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Tillage, Irrigation Levels and Rice Straw Mulches Effects on Wheat Productivity, Soil Aggregates and Soil Organic Carbon Dynamics After Rice in Sandy Loam Soils of Subtropical Climatic Conditions

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Soil organic carbon is considered to be of central importance in maintaining soil quality. We assessed the adoption of different combinations of tillage, crop residue and irrigation on soil organic carbon (SOC) dynamics in different sized soil aggregates and also on crop yield after 4 years in wheat monoculture field plot experiment in a sandy loam soil under subtropical climatic conditions. Results showed that tillage crop residue and irrigation significantly increased water stable aggregates and had profound effects in increasing the mean weight diameter as well as the formation of macro-aggregates, which were the highest in both surface (14.5 &12.5%) and subsurface (13.4 & 12.1%) soil layers under FIRB and ZT with application rice straw and I_5 treatments after 3 years. Hence, better aggregation was found with FIRB with 6t rice straw + I_5 where macro-aggregates were greater than 30% of total soil mass. The same treatment also enhanced the labile C and N fractions such as water soluble C, particulate and light fraction organic matter from 7.1 mg·kg^{-1} conventional tillage to 17.6 mg·kg^{-1} in surface layer and from 6.5 to 16.3 mg·kg^{-1} in subsurface layer after 3 years leading to the 42% and 39% higher water soluble C stocks over CT in 0-15 cm soil layers, respectively. The changes in water soluble C stocks after 4 years were 45% and 40%. WUE increased as mulching increased for the I_2, I_3, and I_4 treatments, but not for the I_5 treatment. We conclude that variants of conservation tillage increase SOC stock in the sandy loam soils of subtropical climatic conditions of western U. P., India and are therefore more sustainable practices than those currently being used.

Keywords: Conservation tillage; Rice straw; Water Stable *Aggregates;* Soil organic carbon, Water use.

Soil organic matter (SOM) is an important indicator of soil fertility and productivity because of its crucial role in soil chemical, physical and biological properties (Gregorich *et al*., 1994). Soil tillage and water management are all examples of cultivation practices that could either reduce or increase soil C sequestration (Dobermann and Witt, 2000).Physical fractionation of soil for aggregate-size fractions has been an effective technique for evaluating soil aggregation and degradation induced by management practices, studying the forms and cycling of SOC, and providing important

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information about C sequestration mechanisms (Six *et al*., 2004). Many studies indicate that various tillage systems have a strong effect on soil aggregation, and SOC distributions in aggregates size fractions. Such effects varied depending on regional climate, soil type, residue management practice, and crop rotation (Puget and Lal, 2005). Research on soil C sequestration for specific soil/ climate/cropping system is therefore necessary. Furthermore, there has been very little number of studies investigating the effects of conservation tillage on C sequestration under subtropical climatic conditions of western Uttar Pradesh, India.

Irrigation is expected to enhance the total root biomass and thus total SOC content and organic-mineral interactions. On the other hand, the availability of soil moisture would mostly improve the decomposition process (Bhattacharyya *et al*., 2013). Thus, unlike tillage, irrigation has the potential to impact both stable and unstable C in soils. Li *et al*. (2010) reported that wheat receiving four irrigations at CRI, maximum tillering, boot stage and milk stage resulted in 13.7 and 29.0% higher grain yield over two (at CRI and boot stages) and three irrigations (at CRI, boot and milk stages),respectively. Irrigations are recommended at times corresponding to the specific growth stages (crown root initiation, early tillering, late jointing/ boot, and heading/flowering) of the wheat (Maurya *et al*., 2008). Water stable aggregates (WSA) play an important role in nutrient cycling and in supplying substrate for microbial processes that lead to structural stability (Mohanty *et al.*, 2012), while the size of aggregates indicates the influence of management on soil structural stability (Król *et al.*, 2013). However, labile organic matter fractions are readily accessible sources to microorganisms, turnover rapidly (weeks or months), and have direct impact on plant nutrient supply Kumar *et al*., (2011). Labile organic matters fractions generally include water soluble C (WSC), particulate organic matter (POM) and light-fraction organic matter (LFOM).

Tillage plays a key role in changing the hydro-physical properties. Huang *et al*., (2012) indicated that water infiltration and runoff are closely related to the physical condition of the upper layer of the soil profile. Soil physical properties such as bulk density, soil water content, aggregation and porosity near the soil surface are most important for dictating the infiltration characteristics of the soil at the soil-water interface (Bhattacharyya *et al*., 2013 and Naresh *et al*., 2015). Zero tillage (ZT) systems conserve the land resource and are cost effective and efficient. Moreover, this tillage system also avoids challenges with clod formation (Ram *et al*., 2012). The results of other studies showed that surface soil in zero-tilled plots had significantly greater aggregate mean weight diameter (MWD) and available water capacity than soil that had been tilled (Gulde *et al*., 2008). Few studies have examined the combined effects of tillage, irrigation and mulch on soil properties, yield and water use efficiency under irrigated conditions. The practice is required to conserve underground water which is depleting at an alarming rate in study area. The present investigation was therefore, carried out with the objectives to study the interactive effect of variable irrigation levels, tillage's and rice mulch on soil aggregation potential and C sequestration and sustainable yield in sandy loam soils of subtropical climatic conditions.

MATERIALS AND METHODS

Experimental

A 4-year field experiment on wheat crop was established in 2008 at Sardar Vallabhbhai Patel University of Agriculture &Technology, Meerut research farm (29° 04', N latitude and77° 42' 'E longitude a height of 237m above mean sea level) U.P., India. During the 4-year period of field experiment, mean weekly maximum and minimum air temperature for the crop seasons were recorded ranged from 16.3 to 36.4°C and 5.2 to 19.6°C, respectively. 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 is shown in Fig.1.

Soil of the experimental site

A composite soil sample was collected from the experimental field to study the contents of available N, P and K, pH, electric conductivity, organic carbon content and some physical properties of the soil. The soil analysis revealed that the soil was sandy-loam in texture (Typic Ustochrept), low in organic carbon, available nitrogen and available phosphorus contents while it was medium in available potassium. The soil reaction was near neutrality with slight alkaline tendency

Treatments

The experiment was laid out in a split plot design keeping nine tillage crop establishment methods T_1- ZT without residue, T_2-ZT with 2 t rice straw,T_3-ZT with4 t rice straw ,T_4-ZT with 6 t rice straw,T_5-FIRB without residue, T_6-FIRB with 2 t rice straw,T_7-FIRB with 4 t rice straw,T_8-FIRB with 6 t rice straw,T_9- Conventional tillage in main plots and five irrigations levels in sub-plots, and replicated three times. The experiment was conducted in main plot of 8.0 m×9.6 m having subplot of 8.0 m×2.0 m size with buffers all around the main plots. The experiment was established on same location and treatments were imposed on same plots in all the years of study. Chopped rice straw of size 15–20 cm was applied as mulch manually on the same day after sowing of wheat in each year.

