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Tillage, crop residue, and nitrogen levels on dynamics of soil labile organic carbon fractions, productivity and grain quality of wheat crop in *Typic Ustochrept* soil

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Abstract
Labile soil organic carbon pools are valuable indicators of soil quality, early changes in soil total organic carbon (SOC) stocks, and (hence) changes in soil carbon sequestration pools and dynamics induced by changes in soil management practices. To improve the management of *Typic Ustochrept* soil in North West India, we have examined effects of tillage, crop residue and N management methods applied in a 02-year experiment on SOC and the various fractions: particulate organic carbon (POC), light fraction organic carbon (LFOC), microbial biomass carbon (MBC) and dissolved Organic Carbon (DOC). The tillage crop establishment methods wereT_1- Zero tillage with residue retention;T_2-,Zero tillage without residue retention;T_3-Reduced tillage with residue retention;T_4-Reduced tillage without residue retentioT_5-Conventional tillage with residue incorporation;T_6- Conventional tillage without residue incorporation. Tillage crop establishment was combined with the following nutrient management treatments: F_0-Control; F_1- 80 kg Nha^{-1}; F_2-120 kg Nha^{-1}; F_3-160 kg Nha^{-1} and F_5-200 kg Nha^{-1}. After 2 years, the Conventional tillage without residue treatment resulted in significantly lower SOC by 24% and labile C fractions by 27–48% than T_2 and T_3, respectively. However, treatment T_1 markedly increased all labile C fractions by 32–52% except POC relative to T_3, but treatments T_1 and T_3 resulted in similar SOC contents (21.2 g kg^{-1} and 20.3 g kg^{-1}, respectively). Of the four C fractions, LFOC and DOC were the most sensitive indicators of changes in SOC induced by the tillage crop establishment methods. Under T_1, SOC contents were in 200kg Nha^{-1}>160kg Nha^{-1} > and 120kg Nha^{-1}plots, and significantly higher than those in control plots (by 37, 33 and 21%, respectively).Labile C fractions were also significantly higher following the treatments including residue retention/incorporation than following applications solely of chemical fertilizers. Application solely of 80kg Nha^{-1} chemical fertilizers had no significant effects on LFOC and DOC fractions compared with control. Nevertheless, application of 200kg Nha^{-1} or 160kg Nha^{-1} significantly increased contents of POC and MBC relative to control (by 50 and 46% or 41 and 44%, respectively). Thus, LFOC and DOC fractions were not sensitive indicators of changes in SOC induced by mineral nutrient practices under current conditions. Overall, given the minor differences between the effects of the 200kg Nha^{-1} and160kg Nha^{-1} treatments, zero tillage with residue retention appears to be the most suitable practice for improving soil labile organic carbon fractions in the *Typic Ustochrept* soil.

Keywords: Conservation tillage, Organic matter fractions, Soil organic carbon, Microbial biomass carbon

Introduction
Increasing concern about global climate change, driven by rising atmospheric concentration of greenhouse gases, particularly CO_2, have enhanced the interest in soil C sequestration as a strategy to offset anthropogenic CO_2 emissions (Lenka and Lal, 2013) [34]. Globally, agricultural lands have the potential to sequester approximately 5500–6000 Mg CO_2-eq. yr^{-1} by 2030 (Smith *et al*., 2008) [47]. Strategies for increasing the SOC pool is needed not only to mitigate CO_2 emissions but also to improve soil quality and economic crop production (Kahlon *et al*., 2013) [28]. According to Tan *et al*. (2007) [52], conversion of CT to NT practice could result in a reduction of 104 kg C ha^{-1} yr^{-1} release from the croplands of western North Dakota (ND). Mikha and Rice (2004) [41], also revealed that NT greatly enhances C accumulation within soil aggregates and increased tillage intensity in many conventional tillage systems; such as plowing, chisel plowing and multiple tillage trips prior to seeding disrupts soil aggregates and expose aggregate protected C to microbial attack. Moreover, tillage can greatly modify edaphic factors and thereby influences the rate of C mineralization (Curtin *et al*., 2012) [14]. Tillage can also increase the effect of drying-rewetting and freezing-thawing cycles, which increases the susceptibility of aggregates to physical disintegration (Lee *et al*., 2009). Previous studies have pointed out that SOC increases in reduced as compared

with intensive tillage systems (Kahlon *et al*., 2013, Naresh *et al*., 2016) [28, 44]. In some studies, however, tillage effects on SOC have been limited or absent (Cookson *et al*., 2008) [13]. The magnitude and direction of tillage induced changes are soil and site specific (Chatterjee and Lal, 2009) [10], and, because of high background C content, the effect of tillage practices on SOC contents may not be detectable early (Geisseler and Horwath, 2009) [20]. Therefore, a variety of physical, chemical, and biological fractions of SOC such as particulate organic matter carbon (POC), oxidizable carbon (OC), microbial biomass carbon (MBC), and potential mineralizable carbon (PMC) have recently received more attention due to their sensitivity to management practices compared with total SOC (Dou *et al*., 2008) [17]. These fractions change rapidly with time and can provide an early assessment of SOC changes induced by management practices such as tillage, crop residue, and N fertilization (Chen *et al*., 2009) [11].

Aziz *et al*., (2013) [3] showed that soil biological quality indices were more consistent, sensitive, and early indicators of soil quality as compared with soil physical and chemical quality indicators in response to tillage management. On the other hand, Zagal *et al*., (2009) [61] documented that soil MBC, mineralizable C and N was responsive to crop managements for silty-volcanic alluvium in Chile. Similarly, based on the fact that $KMnO_4$ also reacts with the stable fraction of total C, the reliability of this method as an index of soil labile carbon has been questioned recently (Tirol-Padre and Ladha, 2004, Naresh *et al*., 2016) [54, 44]. Soil organic C fractions are interrelated properties of soil (Haynes, 2005) [24]. Sensitivity of these fractions may vary with site, climate, and management practices. Therefore, measurement of a suite of SOC fractions and elucidation of the interactive relationships among different SOC fractions would perhaps more reflect tillage, crop residue and N management induced changes in soil quality (Strosser, 2010) [51]. Relatively few studies have emphasized on the combined effects of tillage, crop residue and N-fertilizer management on the physical, chemical, and biochemical fractions of SOC in *Typic Ustochrept* soil in the North India. Soil and crop management practices can alter the quantity, quality, and placement of crop residues in the soil, thereby influencing soil C and N storage, microbial biomass and activity, and N mineralization–immobilization Halvorson *et al*., 2002b [22]. Residue placement in the soil under different tillage systems can influence C and N levels by affecting soil aggregation, aeration, and C and N mineralization Malhi and Lemke, 2007 [40]. Knowledge about the changes in SOC and its fractions under different tillage practices coupled with crop residue and N managements is necessary to assess the feasibility of adoption of conservation practices for sustaining productivity and protecting the environment. The objectives of this study were to (i) determine the effect of three tillage practices (ZT, RT, and CT) and N-fertilizer managements on SOC, POC, LFOC, LFON, PMN, MBC, MBN, and DOC (ii) test the relationships among the SOC fractions, with wheat in *Typic Ustochrept* soil. Overall, we hypothesized that management induced changes in SOC at the surface 0–30cm soil would predominantly be reflected by parallel changes in different physical, chemical and biological fractions of SOC.

