Long-term influence of crop residue management and tillage practices on distribution of C and N within aggregate size fractions in alluvial soils

Abstract

Aims: The goal of this experiment is to observe the variations in soil aggregate fractions and the change in percentage of carbon and nitrogen stored in the fractions due to the effect of crop residue management and tillage practices in Rice-Wheat cropping system.

Study Design: An experiment was set up in Randomized Block Design with five treatments, i.e, T0-control, T1- zero-tillage+ no residue application, T2- zero-tillage+ residue application, T3-conventional tillage + no residue application, T4- conventional tillage+ residue application.

Place and Duration of Study: It was conducted in a long-term experimental plot situated in University Research Farm at Pundibari in Coochbehar district of West Bengal. The data was taken in the 9th and 10th year of the experiment, i.e, 2018 and 2019.

Methodology: Samples were collected from three different depths, i.e., 0-5 cm, 5-15 cm and 15-30 cm from four cropping seasons, i.e., wheat 2018, rice 2018, wheat 2019 and rice 2019 and were prepared and analyzed for physico-chemical factors. Dry stable aggregates were obtained by the method of sieving and change of carbon, nitrogen and C/N ratios in various fractions were observed.

Results: Mostly for all the soil depths the total organic carbon content was highest for the treatment with zero-tillage and application of residues (T2). Total nitrogen content also followed the similar trend. Whereas in most of the crop seasons, the C/N ratio was observed to be higher in the treatment where conventional tillage was followed along with residue incorporation (T4). Within the short span of two years positive changes in total organic carbon and total nitrogen content was observed for almost all the treatments, across the depths.

Conclusion: The optimum percentage of decrease in C/N ratio of the control as well as the treatment with zero-tillage and residue application (T2) in the large aggregate fractions (<2mm) indicates the suitability of the soil for higher productivity.

Keywords: *Aggregate, fractions, residue, tillage, carbon, nitrogen, productivity, conservation*

1. INTRODUCTION

The significance of understanding the carbon cycle has increased in the recent times due to the higher emissions of greenhouse gases and the related concerns, like climate changes. In order to preserve environmental sustainability and increase soil productivity, it is essential to understand and increase the carbon sequestration in agricultural soils as it has potential to mitigate the increase in atmospheric greenhouse gases (Young 2003). Conventional agricultural practices like intensive tillage and insufficient incorporation of crop residues is the primary reason for soil degradation, erosion and environmental pollution (Montgomery 2007) resulting in unbalanced ecosystem functions (Srinivasan *et al*, 2015). Conservation agriculture can help in maintaining balance in soil ecosystem and restoration of soil heath. Practices like zero-tillage and residue retention not only curtails the production cost, but also helps in minimizing the degradation of soil, water and other natural resources (Ladha *et al*, 2009; Jat *et al*, 2009; Saharawat *et al*, 2012). These practices can be an effective measure to conserve soil and water and increasing the carbon storage in soil (Blanco-Canqui and Lal, 2007). Practice of retaining crop residues on the surface of the soil in combination with no-tillage can initiate certain processes that helps in improving soil quality and resource enhancement (Akter and Gathala, 2014). The crop derived residues are the primary source of soil organic matter for agricultural soils and the optimum levels of SOM can only be maintained by suitable management practices like tillage methods, required dose of organic and inorganic fertilization and cropping system components (Purakayastha *et al,* 2008). Fractions of soil organic carbon are highly susceptible to change with time and the change can be induced by multiple factors like tillage, cropping system, and N fertilization (Ju *et al,* 2009). Therefore, measurement of organic carbon and total nitrogen in various soil fractions can provide us an overview about the effects of tillage, crop residue retention and application of fertilizer on variation in soil health (Strosser 2010) as it leads to formation of stable aggregates. Formation of stable aggregates results in favourable soil structure and are essential in stabilization and storage of soil organic carbon (Balesdent *et al,* 2000). A well-aggregates soil promotes optimum plant growth by maintaining a soil physico-chemical factors like C stabilization, aeration, porosity, water retention, hydraulic conductivity and erosion resistance. With the change in land-use patterns and tillage practices the variation in aggregate associated carbon and distribution of soil aggregates can be observed (Six and Paustian 2014; Wang *et al,* 2014). In the case of no-tillage, the turnover rates of macro-aggregates slows down and soil organic carbon remains protected within the aggregates (Six *et al,* 2000). In soil, organic carbon acts as a binding agent and helps in increasing aggregate associated C. The physical protection of organic C from microbial decomposition and oxidation is rendered by the incorporation of organic C in aggregates and can be effectively used as an index of assessing stability of organic C in soil subjected to change in land use patterns (Six and Paustian, 2014). Therefore, determination of the effects of management practices on soil organic carbon content and distribution of carbon within aggregate fractions will provide an understanding of processes involved in aggregate stabilization and can assist in knowing the fertility status of soil. Nitrogen reserves in soil are replenished by addition of organic matter and inorganic fertilizers which is converted into mineral forms by the action of bacteria residing in the soil. The storage of total nitrogen in soil is dependent on various factors like climate, vegetation and soil depth. The mineral nitrogen is also prone to loss by processes like volatilization, leaching and denitrification. N values were majorly influenced by drainage and amount of litter present in the soil (Shearer and Kohl, 1988). Continuous tillage results in disruption of macro-aggregates increasing the susceptibility of aggregate associated SOC and STN to mineralization (Six *et al,* 2000). Incorporation of increased amount of crop residues into the soil contributes in soil aggregation by enhancing SOC, STN, and microbial biomass (Mendez *et al,* 1999). Aggregation formation also depends on the rate of decomposition of organic matter that further influences C/N ratio (Sainju *et al*, 2003). For millions of people in South Asia, irrigated and intensively cultivated Rice-Wheat system is fundamental for livelihoods (Paroda *et al*, 1994). Burning of the stubbles or crop residues is practiced widely by many farmers of India which increases the production of greenhouse gas and contributes to climate change. Thus it causes air pollution and results in soil organic carbon reduction (Timsina and Connor, 2001). Therefore, variation in soil organic carbon depends mainly on production and decomposition (Lutzow and Knaber, 2009). Hence, in order to combat the increasing levels of CO2 and N2O in atmosphere, sequestration of carbon and nitrogen in soil can be a potential mechanism. The aim of the study is to observe the variations in carbon, nitrogen and C/N ratio in different aggregate fractions due to crop residue management and tillage practices.