Irrigation

The irrigation levels included: I_1 one irrigation at CRI; I_2 two irrigations at CRI (21–25 DAS) and boot stage (80–85 DAS); I_3 three irrigations at CRI, tillering (45–50 DAS) and boot stage:I_4 four irrigations at CRI, tillering, booting and dough stage(100–105DAS);and I_5five irrigations at CRI, tillering, jointing (65–70DAS), booting and dough stage. The critical growth stages of wheat were selected based on the information available from the previous studies (Huang *et al*., 2012).

Cultural practices

Fertilizers application

In experiment, all plots received N: P: K 120:60:40 kg ha^{-1}.Half dose of N and full dose of P and K were applied as basal at the time of seeding through multi crop zero till cum raised bed planter with inclined plate seed metering device. Remaining half N was top dressed in two equal split doses; first split before 1st post-sowing irrigation at CRI stage and the second split before 3rd irrigation at pre-flowering stage.

Preparation of field for conventional tillage

After the rice harvest, following the conventional practice of two harrowing, three ploughing (using a cultivator) and one planking (using a wooden plank) that followed pre-sowing irrigation and wheat was seeded in rows 20 cm apart using a seed drill with a dry-fertilizer attachment.

Preparation of furrow irrigated raised beds

At the beginning of the experiment soil was tilled by harrowing and plowings followed by one field leveling with a wooden plank, and raised beds were made using a tractor-drawn multi crop zero till cum raised bed planter with inclined plate seed metering devices. The dimension of the wide beds were 107 cm wide (top of the bed) x 12 cm height x 30 cm furrow width (at top) and the spacing from centre of the furrow to another centre of the furrow was kept at 137 cm. Six rows of wheat were sowing on each raised bed.

Crop management

Wheat variety DBW-17 was seeded at 100 kg seed ha^{-1} at 20-cm row spacing in conventional tillage and zero tillage, and a seed rate of 80 kg ha^{-1} was used in bed planting. Six rows of wheat were planted on bed. To control weeds Sulfosulfuron @ 25g a.i.ha^{-1} and Metsulfuron @ 4g a.i.ha^{-1} at 30-35 DAS were used to control grass and broadleaf weeds, respectively.

Measurement of soil properties

The samples for determination of soil physical properties were collected at the start of the experiment and after the harvest of each crop. The infiltration rate was measured at the onset of the experiment and after the 4 years of study. Soil bulk density was measured by core method (Blake & Hartge, 1986). The infiltration rate was measured using a double-ring infiltrometer. For aeration porosity, soil cores were saturated and brought to equilibrium in the hanging water column at a suction of 0.5 m. Volume of water released per unit volume of soil was used as a part of pore space which is filled with air and expressed in percentage as aeration porosity.

Soil Sampling and analyses

Aggregate size separation was performed by a wet-sieving method adapted from Yoder (1936). Briefly, a 100-g air-dried (8-mm sieved) soil sample was placed on the top of a 2mm sieve and submerged for 5 min in deionizer water at room temperature to allow slaking (Kemper and Rosenau, 1986).The sieve nest was then clamped and secured to a drum. The sieve assembly was oscillated up and down by a pulley arrangement for 20 min at a frequency of 30 to 35 cycle's min^{-1} with a stroke length of 4 cm in salt-free water inside the drum. A series of five sieves (5,2,1,0.5, and 0.25 mm) was used to obtain six aggregate fractions (i) >5 (Very large macro-aggregates), (ii) 2-5 (large macro-aggregates), (iii) 1-2 (medium macro-aggregates), (iv) 0.5-1 (small macro-aggregates) ,(v) 0.25-0.5 (micro-aggregates), and (vi) <0.25 (silt- and clay-sized particles). After the completion of IIIrd and IVth years of wheat crop season, representative soil samples were collected from four random spots within each plot and mixed thoroughly to prepare a composite sample for 0–5 and 5-15cm layer and air dried under shade. A portion of each sample was passed through 2 mm sieve and water soluble C was determined by the method of McGill *et al., (1986)* and particulate organic C and N (POC and PON) were determined by the method of Gambardella and Elliott, (1992) and light fraction organic C and N (LFOC and LFON) were determined by the method of Compton and Boone (2002).

Crop harvest and yield determination

At maturity, wheat was harvested manually at 10 cm above ground level. Grain and straw yields were determined from an area of 70.2 m^2 in flat beds and 69.7 m^2 in raised beds located in the center of each plot. The grains were threshed using a plot thresher, dried in a batch grain dryer and weighed. Grain moisture was determined immediately after weighing. Grain yield was reported at 12% moisture content.

Statistical analysis

Data were pooled and all parameters were analyzed as Split-plot model (Tillage crop residue practices as main effect, irrigation levels as sub-plot effect) by SAS software. All the treatments were compared by F-test at 5% level of probability.

RESULTS AND DISCUSSION

Soil Physical Properties

Bulk Density, Cone index and Infiltration rate

Tillage operations are done to loosen the soil and facilitate root penetration for better anchorage and exploitation of soil nutrients and water by the plant. In the study it was found that bulk density was the highest in T_1 followed T_9, T_2 and T_5 **(Table 1).** The soil bulk density in the top layers (0–10 and 10–20 cm) of the FIRB treatment was 6.1 to 7.7% lower (significant at $P < 0.05$) than that of T_1 treatment **(Table 1).** The mean soil bulk density in the 0- to 20-cm soil layer of the FIRB with residue retention and ZT with residue

Table 1. Effects of tillage crop residue practices on bulk density, aggregate porosity, total porosity, cone index, and infiltration rate and penetration resistance of wheat crop under rice -wheat cropping system after 4 years of experimentation in 0-20 cm