Materials and Methods

2.1. *Experimental site*

The field experiment was established in 2014 at Sardar Vallabhbhai Patel University of Agriculture &Technology, Meerut research farm (29^0 04', N latitude and77^0 42' ‘E longitude a height of 237m above mean sea level) U.P., India. The region has a semi-arid sub-tropical climate with an average annual temperature of 16.8 ^{0}C. The highest mean monthly temperature (38.9 ^{0}C) is recorded in May, and the lowest mean monthly temperature (4.5 ^{0}C) is recorded in January. The average annual rainfall is about 665 to 726 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon period. The predominant soil at the experimental site is classified as *Typic Ustochrept*. Soil samples for 0–20 cm depth at the site were collected and tested prior to applying treatments and the basic properties were non-saline (EC 0.42 dS m^{-1}) but mild alkaline in reaction (pH 7.98). The soil initially had 4.1 g kg^{-1} of SOC and 1.29 g kg^{-1} of total N (TN), 1.23 g kg^{-1} of total phosphorus, 17.63 g kg^{-1} of total potassium, 224 mg kg^{-1} of available N, 4.0 mg kg^{-1} of available phosphorus, and 97 mg kg^{-1} of available potassium.

2.2. Experimental design and management

A detailed description of different tillage systems is necessary to compare the influence of tillage practices on environmental performance (Derpsch *et al*., 2014) [16]. Six tillage crop establishment methods **T_1**- Zero tillage with residue retention (ZTR);**T_2**-,Zero tillage without residue retention (ZTWR) ;**T_3**- Reduced tillage with residue retention (RTR);**T_4**- Reduced tillage without residue retention (RTWR),**T_5**-Conventional tillage with residue incorporation (CTR);**T_6**- Conventional tillage without residue incorporation (CT) in main plots and five nitrogen management practices were **F_0**-Control; **F_1**- 80 kg Nha^{-1}**;** **F_2**-120 kg Nha^{-1} ; **F_3**-160 kg Nha^{-1}*;* **F_5**-200 kg Nha^{-1} allotted to sub-plots in a split-plot design and replicated thrice. The gross and net plot sizes were 10 m×2.8 m and 8.0 m×2.1 m, respectively and treatments were superimposed in the same plot every year to study the cumulative effect of treatments.

2.3. *Soil sampling and processing*

Soil samples from each replicated plot were collected randomly from three spots with the help of a core sampler (10 cm internal diameter and 15 cm height) after the harvest of wheat crop in the year 2015 & 16. The soil cores were collected from 0 to 15, 15 to 30, 30 to 45 and 45 to 60 cm soil depth. One composite sample representing each replication was prepared by mixing two cores of respective soil depth. Immediately after collection, the soil samples were brought to the laboratory and stored in a refrigerator for measurement of microbial biomass carbon (MBC). A subset of soil samples was air dried and passed through a 2 mm sieve for determination of pH, SOC and particulate organic carbon (POC). The third core sample was used for the estimation of bulk density. The soil porosity was computed from the relationship between bulk density and particle density using

$$\text{Porosity (\%)} = 1 - \frac{BD}{PD}\ x100 \qquad \textbf{(1)}$$

Where

BD is bulk density (g cm^{-3}), and

PD is particle density (g cm^{-3})

The double ring infiltrometer method was used to determine the water infiltration and was computed as cumulative infiltration and rate of infiltration in mm h^{-1}.

2.4. Separation of soil aggregates

Aggregate-size separation was performed using a wet sieving method (Elliott, 1986) [18]. Soil samples (100-g air-dried <5 mm) were placed on top of a 2.0 mm sieve and submerged for 5 min in deionized water, to allow slaking (Kemper and Rosenau, 1986) [32]. Sieving was performed mechanically moving the sieve up and down 3 cm, 50 times in 2 min using a modified Yoder's apparatus. A series of five sieves (2, 1, 0.5, 0.25 and 0.11 mm) was used to obtain six aggregate fractions **(i)** >2 (Very large macro-aggregates), **(ii)** 2-1(large macro-aggregates),**(iii)**1-0.5 (medium macro-aggregates),**(iv)** 0.5-0.25(small macro-aggregates)**, (v)** 0.25-0.0.106 (micro-aggregates), and **(vi)** <0.106 (silt- and clay-sized particles).

2.5. Aggregate stability (AS) of soils

(Castro-Filho *et al*., 2002) was computed as

$$AS = \left[\frac{(\text{weight of the aggregates} - \text{wp25} - \text{S})}{(\text{weight of the dry sample} - \text{S})}\right]100$$

Where,
Wp25 is the weight of aggregates < 0.25 mm (g) and
S the weight of particles between 2 and 0.053 mm (g), that is, sand content.

2.6. Soil analysis

The soil pH was measured in soil: water suspension (1:2). The electrical conductivity (E_{Ce}) was determined in soil saturation extract. The bulk density of soil was measured using core sampler method as suggested by Veihmeyer and Hendrickson (1948) [55].

2.6.1. Soil organic carbon

Soil organic carbon was determined by wet digestion with potassium dichromate along with 3:2 H_2SO_4: 85% H_3PO_4 digestion mixture in a digestion block set at 120°C for 2h (Snyder and Trofymow, 1984) [48]. A pre-treatment with 3 ml of 1 NHCl g^{-1} of soil was used for removal of carbonate and bicarbonate. By using the bulk density value the SOC for each soil layer was calculated and expressed as Mg ha^{-1}.

2.6.2. Light Fractions Organic C and N

PMN in soil was determined by the method described by Keeney (1982) [30, 31]**,** where 10 g air-dry soil was taken in a test tube with distilled water (1:2) and incubated for 7 days under waterlogged conditions at 40°C. The mineralized NH_4^+ N was determined by the Kjeldahl's distillation method. The amount of PMN (mg NH_4^+ N kg^{-1} d^{-1}) was determined by subtracting the concentration of NH_4^+ N at the beginning of incubation.

2.6.3. Particulate organic carbon

Particulate organic matter (POM) was separated from 2 mm soil following the method described by Camberdella and Elliott (1992) [7]. Briefly a 10 g sub-sample of soil was dispersed in 100 ml 0.5% sodium hexa-metaphosphate solution by shaking for 15h on a reciprocal shaker. The soil suspension was poured over a 0.05 mm screen. All material remaining on the screen, defined as the particulate organic fraction within a sand matrix, was transferred to a glass beaker and weighed after oven-drying at 60°C for 24 h. The particulate organic carbon in POM was determined following the method of Snyder and Trofymow (1984) [48].

2.6.4. Water soluble organic carbon

The water soluble organic carbon (WSOC) was successively analyzed according to the method described by Zhang *et al*. (2010) [62]. Briefly, the soil samples were first suspended in distilled water at 70±1°C for 60 min. The supernatant was referred to as the water soluble fraction (WSF)

2.6.5. Dissolved organic carbon

Dissolved organic C (DOC) was extracted from 10 g of moist soil with 1:2.5 ratio of soil to water at 25.8 °C Jiang *et al*., (2006). After shaking for 1 h and centrifuging for 10 min at 4500 r min^{-1}, the supernatant was filtered with a 0.45 mm membrane filter. The filtrate was measured by oxidation with potassium dichromate and titration with ferrous ammonium sulphate.