2. MATERIALS AND METHODS

2.1. Field Site

The research was conducted in University Research Farm situated at Pundibari in Coochbehar district of West Bengal. The experiment was established in the year of 2009 under a long-term experimental plot and the observations were taken in the year of 2018 and 2019 in the month of April and November. The experimental site ($26^0$19' N, 89^0 23'E; 43 m above msl) is located under Terai agro-ecological region having sub-tropical climatic condition and per-humid in nature. The formation of the soil took place from alluvial deposits under the influence of high rainfall and intense leaching. The soils are mainly characterized as coarse-textured having acidic reaction. The soil was found to be sandy loam in texture with the average of 56% of sand, 32.5% of silt and 11.5% of clay. According to USDA soil taxonomy, the experimental area is classified under Aquic Ustifluvaquents (Biswas et al, 2020). The average minimum and maximum temperature for the sites selected were between 10℃ to 32℃ with average annual rainfall of 2700mm. Rate of residue application was 6 ton/hectare.

2.2. Experimental Details

Five treatments were studied in this experiment, i.e., control, zero-tillage, zero-tillage+ residue, conventional tillage, conventional tillage + residue which was laid out in a randomized block design (RBD) with 5 replications which is given in table 1.

Table 1-The details of treatment combinations followed in rice and wheat crop under the long-term experimental plot

Sl. No.	Treatments	Treatment details
1	**T0-Control**	**Untouched plot with no crops grown**
1	**T-1 - ZTR_0**	**Zero tillage + residue removed**
2	**T-2 – ZTR_1**	**Zero tillage + residue added**
3	**T-3 - CTR_0**	**Conventional tillage + residue removed**
4	**T-4 – CTR_1**	**Conventional tillage + residue added**

2.3. Crop Management

After harvesting of Wheat, stubbles were retained in the zero-tillage plots at about 12-15 cm height and was used as partial source of crop residues in zero-tillage plots as per the treatments. The above ground biomass that was left behind after harvesting and threshing fulfilled the remaining requirement of rice crop in both the zero-tilled and conventionally tilled plots. The crop residues that were added to the Wheat crop was derived in the similar way after Rice crop. Application of residues were done in both the zero-tilled and conventionally tilled plots after they were air-dried. Along with that, recommended dose of fertilizers were applied for both the crops. Management practices were common for both the tillage systems except in the case of conventionally tilled plots, where three tillage by cultivator, two passes by rotavator and three tillage by power tillage were done for land preparation and puddling in case of paddy. Whereas, in case of conventionally tilled Wheat crop two passes with cultivator and three passes with power tiller were sufficient. Finally planking was done to level the land. The control plot remained untouched with no crops grown since the starting of the long-term experiment (2009).