Treatments	Bulk density (kg/m^3) Soil depth (cm) 0-5	5-10	10-15	15-20	Mean bulk Density	Aggregate porosity (%)	Total porosity (%)	Cone index (kg/cm^2)	Cumulative infiltration rate at 3hr at harvest(cm)
T_1	1.61	1.63	1.69	1.82	1.69	43.2	39.6	204.8	16.26
T_2	1.48	1.55	1.70	1.75	1.61	40.8	51.9	332.9	16.85
T_3	1.45	1.53	1.57	1.61	1.55	42.7	52.4	235.6	17.60
T_4	1.43	1.48	1.53	1.59	1.51	40.2	54.3	367.5	18.25
T_5	1.39	1.45	1.68	1.79	1.58	41.3	42.6	289.7	17.30
T_6	1.45	1.49	1.59	1.72	1.55	39.6	44.9	418.7	18.50
T_7	1.47	1.58	1.63	1.73	1.49	36.2	45.6	423.8	18.90
T_8	1.40	1.48	1.56	1.64	1.46	46.8	49.3	456.8	19.35
T_9	1.51	1.54	1.67	1.78	1.63	49.2	41.2	488.3	16.79

Table 2. Water stable aggregates distribution (WSA) in different sizes (%) and mean weight diameter (MWD) mm in six aggregate size classes in the 0-5-cm and 5-15 cm soil layer after 4 yrs of wheat crop

Treatments	Distribution of WSA in different sizes (%)													
	0-5 cm							5-15 cm						
	>5mm	2–5	1-2	0.5-1	0.25–0.5	<0.25	MWD	>5mm	2–5	1-2	0.5-1	0.25–0.5	<0.25	MWD
Tillage crop residue practices														
T_1	11.2a	11.2a	11.5a	18.5a	19.9a	27.5a	0.90a	5.0b	4.2b	2.2c	1.9c	0.8b	4.7b	0.58c
T_2	9.3b	9.7b	10.9a	16.0b	17.5b	36.6b	0.94b	5.7b	5.3b	3.3b	3.1a	1.7b	5.6c	0.60d
T_3	8.3b	8.4b	8.6b	13.5c	16.1b	45.1c	1.36b	5.5b	5.8b	4.1a	3.7a	1.9a	6.3c	0.88b
T_4	5.1c	6.2c	6.3c	10.8d	12.5c	59.1d	1.13b	6.4ab	5.1c	3.6b	2.8b	1.7b	6.1c	0.61d
T_5	4.5c	5.4c	5.9c	9.4d	10.7d	64.1e	1.43ab	6.5ab	5.6bc	4.2a	3.1a	2.0a	6.7bc	0.89c
T_6	12.3a	12.4a	12.3a	19.2a	20.2a	23.6a	1.85a	5.6b	5.9c	4.9a	3.9a	2.1a	7.2ab	0.88c
T_7	11.2a	12.2a	10.9b	17.5b	18.6b	29.6b	1.56 b	7.2a	5.3bc	4.6a	3.6a	1.9a	6.9bc	0.85b
T_8	10.8b	10.9b	9.9b	16.1b	18.1b	34.2c	1.70a	7.3a	6.4ab	5.1a	4.1a	2.2a	7.3ab	1.11b
T_9	9.8b	9.3b	7.9c	12.8c	14.2c	46.0d	2.03 a	8.6b	7.3a	5.6a	4.3a	2.4a	7.6a	1.57a
Irrigation levels														
I_1	7.8c	8.1c	6.3c	10.7d	12.6c	54.5e	1.40a	5.8b	6.8ab	5.7ab	4.5ab	2.3b	6.8b	0.76a
I_2	2.13 a	6.06 a	5.59 a	5.33 a	13.08 a	66.91 a	1.56 b	6.1a	6.4b	4.8bc	3.3b	2.2b	7.0b	0.82b
I3	5.34 b	4.29 a	5.67 a	17.6 a	35.45 b	31.66 b	1.23b	5.4a	7.2bc	5.4bc	4.6ab	2.4a	6.9b	0.71a
I_4	6.60 b	9.79 b	8.09 a	8.95 a	12.83 a	53.73 a	1.34 b	6.3a	7.6bc	5.9ab	5.1a	2.5a	7.8a	0.77a
I_5	6.71 b	5.72a	4.05 a	15.1 ab	11.07 a	57.47 a	1.41a	6.5a	6.9bc	5.0bc	3.9b	2.4b	8.0a	0.79a

a-d Values followed by the same letter within the same aggregate class and treatment are not significantly different at the 0.05 probability level ($P<0.05$).

retention plots was 12.4 and 6.8% lower, respectively ($P < 0.05$), than the CT plots. In addition, the FIRB treatment had significantly ($P < 0.05$) lower soil bulk density in the 0- to 10- and 10- to 20-cm soil layers than CT by 14.3 and 12.8%, respectively. The changes in bulk density were mainly confined to top 10-15 cm layer.

The soil strength measured at 70% field capacity for the top 10 cm depth and presented as cone index increased with bulk density, and the minimum value was recorded for treatment T_8. The lower bulk density means more porosity especially in upper surface and maximum bulk density for T_1. The average of four years cumulative intake of water at 3 hr was higher under FIRB than conventional and zero tillage. Cumulative infiltration decreased with time probably because of progressive destruction in soil structure and an increase in subsoil compaction, which more or less stabilized thereafter. Cumulative infiltration in FIRB and ZT increased with time, indicating improvement in soil structure, as also supported by soil aggregation. Fuentes a *et al*., (2009) reported that ZT in medium textured soils enhanced infiltration rates with time.

Aggregate porosity and Total porosity

Soil porosity results showed that the residue retention treatments could increase the total porosity of soil, while zero tillage without residue (T_1) would decrease the soil porosity for aeration, but increase the aggregate porosity; 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 on the total porosity and aggregate porosity distribution were not significant and zero tillage without residue (T_1) could increase the quantity of big porosity. Residue retention treatments shown an improvement in the aggregate porosity and was most probably related to the beneficial effects of soil organic matter caused by ZT and FIRB with residue cover **(Table 1).**Husnjak and Kosutic (2002) reported that higher BD reduced the total porosity and changed the ratio of water holding capacity to air capacity in favour of water holding capacity.

Water-stable Aggregate Distribution

Small macro-aggregates accounted for >30% of the total aggregates (mean of both main plots) in the surface soil layer. Silt- plus clay-sized aggregates comprised the greatest proportion of the whole soil, followed by the small macro-aggregates. The amount of water-stable large and small macro-aggregates in the FIRB and ZT plots were significantly higher than in the CT plots in the 0- to 5-cm soil layer (Table 2). Hence, the plots under CT had significantly smaller MWD than FIRB and ZT plots in the 0- to 5-cm soil layer (Table 2). The tillage × irrigation interaction effects were significant for macro-aggregates in that soil layer (Table 2). Plots under I_5 had 16.7% and -more macro-aggregates than I_3 plots for FIRB and ZT than CT. Apart from the large macro-aggregates (>5mm), however, tillage had no effect on soil aggregation (and thus on MWD) in the subsurface soil layer (5–15 cm) and no interaction effects were significant (Table 2). Plots under ZT had about 12.2% more macro-aggregates than CT plots in the 5- to 15-cm depth layer (Table 2).