2.5.6. Black carbon

Black carbon (BC) was analyzed by the method given by Aiken *et al*. (1985) [1]. Soil samples were reacted with 25 ml of 01 mol L^{-1} $K_2Cr_2O_7$+2mol L^{-1} H_2SO_4 solution at 55±1 °C for 60 h, and the oxidized organic C was determined by titration using 0.2mol L^{-1} $FeSO_4$ solution. The content of BC was calculated by subtracting the oxidized organic carbon from the TOC.

2.6.7. Soil microbial biomass carbon

For the estimation of soil microbial biomass C and N by the chloroform fumigation and incubation method Horwath and Paul, (1994) [25] soil moisture was adjusted to 55% field water capacity, pre-incubated at 25 °C for 7 days in the dark, and each soil sample was subdivided into two subsamples for fumigated and non-fumigated treatments. For MBC, soil samples, equivalent to 30 g dry weight, were fumigated with $CHCl_3$ for 24h at 25 °C. After removing the $CHCl_3$, each soil sample was incubated at 25 °C for a period of 10 days in closed tight Mason jar along with vials containing 1.0 ml 2 M NaOH. The flush of CO_2-C released upon fumigation was determined from titration with HCl.

The MBC was computed using Eq. (2):

$$\text{MBC (mg kg}^{-1}\text{)} = (\text{Fc}-\text{UFc})/\text{Kc} \quad \textbf{(2)}$$

Where, Fc is CO_2 evolved from the fumigated soil,
UFc is CO_2 evolved from the unfumigated soil, and
Kc is a factor with value of 0.41 Anderson and Domsch, (1978).

For MBN, fumigated and non-fumigated soil samples after 10-day incubation were extracted with 2 M KCl (5:1 ratio of extractant: soil) for 1 h and inorganic N was determined by the Kjeldahl distillation as described by Keeney and Nelson (1982) [30, 31]. The MBN was computed using Eq. (3):

$$\text{MBN (mg kg}^{-1}\text{)} = (\text{Fn}-\text{UFn})/\text{Kn} \quad \textbf{(3)}$$

Where,
Fn is mineral N from fumigated soil, UFn is mineral N from unfumigated soil, and Kn is a factor with value of 0.57 Jekinson, (1988) [26].

2.7. Statistical Analysis

Statistical analysis of data of various soil health parameters was carried out by ANOVA in split-split plot design Cochran and Cox, (1950). The effects of different treatments were evaluated using the least significant difference (LSD) test at the 0.05 level of probability. The data presented in figures are means ± standard deviation (SD) of three replications.

3. Results and Discussion

3.1 Changes of Soil Physical Properties

3.1.1 Bulk Density and Porosity

Among tillage and crop establishment methods, plots under zero till without residue T_2 had about 5% higher soil bulk density ($1.62 gm^{-3}$) than T_6 plots (Table 1).Unlike residue management, tillage had greater impacts on soil bulk density. Plots under T_3 ~3.6% and T_5 had ~6.7% less soil bulk density as compared with T_6 plots (Table 1).The bulk density did varied significantly due to seeding techniques and it was significantly reduced under conventional and reduced tillage with residue retention compared to zero tillage. This was attributed mainly due to more pore spaces created in these techniques through modified land configuration by accumulations the topsoil. The decrease in BD under CA could be due to higher SOC content, better aggregation and biomass (Unger and Jones, 1998). Elsewhere, the similar findings of lower BD values under ZT were also reported by Verhulst *et al*., (2011); Naresh *et al*., (2015) [43]; Salem *et al*., (2015) and Singh *et al*., (2016) [44].

The field capacity (FC) was also increased due to different tillage practices. The highest field capacity increase (12.9%) was found in T_1 followed by T_3. After two years treatment T_6 showed the lowest increase of field capacity value (Table 1). Permanent wilting point (PWP) was also influenced by the different tillage practices. After two years, the PWP was decreased and highest reduction ((7.8%) was found in CT and the lowest reduction (7.5%) in ZT with residue retention (Table 1). Soil porosity results showed that the residue retention treatments (T_1, T_3 and T_5) could increase the total porosity of soil, while zero tillage without residue (T_2) would decrease the soil porosity for aeration as a result; it enhances the water holding capacity of soil along with bad aeration of soil. However, the effects of tillage and residue retention treatments (T_3 and T_5) on the total porosity and porosity size distribution were not significant and zero tillage without residue (T_2) could increase the quantity of big porosity. Residue retention treatments shown an improvement in the soil porosity and was most probably related to the beneficial effects of soil organic matter caused by zero tillage with residue cover (Table 1).

3.1.2. Cation Exchange Capacity and Aggregate stability

Other notable changes in soil quality due to the legacy of residue harvesting are evident in (Table 1). Cation exchange capacity (CEC) was also increased due to tillage and crop residue management. The highest CEC increase (10.3%) was found in T_1 followed by T_3 (5.0%) and T_5 (2.4%) as compared to T_6 which obtained the lowest CEC from the experimentation (Table 1).The large loss of aggregate stability for the zero-till system is of particular concern, as it suggests that the increased aggregate stability of surface soil under zero-till is due to surface residue rather than an intrinsic property of zero-tillage (Table 2).The enhanced microbial activity induces the binding of residue and soil particles into macro-aggregates, which could increase aggregates stability thus improving the concentration of SOC and increasing C sequestration (Liqun *et al*., 2014) [38]. The increased aggregate stability in ZT with residue retention (T_1) compared to ZT without residue retention (T_2) and CT (T_6) practices resulted in increased infiltration and soil water content (Verhulst *et al*. 2011).

3.1.3. Infiltration rate

Among the various tillage and residue management practices treatment T_5 was found to be significantly superior to all the treatments, except T_1 and T_3 also recorded highest infiltration rate (11.2 hr cm^{-1}) during the year of experimentation. The difference in infiltration rate due to tillage practices with crop residue retention treatments proved significant. Treatments T_1 and T_3 were significantly superior to the remaining treatments. T_4 was also significant over T_6 treatment which recorded lowest infiltration rate (6.9 hr cm^{-1}), during the year of study. However, the highest increase (38.4%) was found in T_5 followed by T_3 (34.3%) and T_1 (31%), whereas T_2 and T_6 showed decreasing trend (Table 1). Tillage plays a vital role in improve the soil condition by altering the mechanical impedance to root penetration, hydraulic conductivity and water holding capacity. Increases in the bulk density usually result in large decreases in water flow through the soil and retaining crop residues on the soil surface with conservation tillage would reduce evapo-transpiration and increase infiltration rate (Naresh *et al*., 2015) [43].

Table 1: Effect of tillage crop establishment on soil P^H, Bulk density, Cation exchange capacity, Total porosity, Hydraulic conductivity, Field capacity, Permanent wilting point, and Infiltration rate in RWCS.

