15 cm soil with different conservation tillage and crop rotation practices: fallow-wheat (FW), mungbean-wheat (MW).

		2016-2017		2017-2018	
Treatment		**Summer**	**Winter**	**Summer**	**Winter**
Conventional Tillage	MW	5.82 c	5.66 e	5.83 e	5.98 d
	FW	5.54 c	6.02 de	6.03 e	5.96 d
Minimum Tillage	MW	5.81 c	6.31 cd	6.59 cd	6.72 bc
	FW	5.72 c	5.89 de	6.24 de	6.31 cd
Reduced Tillage	MW	6.17 abc	6.50 bc	7.14 ab	7.21 b
	FW	6.03bc	6.10 cd	6.73 bcd	6.86 bc
Zero Tillage	MW	6.72 a	7.14 a	7.42 a	7.90 a
	FW	6.59 ab	6.72 ab	7.07 abc	7.35 ab

Means with different letters show significant differences (p< 0.05).

Mineral Associated Organic Carbon: By the end of first year, only tillage practices had affected the soil MOC (p = 0.0002) and crop rotation effects were non-significant. However, in the second year, tillage and crop rotation both significantly affected MOC. The highest amounts of MOC were observed in ZT (5.1 g kg^{-1}) and RT (4.85 g kg^{-1}) in MW. Similarly, ZT (4.85 g kg^{-1}) and RT (4.57 g kg^{-1}) resulted in higher values in FW crop residue retention and then in MT as compared to CT (p = 0.0003) (Figs.2 and 3). In second year, MW had higher soil MOC (4.59 g kg^{-1}) than FW (4.36 g kg^{-1}) rotation (p = 0.013).

Particulate Organic Carbon: ZT and RT with both crop residues retention significantly affected the soil POC as compared to other tillage treatments (p< 0.05) in both years. The highest POC (p= 0.0001) values were observed in ZT (2.35 gkg^{-1}) and RT (2.29 g kg^{-1}) at the end of the second year in MW residues retention. Similarly, soil POC was highest in ZT (2.21g kg^{-1}) and RT (1.87 g kg^{-1}) in FW residues retention, followed by

MT as compared to CT. The lowest soil POC was determined in CT (1.02 g kg^{-1}) treatment under FW rotation (Table 2). Among crop rotations, MW (1.77 g kg^{-1}) rotation had significantly higher soil POC than FW (1.62 g kg^{-1}) rotation (p = 0.012).

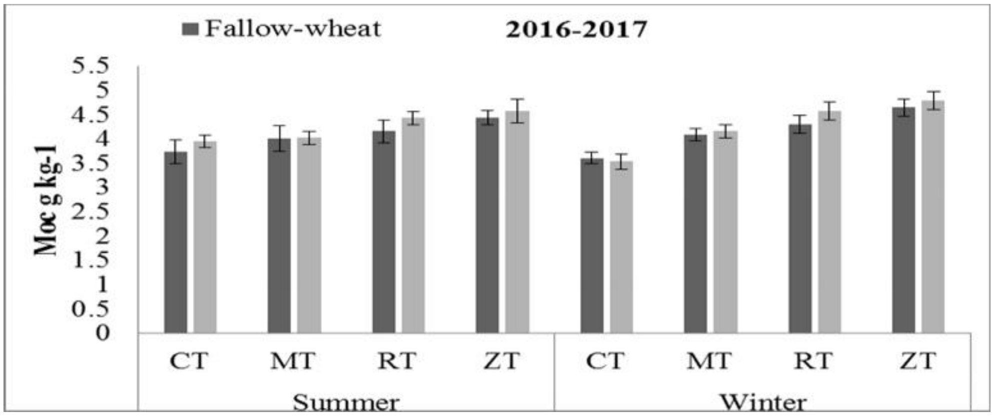

Figure 2. Soil MOC changes in 0-15 cm soil with different conservation tillage and crop rotation practices. Error bars in the mean values indicates the standard error. Abbreviations: MOC = mineral associated organic carbon,CT= conventional tillage, MT = minimum tillage, RT = reduced tillage, ZT = zero tillage.