Irrigation had a significant impact on soil aggregation in both surface layers. Plots under I_5 had significantly more large macro-aggregates in the 0- to 5-cm soil layer than I_4, I_3, I_2, or I_1 plots (Table 2). Similarly, I5 plots had more small macro-aggregates than I_3, and I_2 plots (Table 2). Thus, MWD increased by 14 and 27% in the I_5 plots compared with the I_3 (0.97 mm) and I_2 (0.86 mm) plots, respectively, in the surface soil layer (Table 2). In the 5- to 15-cm soil layer, however, only large macro-aggregates and MWD were impacted by irrigation (Table 2). Plots under I_5 had significantly more large macro-aggregates and MWD than I_1 plots in the 5- to 15-cm depth layer (Table 2). Thus, I_1, I_2, I_3, and I_4 plots had similar effects on soil aggregation in the subsurface soil layer. This implies that irrigation had a substantial effect on soil aggregation with increasing years of cultivation. The decline in the size of aggregates with CT could be due to mechanical disruption of macro-aggregates, which might have exposed SOM previously protected against oxidation

Distribution of Aggregates in Different Size

As compared to the conventional tillage treatments, zero tillage and furrow irrigated raised beds treatments had significantly higher amount of total aggregate associated carbon within all the aggregate size classes in surface soil depth. In the 0–5 cm layer of soil with residue retention the organic C content in the large macro-aggregates was greater (av.12.3%) than in soil where residue was removed (av.8.8%), except in the T_6 and T_7

Table 3. Impacts of tillage practices and irrigation levels on organic C content in six soil aggregate size classes and mean weight diameter (MWD) in the in the 0-5-and 5-15 cm soil layer after 4 yrs of wheat crop

Treatments	Aggregate size distribution g C kg^{-1} soil aggregate fraction													
	0-5 cm							5-15 cm						
	>5mm	2–5	1-2	0.5-1	0.25–0.5	<0.25	MWD	>5mm	2–5	1-2	0.5-1	0.25–0.5	<0.25	MWD
Tillage crop residue practices														
T_1	*11.65c*	*9.23c*	8.39c	6.69d	6.20c	5.56bcd	0.98	2.90 a	3.57 a	4.17 a	5.53 a	12.34 a	72.08 a	*0.77*
T_2	13.35abc	*10.23c*	9.39c	7.69d	7.20c	6.56bcd	1.07	4.44ab	5.68a	5.22a	20.23b	36.90b	27.55b	*0.86*
T_3	14.90ab	12.21b	10.80ab	10.09ab	7.69a	7.50c	1.03	5.34 b	4.29 a	5.67 a	17.60 a	35.45 b	31.66 b	0.63
T_4	15.32a	12.07bcd	11.79b	11.08a	9.95ab	7.65bc	1.24	6.71 b	5.72 a	4.05 a	14.98 a	11.07 a	57.47 a	6.71 b
T_5	11.52b	10.70ab	9.94b	8.97a	7.75a	6.72b	1.02ab	2.13 a†	2 6.06 a	5.59 a	5.33 a	13.08 a	66.91 a	0.78
T_6	12.50bc	13.91a	12.07b	11.65a	10.38a	7.41ab	1.14	3.56 a	4.07 a	3.09 a	4.10 a	11.90 a	76.86 a	*0.61*
T_7	13.91a	11.54cde	10.42	9.86bc	7.20ab	7.13c	1.09 a	4.70 a	4.19 a	3.52 a	4.70 a	21.06 b	61.84 ab	*0.86*
T_8	14.26abc	10.33e	10.04c	9.90bc	8.64c	7.80bc	1.20	6.60 b	9.79 b	8.09 a	8.95 a	12.83 a	53.73 a	*0.58*
T_9	7.2ab	6.1a	3.1ab	2.3a	5.9c	4.9a	0.79 a	7.93 a	8.58 b	8.43 b	13.96 b	17.56 ab	43.55 b	0.71
Irrigation levels														
I_1	4.5 ab	4.72 a	4.80 a	14.17 b	31.47 b	40.35 b	0.75 ab	3.20 a	4.24 a	4.25 a	4.79 a	12.44 a	71.95 a	0.70 b
I_2	5.6c	4.8b	10.0 c	28.3 b	24.6 ns	37.1 a	0.86 c	4.9bc	5.4a	6.9bc	7.1a	15.3bc	64.6a	1.02b
I_3	6.1c	5.3b	12.6 ab	30.7 b	25.2	31.5 bc	1.02 ab	5.6c	6.8b	7.1bc	7.6b	15.3b	53.3b	0.98
I_4	6.3c	5.5.a	11.7 b	30.3 b	24.9	33.1 b	0.97 b	6.3c	5.5.a	6.8ab	7.1a	15.8b	54.1a	0.88 b
I_5	6.7bc	5.8b	13.7 a	33.7 a	23.2	29.3 c	1.11 a	6.41 b	8.03 b	7.52 b	9.30 ab	13.82 a	54.92 b	0.79 a

‡Values followed by different letters within a column for a particular management practice are significantly different at $P < 0.05$

treatment where it was similar (9.3%) to treatments without residues and in the T_2 and T_3 (11.8%) where it was similar to treatments with residues (Table 3). In the small macro-aggregates, the greatest organic C was found for treatment T_4 (av.13.4%), while the lowest organic C was found in soil without residues cultivated (av.6.3%) (Table3). Residue management had a significant ($P<0.05$) effect on C content in large and small macro-aggregates.

In sub-surface soil layer (Table 3), treatment (T_9) resulted in 11.8% higher total soil aggregated carbon as compared with wheat in zero tillage without residue retained treatment (T_1). In surface soil, the maximum (13.5%) and minimum (4.3%) proportion of total aggregated carbon was retained with >2 mm and <0.053 mm size fractions, respectively. Similarly in, the sub-surface layer >2 mm size particles occluded highest proportion (12.0%) of total aggregated carbon followed by 0.25 - 2.0 mm, 0.053– 0.25 mm and <0.053 containing 9.4% 5.9% and 3.7%, respectively. Conservation tillage (both ZT and FIRB) caused 35.5%, 28.1%, 17.9% and 10.5% higher accumulation of SOC in>2mm, 0.25 -2.0 mm, 0.053– 0.25mm and <0.053 size particles, respectively, than conventional tillage treatments(T_9).Wheat seeding on wide raised beds with residue retention (T_8) had the highest capability to hold the organic carbon in surface (10.73g kg^{-1} soil aggregates) and retained least amount of SOC in sub-surface (7.13g kg^{-1} soil aggregates) soil.