2.4. Collection and preparation of soil samples

Composite soil samples were formed from sub-samples from each treatment of the experimental plot at 0-5cm, 5-15cm and 15-30 cm depths immediately after harvesting of paddy as well as wheat in the consecutive seasons. Sub-samples were drawn with cores from each treatment plot and were mixed together to form a composite sample for each treatment plot. The samples were air-dried at room temperature, grounded in wooden mortar and were sieved through 2mm sieve, after removal of stubbles, residues root biomass the samples were homogenized till the final weight of 500 gm was obtained. The samples were then stored in an air-tight container for further analysis. For analysis of aggregate sizes, C and N within aggregates, samples were collected from each treatment with five replications and were dried at room temperature. The samples were broken into small crumbs and passed through 5mm sieves but can be retained on 2mm sieve. To evaluate the carbon and nitrogen and their distribution within aggregates on 9th and 10th year of the long term experiment, post rice and post wheat soil samples were collected from the depths of 0-5 cm, 5-15 cm and 15-30 cm.

2.5. Analysis of soil-samples

The samples were analyzed for physico-chemical parameters like pH, bulk density, texture, total organic carbon and total nitrogen. pH of the soil suspension (1:2.5) was measured with the help of a pH meter following the method by Jackson (1973). Bulk density was determined using core sampler method (Singh 1980). Soil was dried at 55℃ for 3 days and was further crushed over 5mm sieves prior to sieving. For determination of dry-stable aggregates a 100 g of soil sub-sample was taken at the top of 2mm sieves followed by sieves with openings of 1mm, 0.5mm, 0.25mm, 0.1 mm and 0.053mm and was shaken for 2mins at the rate of 125 cycles per minute. The soil that was retained different sieves were weighed and stored separately and were reconstituted as required for determining the weight of various aggregate size fractions. For total organic carbon determination after passing the samples through 0.1mm sieve carbon was determined by Vario EL CHNS analyzer (Nelson and Sommer, 1996). Modified Kjeldahl method was used to determine total N where sample digestion was done by concentrated, salicyclic acid, sodium thiosulphate and catalyst mixture. The sample that was digested was then stem distilled using concentrated 40% NaOH. The liberated ammonia was absorbed in boric acid and titration was done with standard H_2SO_4 (Bremmer 1965). Soil was also collected from Post-rice 2017 soil for each treatment and analyzed to get an idea about the initial soil status, which is depicted in table 2.

Table 2: pH, Bulk density (g/cm^3), total C (g/kg) and total N (g/kg) of the soils collected from post-rice soils in the year of 2017

Sl. No.	Treatments	pH	BD (g/cm^3)	TOC (g/kg)	TN (g/kg)
			0-5cm		
1	T-0-Control	6.10	1.26	14.18	1.62
2	T-1 - ZTR_0	5.45	1.29	14.09	1.75
3	T-2 – ZTR_1	5.58	1.18	14.18	1.81
4	T-3 - CTR_0	5.32	1.33	14.58	1.32

5	T-4 – CTR_1	5.38	1.25	15.21	1.43
			5-15cm		
1	T-0-Control	5.59	1.31	12.58	1.34
2	T-1 - ZTR_0	5.32	1.33	11.38	1.51
3	T-2 – ZTR_1	5.30	1.21	13.00	1.45
4	T-3 - CTR_0	6.32	1.36	11.36	1.21
5	T-4 – CTR_1	6.25	1.28	12.84	1.35
			15-30 cm		
1	T-0-Control	5.71	1.33	10.00	0.98
2	T-1 - ZTR_0	5.58	1.35	9.34	1.18
3	T-2 – ZTR_1	6.34	1.25	10.68	1.21
4	T-3 - CTR_0	6.59	1.38	8.54	0.84
5	T-4 – CTR_1	6.49	1.33	11.38	1.12

3. RESULTS AND DISCUSSION

3.1. Total carbon, total nitrogen and C/N ratio in post-wheat and post-rice soils

Table 3- Effect of tillage and crop residue management on total C (g/kg) in post-wheat and post-rice soils