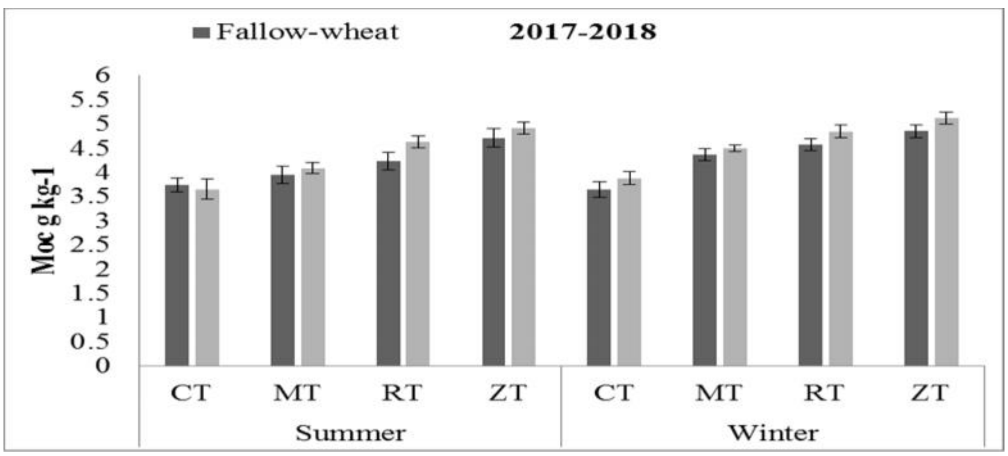

Figure 3. Soil MOC (mineral associated organic carbon) changes in 0-15 cm soil with different conservation tillage and crop rotation practices. Error bars in the mean values indicates the standard error. Abbreviations: MOC = mineral associated organic carbon, CT = conventional tillage, MT = minimum tillage, RT = reduced tillage, ZT = zero tillage.

Table 2. Soil particulate organic carbon (g kg-1) changes in 0-15 cm soil with different conservation tillage and crop rotation practices: fallow-wheat (FW), mungbean-wheat (MW).

		2016-2017		2017-2018	
Treatment		**Summer**	**Winter**	**Summer**	**Winter**
Conventional Tillage	**MW**	**1.02 d**	**1.14 e**	**1.32 de**	**1.20 f**
	FW	**1.10 bcd**	**1.31 de**	**1.23 e**	**1.38 e**
Minimum Tillage	**MW**	**1.39 ab**	**1.44 cd**	**1.53 cd**	**1.66 cd**
	FW	**1.10 cd**	**1.24 e**	**1.32 e**	**1.56 de**
Reduced Tillage	**MW**	**1.53 a**	**1.72 ab**	**2.01 a**	**2.29 ab**
	FW	**1.35 abc**	**1.59 bc**	**1.60 bc**	**1.87 c**
Zero Tillage	**MW**	**1.65 a**	**1.91 a**	**1.86 ab**	**2.35 a**
	FW	**1.51 a**	**1.68 bc**	**1.81 ab**	**2.21 b**

Means with different letters showed significant differences (P < 0.05).

Microbial Biomass Carbon: Soil MBC was also significantly affected by tillage and crop rotation in both years. Among different tillage systems, the highest values were observed in ZT (359.37 μgg^{-1}) and (295.12 μg g^{-1}) followed by RT (294.03 μg g^{-1}) and (251.56 μg g^{-1}) in MW and FW residues retention ($p = 0.0003$), respectively (Table 3). The lowest amount of MBC (141μg g^{-1}) was observed in CT in the FW rotation. Among crop rotation, MW had shown (239.17 μg g^{-1}) significantly higher ($p = 0.009$) value than FW (208.00 μg g^{-1}).

Soil Dehydrogenase Enzyme Activity: The results showed that among tillage systems, soil Dha enzyme activity was significantly higher in ZT, RT and MT than control in first and second years. The highest enzyme activities ($p = 0.001$) were observed in ZT (45.12 TPF μg g^{-1}(dwt) in MW and ZT (43.62 TPF μg g^{-1}(dwt) in FW rotation (Table 4). The lowest activity was observed in CT (22.62 TPF μg g^{-1}(dwt) in FW and CT (25.15 TPF μg g^{-1}(dwt) in MW rotations. Among crop rotations, in the first year of experiment results were non-significant but in the second year, FW rotation had lower ($p = 0.005$) values (33.93 TPF μg g^{-1} (dwt) than MW (37.28 TPF μg g^{-1} (dwt).

Table 3. Soil Microbial biomass carbon (μgg^{-1}) changes in 0-15 cm soil with different conservation tillage and crop rotation practices: fallow-wheat (FW), mungbean-wheat (MW).