MWD in the 0-5cm layer ranged from 0.41 to 0.49mm in CT and 0.46 to0.48 mm in CA system (Table 3). The corresponding values for 5 - 15 cm soil layer varied from 0.41 to 0.51 and 0.43 to 0.48 mm (Table 3). The MWD was significantly higher in CA treatments as compared to CT system in both the soil layers.

Irrigation had a significant impact on soil aggregation in both surface layers. Plots under I_5 had significantly more large macro-aggregates in the 0- to 5-cm soil layer than I_4, I_3, I_2, or I_1 plots (Table 3). Similarly, I_4 plots had more small macro-aggregates than I_3, I_2 and I_1 plots (Table 3). Thus, MWD increased by 14 and 27% in the I_4 plots compared with the I_2 (0.97 mm) and I_1 (0.86 mm) plots, respectively, in the surface soil layer (Table 3). In the 5- to 15-cm soil layer, however, only large macro-aggregates and MWD were impacted by irrigation (Table 3). Plots under I_4 had significantly more large macro-aggregates and MWD than I_1 plots in the 5- to 15-cm depth layer (Table 3). Thus, I_1, I_2, I_3 and I_4 plots had similar effects on soil aggregation in the subsurface soil layer. Because tillage and irrigation had no effect on soil aggregation and aggregate-associated C in the 5- to 15-cm soil layer.

Soil Chemical Properties

Water Soluble C

After 3 years, in 0-5cm soil layer of tillage crop residue practices, T_1, and T_5 increased WSC content from 8.7 mg·kg^{-1} in CT (T_9) to 10.6 and 12.6 mg kg^{-1} without (CR) crop residue, and to 14.3, 16.1 and 19.6 mg·kg^{-1} with (CR) crop residue @ 2, 4 and 6 tha^{-1}, respectively **(Table 4).**The trends were similar after 4 years indicating a small improvement in WSC content of different treatments. Similar increasing trends were observed in 5 -15 cm soil layer, however, the magnitude was relatively lower **(Table 5).**

Particulate Organic C and N

After 3 years of the experiment, in 0-5cm soil layer treatments T_1, and T_5 increased POC content from 260 mg·kg^{-1} in CT (T_9) to 410 and 520 mg·kg^{-1} without CR, and to 647.5, 705.0 and 770.0 mg·kg^{-1} with crop residue @ 2, 4 and 6 tha^{-1}, respectively **(Table 4).** The corresponding increase of POC content under CA system was from 286.5 mg·kg^{-1} in CT system to 441.5 and 528.5 mg·kg^{-1} without CR and 679.3, 747.3 and 819.5 mg·kg^{-1} with CR @ 2, 4 and 6 tha^{-1}, respectively. The trends were similar after 4 cycles of wheat crop indicating a small improvement in POC content of different treatments. In subsurface layer, similar increasing trends were observed, however, the magnitude was relatively lower **(Table 5).** In general, apart from the crop residues, tillage had no effect on PON concentrations in the ZT and FIRB plots in the 5- to 15-cm soil layer; however, plots under ZT and FIRB had similar recalcitrant POC contents (Plots T_4 and T_8) in both soil layers. The amount of applied CR that stabilized in the POC was affected by soil depth. Irrespective of tillage treatments, the 0- 5-cm depth layer had a higher POC concentration than the 5- 15-cm soil layer. Apart from POC concentrations in Plots T_4 and T_8, treatments under I_4 and I_5 had higher POC concentrations in Plots T_3 and T_7 compared with I_3 and I_2 treatments in both soil layers. Plots under I_3 had similar POC concentrations in Plots T_2 to T_6 plots in the 5- to

Table 4. Water soluble C (WSC), particulate organic C (POC), particulate organic N (PON), light fraction organic C (LFOC),and light fraction organic N (LFON) in 0-5cm soil layer after 3 and 4 years of wheat crop as influenced by tillage crop residue management practices and irrigation levels

Treatments	WSC (mg·kg^{-1})		POC (mg·kg^{-1})		PON (mg·kg^{-1})		LFOC (mg·kg^{-1})		LFON (mg·kg^{-1})	
	3rd year	4th year	3rd year	4th year	3rd year	4th year	3rd year	4th year	3rd year	4th year
Tillage crop residue practices										
T_1	10.6	11.2	410	473	47.3	50.7	58.2	59.0	7.9	8.1
T_2	13.4	14.1	600	687	71.3	74.2	89.7	90.5	10.0	11.5
T_3	14.7	16.4	650	709	86.1	87.8	109.2	111.9	11.3	12.1
T_4	17.2	18.9	710	838	99.6	100.5	128.8	130.0	13.0	13.4
T_5	13.6	14.9	520	537	67.7	71.5	79.3	81.0	9.6	10.8
T_6	15.1	17.5	695	735	85.3	86.4	105.2	106.8	10.5	11.2
T_7	18.5	20.7	760	870	98.7	99.5	137.2	138.4	11.6	12.2
T_8	22.0	22.4	830	900	108.0	109.2	157.9	159.4	13.2	13.9
T_9	9.1	10.2	260	313	35.8	36.1	32.3	32.4	5.1	5.6
Mean	14.9	16.3	603.9	673.6	77.8	79.5	99.8	101.2	10.2	10.9
Irrigation levels										
I_1	10.3	12.2	340	380	16.9	17.6	50.8	52.4	7.1	8.1
I_2	10.6	11.8	520	537	61.4	67.8	65.8	66.8	7.4	8.2
I_3	12.9	13.9	590	617	67.7	71.5	79.3	81.0	10.0	11.5
I_4	16.4	19.2	580	680	81.0	82.0	104.0	105.8	11.9	13.7
I_5	14.1	16.8	650	709	86.1	87.8	89.7	90.5	9.6	10.8
Mean	12.9	14.8	420	584.6	62.6	65.3	77.9	79.3	9.2	10.5
Overall mean	13.9	15.7	538.2	641.8	72.4	74.4	91.9	93.4	9.8	10.8
LSD < 0.05										
Tillage	0.6	3.7	57	68	4.8	6.9	6.3	7.1	1.4	1.7
Irrigation	0.8	NS	136	NS	7.3	9.3	14.8	12.4	NS	NS
Tillage x Irrigation	0.5	2.1	62	54	3.7	5.3	3.7	5.1	0.8	1.3

15-cm soil layer, but I_4 plots had significantly higher POC concentrations in Plots T_6 than T_2 plots in the surface soil layer **(Table 4).** The significantly higher POC content was probably also due to higher biomass C.