Treatments	P^H	Bulk density (gcm^{-3})	CEC (cmol kg^{-1})	Total porosity (%)	Hydraulic conductivity (mm h^{-1})	Infiltration rate (hr cm^{-1})	Field capacity (%)		Permanent wilting point (%)	
							0-5	5-20	0-5	5-20 cm
T_1	7.4	1.52	24.40	37.98	53.5	10.0	31	31	11	10
T_2	7.6	1.62	22.33	41.58	45.6	8.8	29	30	12	10
T_3	7.4	1.39	23.04	51.86	43.8	10.5	30	31	12	11
T_4	7.7	1.46	20.87	52.36	46.3	9.0	28	29	11	10
T_5	7.6	1.35	22.43	53.01	36.6	11.2	29	30	13	11
T_6	7.7	1.44	21.89	54.25	35.3	6.9	27	29	12	10

3.1.5. Aggregate-size distribution

Aggregate size distribution in different soil depths were significantly impacted by management practices (Table 2). Macro aggregates accounted for >51% of total aggregates. In topsoil (0–10 cm soil layer), these were the dominant water-stable aggregates (WSA). Significantly higher (60%) water-stable macro-aggregates were recorded in ZT plots compared with CT in the topsoil, with a concurrent decrease in micro aggregates in the RT plots. A similar trend also was recorded in sub-surface soil (Table 2). Small macro-aggregates were the greatest proportion of the whole soil, followed by aggregates <0.106 mm in topsoil. Plots under ZT had significantly more large and small micro-aggregates than RT plots in 0-10 and 10-20 cm soil layers. The ZT plots had significantly more large macro-aggregates, with a concomitant decrease in 'silt + clay' sized aggregates (<0.106 mm) compared with RT plots in the topsoil.

In the sub-surface soil, size distributions of aggregates were also significantly influenced by tillage, practices. Small macro-aggregates comprised the greatest proportion of the whole soil, followed by aggregates <0.106 mm in the 10–20 cm soil layer. Subsurface soil (10–20 cm depth) had 34% higher macro-aggregates than micro-aggregates (Table 2). The percentage of water-stable aggregates of the largest size class (>2 mm) in ZT plots at depth of 0 to 10, 10 to 20, and 20 to 30 cm was approximately twice the percentage under CT but significant only below the 20-cm soil layer. The comparison between RT and CT did not produce significant results until a depth of 20 cm. In contrast, the soil in all layers of the CT treatment had the highest percentage of water-stable aggregates of the smallest size class (<0.106 mm) compared with both the ZT and RT treatments. Aggregate data revealed that the macro-aggregates increased by 39% and micro-aggregates decreased by 9% in ZT plots compared with CT plots. Decrease in micro-aggregates and increase in macro-aggregates with application of conservation tillage might have enhanced soil aggregation processes. Our study revealed that the conservation tillage treatments produced significantly higher amounts of >2 mm macro-aggregates compared with CT. This was because conservation tillage practices decreased tillage times (Wang *et al*., 2013) [57], and reduced the mechanical destruction to soil aggregates. CT with frequent tillage operations disturb soil, and increase the effect of drying–rewetting and freezing–thawing, which increase macro-aggregate susceptibility to disruption (Tian *et al*., 2010) [53]. In our research, macro-aggregates are less stable than micro-aggregates and more susceptible to the disruptive forces of tillage, and the >2 mm macro-aggregates showed the lowest percentage distribution at all depths. This might be attributed to the mechanical disruption of macro-aggregates with frequent tillage operations and reduced aggregate stability.

Table 2: Soil stable aggregate size classes for zero-till (ZT), reduced till (RT), conventional tillage (CT), treatments and aggregate stability in the 0- to 30-cm soil depth

Depth (cm)	***Treatment***	***Aggregate size distribution***						***Macro aggregates (>0.25 mm)***	***Micro-aggregates (<0.25 mm)***	**Aggregate stability**
		>2 mm	***2–1 mm***	***1–0.5 mm***	***0.5–0.25 mm***	***0.25–0.11 mm***	***<0.11 mm***			
		%								
0–10	ZT	6.45	9.73	8.09	8.95	12.83	31.66	33.44	66.57	0.67
	RT	5.31	6.06	5.67	7.60	35.45	53.73	28.89	67.11	0.63
	CT	2.13	4.26	5.59	5.33	13.08	66.91	19.01	79.99	0.53
CD at 5%		1.16	1.93	2.61	1.64	3.87	8.31	4.85	1.54	
10-20	ZT	6.68	5.69	4.05	14.98	11.07	27.55	35.56	64.44	0.65
	RT	4.36	5.62	5.22	20.23	36.90	57.47	31.46	68.54	0.56
	CT	2.90	3.57	4.17	5.53	12.34	72.08	15.59	84.42	0.48
CD at 5%		2.33	2.12	1.19	5.35	3.27	9.73	4.33	4.91	
20-30	ZT	4.70	4.14	3.52	8.70	21.06	61.84	17.10	82.90	0.46
	RT	7.82	8.55	8.43	13.96	16.36	41.55	38.89	61.11	0.44
	CT	3.55	4.10	3.14	4.10	11.90	76.76	13.81	88.76	0.42
CD at 5%		1.26	1.37	1.91	4.82	5.12	11.36	3.49	5.96	
0–30	ZT	6.41	7.96	7.53	9.30	13.82	40.35	31.26	68.74	0.59
	RT	4.46	4.72	4.86	14.17	31.47	52.92	28.18	71.82	0.54
	CT	3.20	4.24	4.25	4.79	12.44	71.85	16.47	84.39	0.48
CD at 5%		1.36	1.61	1.88	4.63	5.38	13.37	4.18	4.93	

3.2. Soil Chemical Properties

3.2.1. Water soluble organic carbon (WSOC)

The distribution of soil mass among the size classes of water stable organic carbon (WSOC) was strongly influenced by tillage and residue management practices in both the soil depths (0–15 and 15-30 cm). WSOC was found to be 5.82% higher in surface soil than in sub-surface soil (Table 3). In both the depths, T_1 treatment had the highest WSOC as compared to the other treatments studied. Compared to CT, ZT and RT coupled with residue retention increased 21.9% WSOC in surface soil and 19.8% in sub surface soil. Among all the treatments, T_1 had significantly higher (12.4%) proportion of WSOC than the other treatments compared. Irrespective of tillage practices, residue retention resulted in 15.7% and 12.3% higher WSOC as compared to the non-residue treatments in surface and sub-surface soil, respectively. The WSOC content in surface soil (0–15 cm) was significantly higher in 200kg Nha^{-1} (F_4) treatment (31.1 gkg^{-1}) followed by 160kg Nha^{-1} (F_3) (30.2 gkg^{-1}), 120kg Nha^{-1} (F_2) (29.5 gkg^{-1}) and least in unfertilized control plot [(F_1) (21.1 gkg^{-1}) (Table 3)]. However, similar significant effect was observed in sub-surface soil (5-30 cm) and the magnitude was relatively lower. The increase in WSOC in 0–15 cm soil depth was 47.4 and 43.1% in 200kg Nha^{-1} (F_4) and 160kg Nha^{-1} (F_3) treated plots over control (F_0).Our results are in agreement with Yagi *et al*. (2005) [58], who attributed the increase of WSOC to the priming effect of the application of fertilizers or fresh organic material to the soil, which stimulated the mineralization of organic matter through increased microbial activity.