Treatment		2016-2017		2017-2018	
		Summer	Winter	Summer	Winter
Conventional Tillage	MW	153.55 bc	163.35 c	157.91 de	174.24 ef
	FW	138.30 c	143.75 c	141.57 e	147.02 f
Minimum Tillage	MW	163.35 bc	186.22 bc	186.22 cde	238.49 cd
	FW	152.46 bc	153.55 c	185.13 cde	206.91 de
Reduced Tillage	MW	185.13 ab	219.98 ab	229.78 abc	294.03 bc
	FW	175.33 bc	186.22 bc	196.02 bcd	251.56 bcd
Zero Tillage	MW	221.07 a	261.36 a	273.34 a	359.37 a
	FW	167.71 bc	217.80 b	240.67 ab	295.12 ab

Means with different letters showed significant differences ($P < 0.05$).

Table 4. Soil dehydrogenase activity (TPF μgg^{-1} (dwt)) changes in 0-15 cm soil with different conservation tillage and crop rotation practices: fallow-wheat (FW), mungbean-wheat (MW).

Treatment	Crop rotaion	2016-2017		2017-2018	
		Summer	Winter	Summer	Winter
Conventional Tillage	MW	25.15 bc	27.12 e	29.54 cd	29.77 c
	FW	22.62 c	24.46 e	27.00 d	26.77 d
Minimum Tillage	MW	29.08 abc	29.08 cde	34.38 bc	37.84 b
	FW	27.12 abc	27.58 de	34.50 bc	33.12 c
Reduced Tillage	MW	31.62 ab	32.08 bcd	37.26 ab	42.69 a
	FW	28.62 abc	32.77 abc	29.54 cd	39.12 b
Zero Tillage	MW	32.77 a	37.62 a	41.65 a	45.12 a
	FW	33.92 a	34.62 ab	37.85 ab	43.62 a

Means with different letters showed significant differences ($P < 0.05$).

DISCUSSION

Present study recorded considerably higher SOC content in ZT with crop residues left after harvest, as compared to traditional intensive tillage (CT). The results are in agreement with findings of Sharif *et al*. (2015) who worked under similar semiarid conditions and found higher SOC, POC, MOC, MBC in ZT than the other tillage treatments. It has been repeatedly reported in semiarid areas that long term application of conservation tillage increased the SOC(Álvaro-Fuentes *et al*., 2008; Hernanz *et al*., 2009; Lopez-Fando and Pardo, 2011). The increase in SOC storage with ZT tillage is also supported by many other studies (Yeboah *et al*., 2016; Kumar *et al*., 2017; Zhang *et al*., 2018).

The slow rate of decomposition process in ZT resulted in accumulation of organic content within soil that cause an increase in SOC in the topsoil (Álvaro-Fuentes *et al*., 2008; Dikgwatlhe *et al*., 2014; Jat *et al*., 2019b).It is often reported that SOC concentration becomes higher due to interacting factors such as higher crop residue addition or retention, minimum soil disturbance, high moisture content, low risk of erosion and lower soil surface temperature(Logan *et al*., 1991; Ismail *et al*., 1994).The high SOC in reduced tillage system improved the sustainability of the system over the long term due to carbon sequestration. Crop residues are precursors for SOC pool. As such, they are linked with increase in SOC (Dolan *et al*., 2006). The effects of conservation tillage may vary with characteristics and the amount of crop residues returned to soil. Moreover, tillage causes redistribution of organic matter in the soil.

A small change in POC can be an early indication in improvement or degradation of soil regarding farm management practices(van Wesemael *et al*., 2019), especially in relation to soil disturbance(Chan *et al*., 2002), the quality, quantity and rate of decomposition of residues (Chivenge *et al*., 2007). POC exerted great effect on the ability of soil to supply nutrient and structural stability(Yoo and Wander, 2008).Thus, it is considered to play an important role in soil quality(Haynes, 2005). In this study, POC was also improved in ZT with residue retention. Results of this study are in line with the earlier studies that have recorded higher POC under no-tillage system with crop rotation as compared to the intensive tillage practices(Motta *et al*., 2007; Dou *et al*., 2008; Awale *et al*., 2013; Martin-Lammerding *et al*., 2013; Aziz *et al*., 2014; Wang and Sainju, 2014).These results are similar to the findings of other studies in same semiarid conditions (Virto *et al*., 2007; Álvaro-Fuentes *et al*., 2008). The high input of carbon within soil through crop residues left in field, recycling in ZT resulted in higher amount of POC (Yoo and Wander, 2008).

In this study, MOC was higher in ZT than conventional CT. Earlier studies also showed similar results in which MOC in reduced tillage management was higher than CT (Carpenter-Boggs *et al*., 2003; Mikha and Rice, 2004; Mahdi *et al*., 2005; Álvaro-Fuentes *et al*., 2008; Dou *et al*., 2008). In no-tillage practices, the higher MOC might be attributed to high carbon substrate availability for decomposition via microbial biomass (Chen *et al*., 2009).