Results on PON content after 3-year showed that in 0-5 cm soil layer of treatments T_1, and T_5 increased from 35.8 mg·kg^{-1} in CT (T_9) to 47.3 and 67.7 mg·kg^{-1} without CR, and to 78.3, 92.4 and 103.8 mg·kg^{-1} with CR @ 2, 4 and 6 tha^{-1}, respectively (Table 4). The corresponding increase of PON content under CA system was from 35.9 mg·kg^{-1} in CT system to 49 and 69.6 mg·kg^{-1} without CR and 79.3, 93.0 and 104.3 mg·kg^{-1} with CR @ 2, 4 and 6 tha^{-1}, respectively. Small improvement in PON content was observed after 4 years of the experiment. Tillage and crop residues retention changes in PON were distinguishable only in the 0- to 5-cm soil layer; the differences were insignificant in the 5- to 15-cm soil layer (Table 4&5). Plots under ZT and FIRB had about 8.8 and 10.1% higher PON than CT plots (35.9 mg·kg^{-1}) in the surface soil layer. The increasing trends in PON content were observed in subsurface layer, however, the magnitude was relatively lower **(Table 5).**Like POC, PON contents of the bulk soil were significantly affected by irrigation in both surface layers **(Table 4&5).** In the 0- to 5-cm soil layer, plots under I_5 and I_4 had about 27.2 and 25.5% higher PON contents, respectively, in the bulk soil than I_1 plots (17.25 mg kg^{-1} bulk soil). Both I_2 and I_3 plots had similar PON contents in that soil layer. In the 5- to 15-cm soil layer, however, plots under I_2 had ~15.6% higher PON content than I_1 plots (14.8 mg kg^{-1} bulk soil) **(Table 5).** Furthermore, the plots under I_4 had significantly higher PON content than I_1, I_2 and I_3 plots in that depth layer. No interaction effect was significant for the POC, PON contents, and neither tillage nor irrigation had an effect in the 5- to 15-cm soil layer.

Light Fraction Organic C and N

Results on LFOC content in 3-year experiment showed that in 0 - 5cm soil layer treatments T_1, and T_5 increased LFOC content from 32.2 mg·kg^{-1} in CT (T_9) to 58.2 and 79.3 mg·kg^{-1} without CR, and to 97.5, 123.2 and 143.4 mg·kg^{-1} with crop residue @ 2, 4 and 6 tha^{-1}, respectively **(Table 4).** After 4 years, there was a further increase in LFOC in most of the treatments. The trends were similar after 4 years of experiment indicating a negligible improvement in LFOC content of different treatments. In 5-15 cm layer, the increasing trends in LFOC content due to the application of CR were similar to those observed in 0-5 cm layer; however, the magnitude was relatively lower (Table 5).

Results on LFON content in 3-year experiment showed that in 0 - 5 cm soil layer T_1, and T_5 increased LFOC content from 5.1 mg·kg^{-1} in CT (T_9) to 7.9 and 9.6 mg·kg^{-1} without CR, and to 10.3, 11.5 and 13.1 mg·kg^{-1} with crop residue @ 2, 4 and 6 tha^{-1}, respectively (Table 4). After 4 years, there was a small improvement in LFON in most of the treatments. In 5 -15 cm layer, the increasing trends in LFON content due to the application of CR were similar to those observed in 0-5cm layer however, the magnitude was relatively lower (Table 5). In general, the impact of applied CR in improving WSC, POC, PON, LFOC and LFON content was significant in 0- 5 cm soil layer and was substantially higher than in 5-15 cm soil layer under tillage crop residue practices. Bhattacharyya *et al.*, (2013) reported that response of the LFOC and LFON contents to residue retention and irrigation treatments were similar to those observed for the POC and PON contents.

A tillage ×irrigation interaction had significant effects for the PON, LFOC and LFON in the surface layer only (Table 4&5). The difference in WSC, POC, PON, LFOC and LFON content between the I_4 and I_2 plots was larger for residue retained plots than CT in the 0-5-cm soil layer. Likewise, the plots under I_4 had 16% higher WSC, POC, PON concentration in crop residue @ 2, 4 and 6 tha^{-1}, than I_1 for CA than CT. Neither tillage nor irrigation had an effect on WSC and POC content in the 5-15-cm soil layer (Table 4 & 5).

Yield parameters

Crop productivity

After 4 yr of cropping, the CT (T_9) plots had mean aboveground biomass yields of wheat (4.9Mg ha^{-1}) similar to the ZT (T_1) plots; however, the (4-yr) mean wheat aboveground biomass of the plots under I_4 and I_5 was about 13 and 12% higher than under I_1 (4.2 Mg ha^{-1}) (Table 6). Irrigation and tillage have a strong effect on production of wheat. However, the residue rates have significant effect on grain yield. Residue retention could lead to an increased yield by 9.9 and 10.8% in the last two consecutive years, respectively, over the corresponding non-residue

Table 5. Water soluble C (WSC), particulate organic C (POC), particulate organic N (PON), light fraction organic C (LFOC), and light fraction organic N (LFON) in 5 -15 cm soil layer after 3 and 4 years of wheat crop as influenced by tillage crop residue management practices and irrigation levels

Treatments	WSC ($mg \cdot kg^{-1}$)		POC ($mg \cdot kg^{-1}$)		PON ($mg \cdot kg^{-1}$)		LFOC ($mg \cdot kg^{-1}$)		LFON ($mg \cdot kg^{-1}$)	
	3rd year	4th year	3rd year	4th year	3rd year	4th year	3rd year	4th year	3rd year	4th year
Tillage crop residue practices										
T_1	9.8	10.9	320	367	20.6	21.3	37.8	40.1	5.6	5.9
T_2	12.9	13.6	460	531	61.7	62.3	69.8	71.0	8.1	8.7
T_3	13.3	15.7	580	617	81.0	82.0	104.0	105.8	11.0	11.4
T_4	16.9	17.8	630	700	108.0	109.2	127.9	129.4	12.5	13.2
T_5	13.1	14.7	400	440	22.6	23.2	57.3	59.2	8.0	8.5
T_6	14.8	16.3	660	683	74.3	74.7	84.9	86.1	9.3	9.8
T_7	18.2	19.7	710	810	98.7	99.5	109.2	111.9	11.4	12.2
T_8	20.2	21.9	780	827	115.3	124.1	153.6	154.4	12.3	13.0
T_9	8.7	9.8	230	285	15.8	16.1	30.1	31.6	4.9	5.1
Mean	14.2	15.6	530	584.4	66.4	68.0	86.1	87.7	9.2	9.8
Irrigation levels										
I_1	10.3	12.2	340	380	13.9	15.6	50.8	52.4	7.4	7.8
I_2	12.3	13.8	410	473	47.3	50.7	58.2	59.0	7.9	8.1
I_3	12.9	13.9	590	680	61.3	67.8	65.8	66.8	8.2	8.6
I_4	13.7	19.1	690	838	99.6	100.5	125.2	125.8	10.5	11.2
I_5	14.8	17.1	600	687	85.3	86.4	128.8	130.0	11.0	11.4
Mean	12.8	15.2	526	611.6	61.5	64.2	85.8	86.8	9.0	9.4
Overall mean	14.1	15.1	528.6	594.1	64.7	66.7	85.9	87.4	9.1	9.6
LSD < 0.05										
Tillage	0.4	2.4	34	65	1.8	3.2	4.8	3.5	0.5	0.9
Irrigation	NS	2.5	NS	NS	3.1	3.1	1.3	3.4	0.8	NS
Tillage x Irrigation	0.4	NS	34	74	1.0	2.6	3.9	3.6	0.2	NS