Treatments	Post-Wheat 2018	Post- Rice 2018	Post-Wheat 2019	Post-Rice 2019
		0-5cm		
T0- Control	14.87b	15.60b	15.85b	15.70b
T1-ZT	13.79d	14.77c	15.21c	15.75b
T2-ZT+R	15.26a	17.55a	17.70a	17.84a
T3-CT	13.79d	14.09d	14.53d	14.58c
T4-CT+R	14.18c	17.26a	17.45a	17.89a
		5-15cm		
T0- Control	13.65b	14.43a	14.67b	15.06a
T1-ZT	12.87c	13.41b	14.04c	14.19b
T2-ZT+R	14.38a	14.48a	15.26a	15.26a
T3-CT	10.92d	12.82c	13.12d	13.51c
T4-CT+R	13.26bc	13.70b	14.19c	14.43b
		15-30cm		
T0- Control	11.56c	11.70c	12.34c	13.80b
T1-ZT	12.34b	12.73b	13.02b	13.26c
T2-ZT+R	13.31a	13.26a	13.51ab	14.68a
T3-CT	10.53d	12.09c	12.19c	12.63d
T4-CT+R	12.19b	13.51a	13.80a	14.04b

[a]Means with different letters in each row are significantly different ($P < 0.05$)

Among the various treatment combinations, for 0-5 cm soil depth, treatment where zero-tillage was followed along with application of residue (T2) observed to have the highest value of total organic carbon (g/ kg) for both the post- wheat and rice soils in the year of 2018 as well as post-wheat soil of 2019 (15.26 g/kg, 17.55 g/kg and 17.70g/kg respectively) as depicted in table 3. Whereas, in post-rice soils of the year 2019, treatment with conventional tillage and application of residues (T4) had the highest value of TOC followed by T2 (zero-tillage+ residue) (17.89 g/kg and 17.84 g/kg respectively) (Table 3). In the depth of 5-15cm, T2 (zero-tillage + residue) showed the highest values of TOC for post-wheat and post-rice soils of 2018 as well as post-wheat and post-rice soils of 2019 (14.38 g/kg, 14.48 g/kg, 15.26 g/kg and 15.26 g/kg respectively) (Table 3). Disruption of large macro-aggregates due to intensive tillage practices and chemical-based cultivation practices with incorporation of minimum quantity of organic matter, ultimately leads to the loss of C from the soil (Ashagrie *et al*, 2007; Zhang *et al*, 2012). The effect of zero-tillage and residue incorporation (T2) showed profound influence on TOC and was found to be highest for post-wheat soils of 2018 (13.31 g/kg). For post-rice soils of 2018 and post-wheat soils of 2019 in 15-30 cm depth, conventional tillage along with residue incorporation (T4) showed the maximum TOC content (13.51g/kg and 13.80 g/kg respectively)(Table 3). However, for post-rice soils of 2019 in 15-30 cm depth of soil, zero-tillage along with residue incorporation (T2) had the highest values of TOC (14.68 g/kg). Intensive tillage leads to temporary loosening of the soil surface but it results in depletion of organic matter over a long-span of time and weakens the structure of the soil. In case of conventional tillage the disintegration process increase which results in destruction of aggregate stability which can be managed with proper tillage practices (Tisdall and Oades, 1980). Therefore, decrease in organic matter was observed as a result of decrease in aggregate stability due to intensive cultivation. In larger size fractions, organic matter content is mainly influenced by incorporation of organic matter and less by soil texture (Hassink, 1995; Quironga *et al*, 1996).

Table 4- Effect of tillage and crop residue management on total N (g/kg) in post-wheat and post-rice soils

Treatments	Post-Wheat 2018	Post- Rice 2018	Post-Wheat 2019	Post-Rice 2019
	0-5cm			
T0- Control	1.47ab	1.56b	1.65b	1.68b
T1-ZT	1.44b	1.51b	1.79a	1.79ab
T2-ZT+R	1.59a	1.86a	1.91a	1.95a
T3-CT	1.36b	1.47c	1.53b	1.66b
T4-CT+R	1.40b	1.52b	1.63b	1.71b
	5-15cm			
T0- Control	1.43ab	1.52ab	1.63b	1.68a
T1-ZT	1.44ab	1.47bc	1.68ab	1.68a
T2-ZT+R	1.52a	1.59a	1.76a	1.71a
T3-CT	1.21c	1.38c	1.49c	1.51b
T4-CT+R	1.36b	1.47bc	1.47c	1.56b
	15-30cm			
T0- Control	1.28c	1.28b	1.40b	1.56a
T1-ZT	1.44ab	1.47a	1.56a	1.60a
T2-ZT+R	1.47a	1.51a	1.60a	1.59a
T3-CT	1.19c	1.36b	1.44b	1.48a
T4-CT+R	1.31bc	1.50a	1.47b	1.56a