Soil microbes turn over organic matter in soil (Mooshammer *et al*., 2014). In present study, ZT showed significantly higher MBC than CT. Similar results were obtained in other studies which reported significant increase in MBC under no-tillage with residue retention and crop rotation than CT (Bausenwein *et al*., 2008; Silva *et al*., 2010; Yeboah *et al*., 2016; Awale *et al*., 2017; Choudhary *et al*., 2018; Jat *et al*., 2019a). Govaerts *et al*. (2007b)performed a long-term experiment in rainfed conditions in Mexico to observe the tillage and residue management and crop rotation effect on soil MBC and microbial activity and found zero tillage resulted in either similar level or increased microbial biomass and activity as compared to conventional tillage.

The fact that no-tillage had higher MBC than CT might be due to high content of SOC and POC associated with no-tillage systems. Some studies reported that tillage practices had influenced MBC (Madejón *et al*., 2009; Melero *et al*., 2009). In no-tillage system, C immobilization increased by microbial biomass was attributed to an increase in organic matter in the form of plant residue(Bayer *et al*., 2002) while the reason for low MBC under CT was related to intensive soil disturbance and reduced plant coverage among other factors (Glover *et al*., 2000). No-tillage protects microbial habitat and decreases the extreme effect of temperature fluctuations (Rhoton, 2000). The soil cover and low soil disturbance protect microorganisms, in addition to improving nutrient availability for microbial activity and growth. Zero tillage, as a result of residue retention, improved water retention and infiltration (Govaerts *et al*., 2007a). Such benefit is crucial under water limiting conditions for agricultural systems in dryland rainfed areas.

In this study, SOC, MBC, POC and MOC were higher in wheat - mungbean rotation than fallow – wheat rotation. Soil biological properties improved with mungbean residues. MBC, microbial activity and mineralizable carbon were higher in mungbean residues receiving plots. Mungbean residues stimulated microbial activity and growth with mineralization of plant nutrients (Naeem *et al*., 2009). Tejada *et al*. (2009)also found that soil biological properties (enzymatic activity and MBC) were positively affected with plant residues. This might be due to more nitrogen fixation and nitrogen released from organic matter decomposition and subsequently incorporated into microbial biomass. The root nodulation and above ground residue after harvest of mungbean indicate the valuable source of nitrogen and organic matter. Their decomposition gives a meaningful contribution to nitrogen in soil. Such results were supported by many researchers (Tejada *et al*., 2006; Tejada and Gonzalez, 2006; Stark *et al*., 2007; Tejada *et al*., 2008).

The Dha was significantly affected by tillage management practices. Soil Dha activity was highest in conservation tillage (ZT) management practices than common traditional methods. These results are consistent with the results of Parihar *et al*., (2016) that performed a long term (field) experiment with different tillage practices and intensive use of crop rotation and reported higher Dha in ZT than CT in legume based crop rotation. The same findings were obtained by Madejón *et al.* (2007) and in rainfed conditions by Kumar *et al*.(2017).A review paper of 68 studies showed that residue retention and reduction in tillage intensity significantly improved soil Dha enzyme (Saikia and Sharma, 2017). The same was proven by the results of Wang *et al*.(2012) and Panettieri *et al*.(2013).The decomposition (residue) may release some nutrients (like nitrogen, phosphorus, and sulfur) necessary for plant and microbial growth (Jat *et al*., 2015). The higher SOC in conservation tillage system enhances soil carbohydrates that supply energy sources for soil microbes (Mina *et al*., 2008).The higher organic content caused an increase in soil dehydrogenase enzyme activity, resulting in decomposition of organic matter (Khan and Joergensen, 2009). The increased Dha in zero treatment might be due to more availability of labile carbon to the microbes compared with others (Jat *et al.*, 2019a).Inclusion of pulse crops in the sequence can increase soil Dha in MW, followed by FW. This trend might be due to high SOC in legume-based crop sequence (Roa-Fuentes *et al.*, 2015; Nawaz *et al.*, 2017)

Conclusion: The conservation tillage and cropping system highly affected SOC fractions and soil dehydrogenase activity. It is clear from the experiment that zero tillage and reduced tillage, with residue retention, had higher SOC, POC, MOC and Dha than conventional tillage practices in loess dryland soil. So, less intensive tillage practice might be the practice to enhance the soil carbon storage that will ultimately influence soil quality and productivity.

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