treatments. Among all the treatments, T_8 had significantly highest yield followed byT_4 and T_7 treatments in the last three years of study. Simultaneously, these three treatments showed a significant and consistent yield increment with passage of time during the period of experimentation. Grain yield was significantly lower in the second compared to the first year due to rice residues accumulation. As rice residues have a slow decomposition rate, un-decomposed residues remained in the field in the second year. Irrigation water which is unsuitable for decomposition. This can immobilize a relevant amount of soil mineral N reducing its availability to wheat crop sown following rice. As a consequence, grain yield decreased in the second year mainly due to immobilization of N as residues with high C:N ratio are incorporated into the soil. Table 6 shown that maximum yield between irrigation and tillage treatment was found as 5.49 tha^{-1} when T_8 I_4 treatment was applied and minimum yield between irrigation and tillage treatment was obtained as 4.52 tha^{-1}for treatment T_9 I_1.Although the overall yield performance was a little worse than the other

Table 6. Crop yield (t ha^{-1}) and water productivity (kg yield m^{-3} water) under various tillage crop residues practices in of wheat crop

Treatments	Yield (t ha^{-1})				Water productivity (kg yield m^{-3} water)			
	2008-09	2009-10	2010-11	2011-12	2008-09	2009-10	2010-11	2011-12
Tillage crop residue practices								
T_1	5.05	5.15	5.20	5.15	1.21	1.32	1.36	1.39
T_2	5.15	5.05	5.20	5.30	1.38	1.49	1.47	1.51
T_3	5.25	5.15	5.25	5.35	1.57	1.62	1.53	1.64
T_4	5.30	5.25	5.35	5.45	1.76	2.08	1.86	1.91
T_5	5.20	5.30	5.25	5.20	1.40	1.38	1.42	1.44
T_6	5.25	5.20	5.30	5.35	1.55	1.67	1.61	1.73
T_7	5.30	5.20	5.35	5.45	1.79	1.90	1.82	1.88
T_8	5.45	5.40	5.55	5.60	2.16	2.21	1.92	1.99
T_9	4.90	4.95	4.80	4.65	0.99	1.11	0.88	0.90
LSD < 0.05	0.59	0.51	0.45	0.43	-	-	-	-
Irrigation levels								
I_1	4.15	4.05	4.30	4.35	1.05	1.11	0.99	1.13
I_2	4.73	4.65	4.90	5.15	1.13	1.17	1.19	1.18
I_3	5.15	4.85	5.20	5.35	1.28	1.31	1.30	1.37
I_4	5.45	5.25	5.50	5.65	1.32	1.37	1.42	1.46
I_5	5.10	4.80	5.20	5.30	1.18	1.19	1.21	1.23
LSD < 0.05	0.56	0.68	0.49	1.08	-	-	-	-

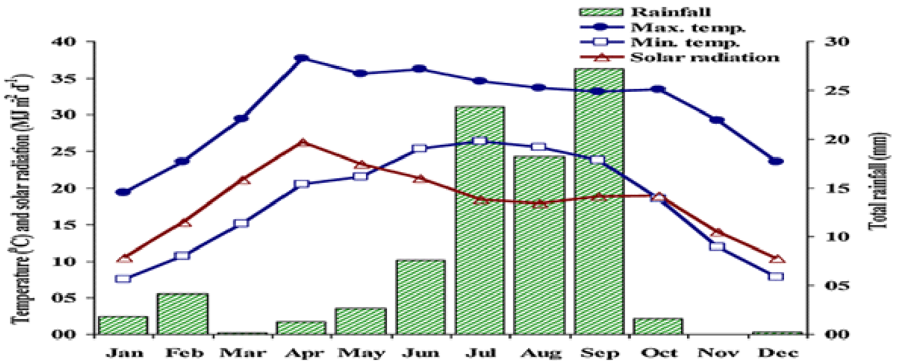

Fig.1. Av.maximum and minimum temperature, solar radiation and monthly rainfall of the experimental site

treatments, but the irrigation water was used most effectively resulting comparatively higher water productivities.

Water productivity

The irrigation water application depends on the total rainfall and its pattern of distribution. On average, the highest water application was in T_8 with I_4 followed by T_4 with I_3, and T_7.TreatmentsT_6, T_5, T_3 and T_1 applied less irrigation water than T_9 (CT). Averaged over 4-yr WP_I wheat was 36.5% higher in raised beds than conventional tillage. The increase in WP_I is the resultant of increase the saving in irrigation water.

DISCUSSION

The management of previous crop residues is the key to soil structural development and stability since organic matter is an important factor in soil aggregation (Verhulst *et al*., 2011). Residue retention caused a significant increment of 19.44% in total water stable aggregates in surface soil (0–5 cm) and 6.95% in sub-surface soil (5–15 cm), which depicted that residue management, could improve 2.1-fold higher water stable aggregates as compared to the other treatments without residue retention (Table 2). Application of organics in the form of residue combined with either conventional or conservation tillage improved the formation of water stable aggregates resulting the preponderance of macro-aggregates compared to micro-aggregates. Release of polysaccharides and organic acids during the decomposition of organic material plays a major role in stabilization of macro-aggregates (Naresh *et al*., 2015). These polysaccharide and organic acids do not spread far from the site of production and the freshly added residues function as nucleation sites for the growth of fungi and other soil microbes (Zhang *et al*., 2012). As a result, the residues and soil particulates are getting bound into macro-aggregates in higher proportion in surface than sub-surface soil layer (Benbi and Senapati, 2010).