3.2.2. Soil organic carbon (SOC) and Oxidizable organic carbon (OC)

Conservation agriculture practices significantly influenced the SOC and OC content of the 0–15 cm soil layer (Table 3). ZTR (zero till with residue retention) (T_1) and RTR (Reduced till with residue retention) (T_3) showed significantly higher SOC and OC content of 19.37 and 18.34 g kg^{-1}, respectively (Table 3) as compared to the other treatments. Irrespective of residue retention, wheat sown in zero till plots enhanced 36.9% and 28.8% of SOC and OC, respectively, in surface soil as compared to conventional tillage. Simultaneously, residue retention in zero tillage caused an increment of 24.1% and 19.4% in SOC and OC, respectively over the treatments with no residue management. Similar increasing trends of conservation practices on different forms of carbon under sub-surface (15–30 cm) soil were observed however, the magnitude was relatively lower (Table 3). Zhu *et al*., (2011) [63] compared to conventional tillage (CT) and zero-tillage (ZT) could significantly improve the SOC content in cropland. Frequent tillage under CT easily exacerbate C-rich macro-aggregates in soils broken down due to the increase of tillage intensity, then forming a large number of small aggregates with relatively low organic carbon content and free organic matter particles. Free organic matter particles have poor stability and are easy to degradation, thereby causing the loss of SOC Song *et al*., (2011) [50]. Results of this work show that the ZT and RT system with residue retention conserved and increased SOC compared to the (CT), respectively. Higher SOC content in residue retention could be attributed to more annual nutrient recycling in respective treatments and decreased intensity of mineralization (Kaisi and yin, 2005) [29]. Less carbon sequestration in reduced tillage than zero tillage in same level of residue retention in this cropping system might be due to earlier dryness, less microbial population and less decomposition in reduced tillage during wheat season. The variation of SOC sequestration also depends on difference in microbial populace, moisture and temperature fluctuation (Govaerts *et al*., 2009) [21].

SOC was found stratified along the soil depth. A higher SOC was found in surface soil decreasing with depth (Table 3). At the 0–15 cm, SOC content less than 200kg Nha^{-1}, 160kg Nha^{-1} and 120kg Nha^{-1} were 24, 22 and 15% greater than under control unfertilized plots, respectively. In 15–30 cm soil layer, 200kg Nha^{-1} had maximum SOC which was significantly higher than all other treatments except 120kg Nha^{-1} treatment. Kundu *et al*. (2001) [33] reported that SOC content improved in fertilized plots as compared to the unfertilized plots due to C addition through the roots and crop residues, higher humification rate constant, and lower decay rate. In this study, the combination of residue retention and inorganic fertilization enhanced the accumulation of SOC which is consistent with many other studies (Majumder *et al*., 2008; Hao *et al*., 2008; Banger *et al*., 2009; Fan *et al*., 2013 and Naresh *et al*., 2016) [39, 5, 19, 44]. Similar pattern was also found in OC content during the year of study.

3.2.3. Black carbon (BC)

The buildup of BC was strongly influenced by tillage and residue management practices in both the soil depths (0–15 cm and 15-30 cm). BC was found to be 8.86% higher in surface soil than in sub-surface soil (Table 3). In both the depths, T_1 treatment had the highest BC as compared to the other treatments studied. Compared to conventional tillage, ZT and RT coupled with residue retention increased 34.5% BC in surface soil and 28.6% in sub surface soil. Among all the treatments, T_1 had significantly higher (24.5%) proportion of BC than the other treatments compared. Irrespective of tillage practices, residue retention resulted in 22.7% and 21.8% higher BC as compared to the non-residue treatments in surface and sub-surface soil, respectively. The buildup of BC was greater in the surface layer as compared to the sub surface layer (Table 3). In the surface layer, all the treatments accumulated significantly greater BC over the control unfertilized plots (F_0). The BC was 58% greater in the residue retention plus inorganic fertilizers (3.76 gkg^{-1}) and 38% greater in the without residue retention plus inorganic fertilizers (2.56gkg^{-1}) over the control treatment (F_0). A similar trend was observed in the subsurface soil, where the BC content ranged from 1.07 g kg^{-1} in control to 3.09 g kg^{-1} in the residue retention plus inorganic fertilizer treatments. In this study, the BC concentration in the surface soil layers was higher under ZT and RT than CT; this is may be due to the placement of residues near the soil surface. Our result supports other studies that recorded higher BC at the upper layers under ZT (Linn and Doran, 1984; Wright *et al*., 2007) [37, 56].

Table 3: Effect of tillage and nitrogen management on distribution of different forms of carbon in soil

Treatments	WSOC (gkg^{-1})		SOC (gkg^{-1})		OC (g kg^{-1})		BC (gkg^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Tillage Practices								
T_1 ZTR	28.8	26.2	23.1	19.3	9.61	9.13	4.69	4.28
T_2 ZTWR	25.3	24.6	18.4	14.8	7.87	7.21	3.76	3.19
T_3 RTR	27.0	25.9	22.4	18.2	8.68	8.17	4.13	3.87
T_4 RTWR	23.7	21.8	18.1	14.2	7.66	7.07	3.12	2.96
T_5 CTR	26.1	24.4	21.8	17.4	8.49	7.96	3.82	3.48
T_6 CT	21.8	20.9	16.1	13.1	6.21	5.64	2.89	2.63
Nitrogen Management								
F_0 Control	21.1	14.9	16.1	13.1	6.13	5.48	1.58	1.07
F_1 80 kg N ha^{-1}	28.3	21.2	17.8	14.7	6.46	6.16	2.46	1.75
$F_2$120 kg N ha^{-1}	29.5	22.1	19.1	16.1	7.25	6.71	3.26	2.18
F_3 160 kg N ha^{-1}	30.2	23.1	20.8	18.2	7.75	7.28	3.82	2.66
F_4 200 kg N ha^{-1}	31.1	25.4	21.3	18.7	7.93	7.48	4.15	3.42

Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test for separation of mean.

WSOC= Water soluble organic carbon, SOC =Total soil organic carbon, OC =Oxidizable organic carbon, BC =Black carbon

3.2.4. Particulate organic carbon (POC)

Particulate organic carbon was found stratified along the soil depth. A higher POC was found in surface soil decreasing with depth (Table 4). At the 0–15 and 15-30 cm, POC content under ZT and RT with residue retention was greater than under without residue and conventional sown plots, respectively. The decrease in the disruption of soil macro-aggregates under ZT plots permitted a greater accumulation of SOC between and within the aggregates. Thus, less soil disturbance is the major cause of higher POC in the ZT and RT plots compared with the CT plots in the 0-15cm and 15-30 cm soil layers. This phenomenon might lead to micro-aggregate formation within macro-aggregates formed around fine intra-aggregate POC and to a long-term stabilization of SOC occluded within these micro-aggregates. Because increased POC is regarded as a potential indicator of increased C accumulation (Six *et al*., 1999), the results of this study indicate that ZT and RT had a significant effect on the formation and stabilization of SOM within the 0-15cm soil layer and the soil amended organic matter by residue decomposition contained significantly higher POC in the 0–15 cm than that in the inorganic fertilizer treatments after two years of wheat crop in *Typic Ustochrept* soil of Northwest India.

The differences in POC under the tested fertilization regimes can be attributed to differences in the associated inputs of organic materials into the soil, the main sources of POC (depending on the treatment) being the residual root and stubble biomass, crop straw, and microbial biomass debris. At the 0–15 cm, POC content under (F_4) 200 kg Nha^{-1}, (F_3) 160 kg Nha^{-1} and (F_2) 120 kg Nha^{-1} were 38.5, 35.4 and 25.4% greater than under control unfertilized plots, respectively. In 15–30 cm soil layer, (F_3) 160 kg Nha^{-1} had maximum POC which was significantly higher than all other treatments except F_2 and F_4 treatments. The F_0 (control), and F_2 (80 kg Nha^{-1}) treatments resulted in the lowest levels of POC, because they produce the lowest crop yields (Yang *et al*., 2002) [60], while the 160 kg Nha^{-1} treatments resulted in the highest levels, presumably because of the fast decomposition of crop residues. Our results in these respects are consistent with those of Yan *et al*., (2007) [59].

3.2.5. Particulate organic nitrogen (PON)

Particulate organic nitrogen (PON) content over CT (T_6) of the field after 2 -year crop cycle is presented on Table 4. Upper and lower depth (0-15 cm & 15-30 cm) had significantly different in PON change. Highest PON change (42.1%) was found in ZT with residue retention (T_1) plots followed by RT with residue retention (T_3) plots (36.9%) as compared to CT. The use of ZT with residue retention (T_1) plots and RT with residue retention (T_3) plots for two crop cycle increased PON by 38.7% and 21.1% more than that of T_2 and T_4, respectively. In lower depth (15-30 cm), similar increasing trends were observed, however, the magnitude was relatively lower (Table 4).

Application of 200 kg Nha^{-1} (F_4) resulted in a significant positive built up of PON over 120 kg Nha^{-1} (F_2) at both soil depths (Table 4). Similarly, 160 kg Nha^{-1} to wheat crop also recorded significantly higher PON concentration over 120 kg Nha^{-1}(F_2) in 0–15 and 15–30 cm soil depths. The additional amounts of organic C input from residue retention in the treatments received 160 kg Nha^{-1}further enhanced the PON contents in these treatments. The main source of PON in this study was mainly the left over root biomass and increased microbial biomass debris. It is suggested that the greater biochemical recalcitrance of root litter might have also increased the PON contents in soil depending upon the root biomass produced. The sequestration rate of PON in all the treatments followed the order 200 kg Nha^{-1}(F_4) > 160 kg Nha^{-1} (F_3) > 120 kg Nha^{-1}(F_2) >800 kg Nha^{-1} (F_1) > control (unfertilized) (F_0).

Table 4: Effect of different treatments on contents of various labile fractions of carbon in soil

Treatments	POC (mgkg^{-1})		PON (mgkg^{-1})		LFOC (mgkg^{-1})		LFON (mgkg^{-1})	
	0-5 cm	5-15 cm	0-5 cm	5-15 cm	0-5 cm	5-15 cm	0-5 cm	5-15 cm
Tillage Practices								
T_1 ZTR	1342.8	967.9	119.5	108.1	194.7	154.8	14.8	12.3
T_2 ZTWR	981.1	667.4	94.6	86.5	120.5	104.7	11.8	10.3
T_3 RTR	1230.2	836.9	109.7	97.8	170.9	144.9	13.7	11.6
T_4 RTWR	869.4	604.4	82.6	76.6	107.1	97.3	9.7	8.6
T_5 CTR	1099.1	779.4	98.4	89.3	143.8	115.9	12.8	10.9
T_6 CT	617.5	481.8	69.2	57.6	90.8	73.6	9.6	7.9
Nitrogen Management								
F_0 Control	709.7	658.6	31.7	26.3	123.9	104.3	6.4	5.8
F_1 80 kg N ha^{-1}	860.7	785.6	68.4	56.2	132.8	116.1	7.6	6.9
$F_2$120 kg N ha^{-1}	952.2	808.9	89.5	78.5	150.6	127.6	9.7	8.6
F_3 160 kg N ha^{-1}	1099.5	823.8	96.8	83.4	168.5	145.7	10.2	9.8
F_4 200 kg N ha^{-1}	1153.1	898.4	103.9	97.3	176.2	152.9	11.7	10.6

Values in a column followed by the same letter are not significantly different ($P < 0.05$).

POC = particulate organic carbon, PON = particulate organic nitrogen, LFOC = labile fraction organic carbon, and LFON = labile fraction organic nitrogen.

3.2.6. Labile fraction organic carbon (LFOC)

The labile fraction organic carbon (LFOC) is considered as a useful approach for the characterization of SOC resulting from different soil management practices including cropping systems and application of sources of nutrients. The values of LFOC in surface soil were 107.1, 120.5, 143.8, 170.9, 194.7 and 90.8 mgkg^{-1} in RT and ZT without residue retention, CT with residue incorporation, RT and ZT with residue retention and conventional tillage (CT) treatments, respectively (Table 4). In 15- 30 cm layer, the increasing trends in LFOC content due to use of tillage practices and residue retention were similar to those observed in 0-15cm layer, however, the magnitude was relatively lower (Table 4).Significant increase in LFOC in surface soil (0–15 cm) was maintained in plots receiving 200 kg Nha^{-1}(F_4),and 160 kg Nha^{-1}(F_3) fertilizer over 120 kg Nha^{-1} (F_2), and over unfertilized control plots (F_0) (Table 4). However, increases in LFOC in sub-surface soil (15–30 cm) were observed only under plots receiving 200 kg Nha^{-1}(F_4), and 160 kg Nha^{-1}(F_4), fertilizer over unfertilized control plots. Increase in LFOC in surface soil was 42.2 and 35.9% in 200 kg Nha^{-1}(F_4), and 160 kg Nha^{-1}(F_3) fertilizer treated plots over control, respectively.

Chen *et al*., (2009) [11] also found that single effect of residue application was not significant but its significance became apparent after its interaction with tillage system. Similar results were obtained in our study. Li *et al*., 2012 [36] explained that crop residue might enter the labile C pool, provide substrate for the soil microorganisms, and contribute to the accumulation of labile C.

3.2.6. Labile fraction organic nitrogen (LFON)

Results on LFON content in 2-year experiment showed that in 0 - 15 cm soil layer of tillage system, T_2, T_3, T_5 and T_6 treatments increased LFON content from 9.6 mg·kg^{-1} in CT (T_6) to 14.8,13.7 and 12.8 mgkg^{-1} with residue retention/incorporation under ZT;RT and CT, respectively (Table 4). In 15 -30 cm layer, the increasing trends in LFON content due to the use of tillage and residue management practices were similar to those observed in 0 -15 cm layer, however, the magnitude was relatively lower (Table 4). Significantly greater amount of LFON content in surface soil was maintained in all the treatments receiving inorganic fertilizer over unfertilized control plot (Table 4). The build-up of LFON in surface soil (0–15 cm depth) were 11.7, 10.2 and 9.7 mgkg^{-1} in plots receiving 200 kg Nha^{-1}(F_4), 160 kg Nha^{-1}(F_3), and 120 kg Nha^{-1}(F_2), respectively as against 6.4 mg kg^{-1} in unfertilized control plot. The LFON increased by 45.3, 37.2 and 34.1% in plots receiving 200 kg Nha^{-1}(F_4), 160 kg

Nha^{-1}(F_3), and 120 kg Nha^{-1} (F_2), respectively over unfertilized plot in 0-15 cm soil depth. Response of the LFOC and LFON contents to fertilization treatments was similar to those observed for the POC and PON contents.