Soil structure is closely associated with water-stable aggregates >1 mm (Tisdall and Oades 1982). The decline in soil structure is increasingly seen as a form of soil degradation and is often related to land use and soil/crop management practices. Obviously, all size water-stable aggregates play a major role and could be an indicator of soil quality. Our studies demonstrate that as the soil depth increases, small aggregates (<0.25 mm) increase in concert with decreases in the large aggregate groups. The data are consistent with the report (Bernard and Eric 2002) that there is a negative correlation between aggregate stability and soil depth. It is possible that large aggregates are disrupted due to water disturbance, resulting in the formation of smaller aggregate sizes and the decomposition of organic matter (Angers *et al*. 1993). Six *et al*., (2004) suggested that large size aggregate formation may be from inorganic particles combined with unstable organic fraction.

Application of rice residue enhances the soil organic C content (SOC) and has direct and indirect effects on soil properties and processes. There was a significant improvement in water stable aggregation and proportion of macro-aggregates; water soluble C, particulate and light fraction organic matter organic C (POC), particulate organic N (PON), light fraction organic C (LFOC), and light fraction organic N with the application of 4-6 tha^{-1} rice residue along with recommended rate of NPK to wheat. After 3 years of the experiment, total WSA in 0-5cm soil layer increased from 71% in ZT (T_1) to a maximum of 83 (T_4) and 85% (T_8) treatments, respectively with the retention of crop residues **(Table 2).** Likewise, the increase in total WSA was from 62% in ZT (T_1) to 77 and 81%, respectively in 5 -15 cm layer (**Table 2**), indicating the beneficial effect of rice straw mulch on the formation of aggregates over the non-residue treatments. The effects were similar after 4 years of experiment with further improvement in WSA, and the effect of tillage was statistically significant. The CA system causes less disturbance of soil and retains crop residue (CR) on soil surface than CT system, which could enhance and protect SOM content and improve soil structure.

After 4 years of study, maximum TOC content was recorded in T_4 and T_8 treatments, which was 5.89 and 5.99 $g{\cdot}kg^{-1}$ in 0 - 5 cm and 4.18 and 4.44 $g{\cdot}kg^{-1}$ in 5 - 15 cm soil layer in ZT with 6 tha^{-1}rice residue and FIRB with 6 tha^{-1}rice residue, respectively (**Tables 3**).Integrated use of inorganic fertilizers and CR significantly improved TOC content. The beneficial effects were more pronounced in 0- 5cm surface layer than 5 -15cm subsurface soil layer. CA resulted in significantly higher TOC than CT. These results are in conformity with Hao *et al*., 2008 who observed that application of inorganic fertilizer alone did not significantly improve TOC content as compared to the control while the application of inorganic fertilizer along with residue significantly increased TOC content. No-till provides greater physical protection to TOC within macro-aggregate protected TOC than with CT but mostly at soil surface (Huang *et al*., 2012). Bhattacharyya *et al*. (2013), suggesting slower macro-aggregate turnover in the ZT plots compared with CT. This phenomenon might lead to micro-aggregate formation within macro-aggregates formed around fine intra-aggregate POM and to a long-term stabilization of SOC occluded within these microaggregates. Because increased POM C is regarded as a potential indicator of increased C accumulation (Six *et al*., 1999), the results of this study indicate that ZT and FIRB had a significant effect on the formation and stabilization of SOM within the 0- to 5-cm soil layer after 4 yr of wheat crop in the subtropical climatic conditions of western Uttar Pradesh.

After 4 years of study, maximum WSC contents of 25.8 and 29.7 $mg \cdot kg^{-1}$ were found in 0 - 5 cm and 19.2 and 26.4 $mg \cdot kg^{-1}$ in 5-15 cm soil layer in T_4 and T_8 treatments in ZT with 6 tha^{-1}rice residue and FIRB with 6 tha^{-1}rice residue, respectively (Tables 4 and 5).Same treatment resulted in the maximum contents of POC, PON, LFOC and LFON in ZT with 6 tha^{-1}rice residue and FIRB with 6 tha^{-1}rice residue and the effect of tillage was statistically significant (Tables 4 and 5). Thus, integrated use of inorganic fertilizers and CR significantly improved these labile C and N pools of soil. The proportions of WSC, POC, and LFOC in TOC and of PON in FIRB were highest in CA system (Tables 4 and 5). Significantly higher contents and proportions of these labile C and N pools obtained with CA than CT were more pronounced in 0-5 cm soil layer. These results indicated that POC, LFOC, PON, and LFOC can be used as sensitive indicators of management effects which could be ascribed to the availability of more carbon as was evident from several other fractions of TOC such as WSC, POC and LFOC. Aulakh *et al*., (2013) suggested that enhanced proportions of WSC, POM-C, LFOM-C in TOC and that of POM-N, LFOM-N, in TN with the supply of optimum and balanced inorganic fertilizers and incorporation of crop residues due to integrated nutrient management (INM).

CONCLUSION

In the North West India of subtropical climatic conditions reduction in tillage intensity led to a significantly affected soil organic matter quantity and quality as well as soil aggregation in the surface soil layer (0–15 cm) after 4 years of wheat crop in a sandy loam soil. ZT and FIRB plots, however, had significantly more soil organic C and WSC, POC, PON, LFOC and LFON portions and MWD compared to CT. Frequent irrigations at the critical growth stages of wheat crop improved the SOC status (both stock on equivalent-mass and equivalent-depth bases and concentration) and aggregate stability in the surface soil layers. ZT and FIRB resulted in a greater proportion of large and small macro-aggregates and a lower proportion of micro-aggregates and silt-plus clay-sized fractions compared with CT; plots under ZT had micro-aggregate- associated C similar to CT plots in the 0- to 5-cm soil layer. Such applications also helped to maintain yield sustainability by improving nutrient supply and chemical/biological activity in soils. Continuous cropping without addition of organic amendments resulted in a decrease in soil total organic carbon and organic carbon fractions and light fraction organic C and N. There was a significant increase in wheat yields in the plots where three irrigations were applied compared with only two irrigation. Wheat yield also increased significantly in plots with five irrigations compared with two irrigations. Our results clearly indicate that the application of rice straw mulches could increase wheat yield and improve the quantitative and qualitative characteristics of soil aggregates and soil organic carbon (SOC) with respect to the conventional agricultural practice during a short-term period. A minimum of three irrigations in wheat crop is necessary for maintaining crop productivity and soil aggregation and aggregate-associated C in the surface soil layer. Frequently irrigated plots had better soil aggregation and aggregate-associated C. Further studies are necessary to assess long-term effects of tillage, irrigation and rice straw mulches practice on SOC dynamics.

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