3.3. Soil Biological Properties

3.3.1. Potentially mineralizable nitrogen (PMN)

After 2 years of the experiment, potentially mineralizable nitrogen (PMN) content showed that in 0-15 cm soil layer T_1 and T_3 treatments increased from 6.7 mgkg^{-1} in conventional tillage (T_6) to 8.5 and 7.6 mgkg^{-1} in ZT and RT without residue retention and 12.4, 10.6 and 9.3mg kg^{-1} ZT and RT with residue retention and CT with residue incorporation (T_1, T_3, T_5), respectively (Table 5). In 15 -30 cm layer, the increasing trends due to the use of tillage crop residue practices were similar to those observed in 0 -15 cm layer however, the magnitude was relatively lower (Table 5).Continuous retention of crop residue resulted in considerable accumulation of PMN in 0–15 cm soil layer than unfertilized control plots (Table 5). Soils under the 200 kg Nha^{-1} (F_4), treated plots resulted in higher PMN in the 0–15 cm soil layer over those under the 120 kg Nha^{-1} and 80 kg Nha^{-1} treated plots. The PMN in surface soil were in the order of 200 kg Nha^{-1} (F_4), 10.4 mgkg^{-1} > 160 kg Nha^{-1} (F_3), 9.8 mgkg^{-1} > 120 kg Nha^{-1} (F_2), 8.9 mgkg^{-1} >80 kg Nha^{-1} (F_1), 7.3 mgkg^{-1}>unfertilized control (3.6 mgkg^{-1}).However, increase in PMN was more in surface as compared to sub-surface soil, which indicate that higher accumulation of organic carbon due to retention of crop residue was confined to surface soil. The increase in PMN in 160 kg Nha^{-1} (F_3) and 120 kg Nha^{-1} (F_2) treatments in surface layer was 63.3 and 59.6% over unfertilized control, while they were 25.5 and 17.9% greater over 80 kg Nha^{-1} (F_1) treatment, respectively.

Table 5: Effect of different treatments on contents of various biological fractions of carbon in soil

Treatments	PMN (mgkg^{-1})		MBC (mgkg^{-1})		MBN (mgkg^{-1})		DOC (mgkg^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Tillage Practices								
T_1 ZTR	12.4	11.2	562.5	471.1	20.2	18.9	198.6	183.6
T_2 ZTWR	8.5	7.6	350.4	302.1	14.1	12.6	167.1	159.2
T_3 RTR	10.6	9.9	490.2	399.3	19.1	17.2	186.4	171.6
T_4 RTWR	7.6	6.6	318.1	299.8	14.4	13.7	159.5	148.7
T_5 CTR	9.3	8.5	402.9	354.4	18.2	16.6	175.9	168.9
T_6 CT	6.7	5.6	307.9	289.5	11.8	9.7	142.5	134.6
Nitrogen Management								
F_0 Control	3.6	2.8	218.3	202.9	10.8	10.4	103.7	92.3
F_1 80 kg N ha^{-1}	5.3	4.4	241.1	199.4	14.9	12.2	128.3	116.9
$F_2$120 kg N ha^{-1}	8.9	7.6	282.7	220.9	16.5	16.1	136.8	123.6
F_3 160 kg N ha^{-1}	9.8	8.4	343.9	262.9	19.4	18.1	164.8	148.9
F_4 200 kg N ha^{-1}	10.4	9.7	346.3	269.6	22.7	21.7	155.7	136.4

Values in a column followed by the same letter are not significantly different ($P < 0.05$).
PMN = potentially mineralizable nitrogen, MBC = microbial biomass carbon, MBN = microbial biomass nitrogen, DOC = dissolved organic carbon

3.3.2. Microbial biomass carbon (MBC)

The level of MBC was indistinguishable between the CT and ZT without residue retention regimes and was markedly lower under these regimes than under ZT and RT with residue retention (Table 5).Changes in MBC can indicate the effects of management practices on soil biological and biochemical properties. The higher MBC was observed in the ZT and RT with residue retention plots than the CT plot under the wheat crop suggests that abandonment of the cropland had substantial beneficial effects on the activity of microbial organisms probably caused by the accumulation of organic C compounds at the soil surface. A possible reason for this difference is that in the absence of growing plants other labile C fractions may provide food for microbes, and thus maintain MBC. Another possible reason could be related to the soil moisture status. Under the CT treatment, in which biomass production would inevitably deplete much more soil moisture, the microbes in the plot would be stressed at the time of sampling (wheat maturity). The microbial biomass carbon (MBC) is an important component of the SOM that regulates the transformation and storage of nutrients. The soil MBC regulates all SOM transformations and is considered to be the chief component of the active SOM pool. It is evident that the MBC contents in both surface and sub-surface soil were significantly higher in plots receiving inorganic fertilizer of 200 kg Nha^{-1} (F_4) and 160 kgNha^{-1} (F_3) compared to 80 kgNha^{-1}(F_1) and unfertilized control plots (Table 5). The values of MBC in surface soil varied from 218.3 mgkg^{-1} in unfertilized control plot to 346.3 mgkg^{-1} in 200 kg Nha^{-1} (F_4) plots, respectively; while it varied from 202.9 mgkg^{-1} (control) to 269.6 mgkg^{-1} in 200 kg N ha^{-1} (F_4) in sub-surface (15-30 cm) soil layer. The values of MBC increased by 36.5 and 37.1% less than 160 kg Nha^{-1} (F_3) and 200 Kg Nha^{-1} (F_4) treatments in surface soil over control. The highest value of MBC due to residue retention with inorganic fertilizer might be due to higher turn-over of root biomass produced less than 200 kg Nha^{-1} treatment. Application of 200 kg Nha^{-1} fertilizer is not only required for better growth of the crop but also required for synthesis of cellular components of microorganisms. Therefore, higher root biomass under 200 kg Nha^{-1} fertilizer treatments helped in increasing MBC over other treatments.

Similar to our results in several studies have reported that ZT management increased MBC in the surface soils (Dou *et al*., 2008; Balota *et al*., 2003; Naresh *et al*., 2016) [17, 4, 44]. Lack of soil disturbance under ZT provides steady source of organic C substrates for soil microorganisms, which enhances their activity and accounts for higher soil MBC as compared with CT – where a temporary flush of microbial activity with tillage events results in large losses of C as CO_2 (Balota *et al*., 2003) [4]. Soil microbial biomass has been generally thought to be limited by energy substrates rather than mineral nutrients. However, studies have demonstrated that soil microbial growth can be constrained by N availability Kaye and Hart, 1997). Bolinder *et al*., (1999) [6] found that the MBC showed higher sensitivity to crop management practices as compared to SOC. Because of the dynamic nature of MBC, it can be promoted as an indicator of early changes in soil organic matter status due to management practices (Powlson *et al*., 1987) [45].

3.3.2. Microbial biomass nitrogen (MBN)

Results on MBN content after 2 years showed that in surface soil were 11.8, 14.1, 14.4, 18.2, 19.1 and 20.2 mgkg^{-1} in ZT and RT without residue retention, CT with residue incorporation, RT and ZT with residue retention and conventional tillage (CT) treatments, respectively (Table 5). In 15- 30 cm layer, the increasing trends in MBN content due to use of tillage practices and residue retention were similar to those observed in 0-15cm layer, however, the magnitude was relatively lower (Table 5).Significant increase in MBN in surface soil (0–15 cm) was maintained in plots receiving 200 kg Nha^{-1}(F_4),and 160 kg Nha^{-1}(F_3) fertilizer over 80 kg Nha^{-1} (F_1), and over unfertilized control plots (F_0) (Table 5). However, increases in MBN in sub-surface soil (15–30 cm) were observed only under plots receiving 200 kg Nha^{-1}(F_4), and 160 kg Nha^{-1}(F_4), fertilizer over unfertilized control plots. Increase in MBN in surface soil was 52.4 and 44.3% in 200 kg Nha^{-1}(F_4), and 160 kg Nha^{-1}(F_3) fertilizer treated plots over control, respectively. Dalal *et al*., (1991) [15] studied the effects of 20 years of tillage practice, CR management and fertilizer N application on microbial biomass and found that MBN was significantly affected by tillage, residue and fertilizer N individually as well as through their interaction. The soil layers under no-till contained higher amount of MBN than that under CT treatments. Our results are in accordance with earlier studies, which reported greater MBN under zero and reduced tillage practices than CT (Carpenter-Boggs *et al*., 2003; Dou *et al*., 2008; Naresh *et al*., 2016) [9, 17, 44]. Zero/reduced tillage practices allow C to build-up in the plow layer by enhancing soil aggregation and reducing oxidation (Carpenter-Boggs *et al*., 2003) [9].

3.3.4. Dissolved Organic Carbon (DOC)

Dissolved organic carbon (DOC) content over CT (T_6) of the field after 2 -year crop cycle is presented on Table 5. Surface and subsurface soil layers (0-15 and 15-30 cm) had significantly different DOC change. Highest DOC change (28.2%) was found in ZT with residue retention (T_1) plots followed by RT with residue retention (T_3) plots (23.6%).The use of ZT and RT with residue retention (T_1 andT_3) plots for two wheat crop cycle increased DOC by 21.2 and 16.1% more than that of ZT and RT without residue retention and conventional tillage (T_2, T_4 and T_6), respectively. In subsurface soil layer similar increasing trends were observed, however, the magnitude was relatively lower (Table 5). Irrespective of soil depths, 160 kg Nha^{-1} invariably showed higher content of DOC over all other treatments. The 80 kg Nha^{-1}and unfertilized treatments showed lower content of DOC. The DOC concentrations in 0–15 cm and 15–30 cm depths were observed highest for 160 kg Nha^{-1} (F_3) followed by 200 kg Nha^{-1}(F_3) and 120 kg Nha^{-1}(F_2), and both of them were significant higher than 80 kg Nha^{-1} (Table 5).However, in the 15-30 cm layer, the difference in DOC between rests of the treatments was not significant. Several field studies have shown that concentration and fluxes of DOC in soil solution decrease significantly with soil depth Kalbitz *et al*., (2000) [27]. The results obtained in the present study are in agreement with earlier investigations reporting higher levels of DOC under conservation tillage practices (Lewis *et al*., 2011; Chen *et al*., 2009) [35, 11]. According to Lewis *et al*., (2011) [35], increasing tillage intensity could reduce DOC levels in soils as a result of destruction of soil macro-aggregates and elevated respiration. Lower amount of DOC, hence is likely under CT due to increased soil disturbances subjecting aggregated protected SOC fraction to rapid decomposition via oxidation. Our results suggest that DOC fraction is sensitive to tillage management practices.

Grain yield

The wheat yield revealed that the crop responded significantly to different levels of nitrogen application as compared to control. Data generated from the present field study clearly indicated that significant (P=0.05) increase in grain yield of wheat with increasing in N level significantly up to 160 kg Nha^{-1} which was 26.54% over control. Maximum grain yield was recorded (4613 and 47.18) with 160 kg Nha^{-1} and it was significantly superior all over the treatment except F_4 (43.90 and 45.69). The lowest value of grain yield was recorded with unfertilized "control" (F_0) plots (Table-6). The grain yield of wheat was significantly increased by the effect of nitrogen management which increased the fertilizer use efficiency and improved the physical and chemical properties of soil hence making better utilization of nutrients might also be a reason towards increased yield Singh *et al.*, (2009) [46]. Similar results were reported by Chuan *et al.* (2013) [12].

Quality parameters

Straw retention/return had significant effects on soil protein %, Gluten % and Hectolitre weight under zero and reduced tillage seeding techniques as shown in Table 4. In general, protein % and Gluten % and Hectolitre weight tin the following order: **T_1** ZTR> **T_3** RTR> **T_5** CTR>**T_2** ZTWR> **T_4** RTWR and > **T_6** CT, during experimentation. Application of 200 kg Nha^{-1} had significantly higher Gluten % and Hectolitre weight as compared to all other treatments except F_3 160 kg Nha^{-1}. However, F_2 and F_1 were at par at with each other and recorded higher Gluten % and Hectolitre weight than F_0 unfertilized "control" plots during both the year of study (Table-6).

Table 6: Effect of tillage practices and nitrogen management on grain yield and quality parameters

Treatments	Grain yield qha^{-1}		Protein %		Gluten %		Starch %		Hectoliter weight (g)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Tillage Practices										
T_1 ZTR	46.13	48.91	12.0	12.2	10.0	10.0	63.4	67.2	76.2	77.6
T_2 ZTWR	41.92	43.64	11.1	11.5	10.2	10.2	63.5	67.2	74.0	75.5
T_3 RTR	44.29	46.73	11.6	11.8	10.3	10.3	63.5	67.3	76.3	79.8
T_4 RTWR	40.82	42.82	11.1	11.4	10.5	10.4	63.5	67.3	75.3	76.1
T_5 CTR	44.16	45.90	11.3	11.6	10.5	10.4	63.5	67.2	78.5	80.6
T_6 CT	41.65	43.54	11.0	11.3	10.6	10.5	63.5	67.3	75.8	78.3
Nitrogen Management										
F_0 Control	30.71	29.89	11.0	11.3	9.6	9.5	63.4	67.2	70.5	72.2
F_1 80 kg N ha^{-1}	33.66	32.51	11.3	11.5	9.8	9.8	63.5	67.2	76.6	77.2
F_2 120 kg N ha^{-1}	39.14	41.83	11.6	11.9	9.9	9.9	63.5	67.3	76.9	77.3
F_3 160 kg N ha^{-1}	46.13	47.18	11.7	12.1	10.6	10.6	63.5	67.3	78.7	80.7
F_4 200 kg N ha^{-1}	43.90	45.69	11.6	11.8	10.7	10.8	63.5	67.3	80.4	81.2

Conclusion

The data acquired from the 02-year, wheat experiment revealed that tillage and crop residue practices had significant effects, of varying magnitude, on SOC and its fractions. Zero tillage with residue retention resulted in markedly higher soil labile organic carbon pools than the conventional tillage without residue, and it could be a suitable management strategy to improve or restore soil quality. Under the tillage crop residue management system, application of 200 kg Nha^{-1} was most effective for improving SOC and its labile pools, followed by 160 kg Nha^{-1}fertilizer plus crop residue, and then 120 kg Nha^{-1} plus crop residue. The surface soil layer had substantially higher levels of all soil health parameters than subsurface layer, presumably due to higher retention of crop stubbles, fallen leaves and root biomass. The enhanced proportions of WSOC, POC, LFOC, MBC in SOC and that of PON, LFON, and DOC with the supply of optimum and balanced nitrogen fertilizer and incorporation/retention of crop residues indicate that the improvement in labile forms of both C and N was relatively rapid than control suggesting that active C and N pools reflect changes due to balance nutrient management. Thus, application of fertilizer in optimum amounts and inclusion of crop residue in the fertilizer schedule could maintain the soil health under intensive agriculture. In conclusion, Nitrogen plays a significant role in building-up/restoring soil health and productivity with co-benefits of improved C sequestration in *Typic Ustochrept* soil inherently low in organic matter and nutrients.

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