[a]Means with different letters in each row are significantly different ($P < 0.05$)

According to table 4, zero-tillage and incorporation of residues (T2) showed positive and significant effects on TN content (g/kg) when compared with other treatments and increased from post-wheat soils of 2018 to post-rice soils of 2019 (1.59 g/kg, 1.86 g/kg, 1.91g/kg, 1.95 g/kg respectively) for 0-5 cm soil depth. The trends are similar to the total organic carbon content in the upper soil layers and were in accordance with the TN content found in open pasture soils, in an experiment conducted by Gelaw (2014). Similarly, for 5-15 cm of soil depth, T2 showed the highest content of TN (g/kg) for all the seasons of rice and wheat (1.52g/kg, 1.59g/kg, 1.76g/kg and 1.71g/kg respectively) (Table 4). Results were similar for 15-30 cm soil depth, where zero-tillage and residue application showed significantly high values of TN in post-wheat and post rice soils of 2018 as well as post-wheat soils of 2019(1.47 g/kg, 1.51 g/kg and 1.60 g/kg)(Table 4). However, zero-tillage without application of residues (T1) showed highest content of TN in the post-rice soils of 2019 (1.60g/kg). In 0–0.1 m depth of soil, no-tillage + crop residue retention with application of 69kg/ha N application for 22 years, almost 28 % of fertilizer was retained as N in soil (Dalal *et al*, 2011). Depth distribution of total N was also found to be similar to that of total organic carbon (Gelaw 2014).

Table 5- Effect of tillage and crop residue management on C/N in post-wheat and post-rice soils

Treatments	Post-Wheat 2018	Post- Rice 2018	Post-Wheat 2019	Post-Rice 2019
		0-5cm		
T0- Control	10.10a	10.00b	9.64b	9.42b
T1-ZT	9.62a	9.74b	8.48c	8.78b
T2-ZT+R	9.65a	9.42b	9.27c	9.15b
T3-CT	10.18a	9.58b	9.53b	8.79b
T4-CT+R	10.13a	11.40a	10.71a	10.49a
		5-15cm		
T0- Control	9.56a	9.51a	8.98b	8.99a
T1-ZT	8.92a	9.11a	8.38c	8.46a
T2-ZT+R	9.52a	9.12a	8.66bc	8.96a
T3-CT	9.04a	9.28a	8.83bc	8.92a
T4-CT+R	9.78a	9.32a	9.64a	9.26a
		15-30cm		
T0- Control	9.00a	9.12a	8.81b	8.85abc
T1-ZT	8.55a	8.65a	8.35b	8.27c
T2-ZT+R	9.10a	8.76a	8.43b	9.24a
T3-CT	8.88a	8.92a	8.45b	8.52bc
T4-CT+R	9.32a	9.02a	9.38a	9.01ab

[a]Means with different letters in each row are significantly different ($P < 0.05$)

As indicated by table 5, for the depth of 0-5 cm, no significant differences were observed between the values of C/N ratios for different treatments. Whereas, for post-rice soils of 2018 and post-wheat and post-rice soils of 2019, conventional tillage along with residue incorporation (T4) showed the highest significant values of C/N (11.40, 10.71 and 10.49 respectively) compared to other treatments. In the depth of 5-15 cm soils, no significant difference was observed between the treatments post-wheat and post-rice soils of 2018 as well as post-rice soils of 2019. Whereas, in the post-wheat soils of 2019, conventional tillage along with residue incorporation (T4) had the highest influence on C/N ratio (9.64). In 15-30 cm of soil depth, there was no significant difference between C/N ratios for post-wheat and post-rice soils of 2018. However for post-wheat soils of 2019, conventional tillage along with residue incorporation (T4) showed significantly high value of C/N (9.38). Whereas, zero-tillage along with residue incorporation had the highest significant value of C/N ratio (9.24) (Table 5). The aggregates of 1-2mm size class were observed to have C/N ratio of 9.9 in corn-soybean cropping system and for corn-soybean-wheat system the value was 10.5 respectively (Shen *et al*, 2021). The stabilization of soil organic matter in micro-aggregates mainly depends on tillage because intensive tillage enhances the breakdown of macro-aggregates which leads to mineralization of soil organic matter and less C/N ratio Application of residues and reduced rate of mineralization of soil organic matter also results in higher C/N ratios.

3.2. Change in different aggregate size fractions in post-wheat and post-rice soils

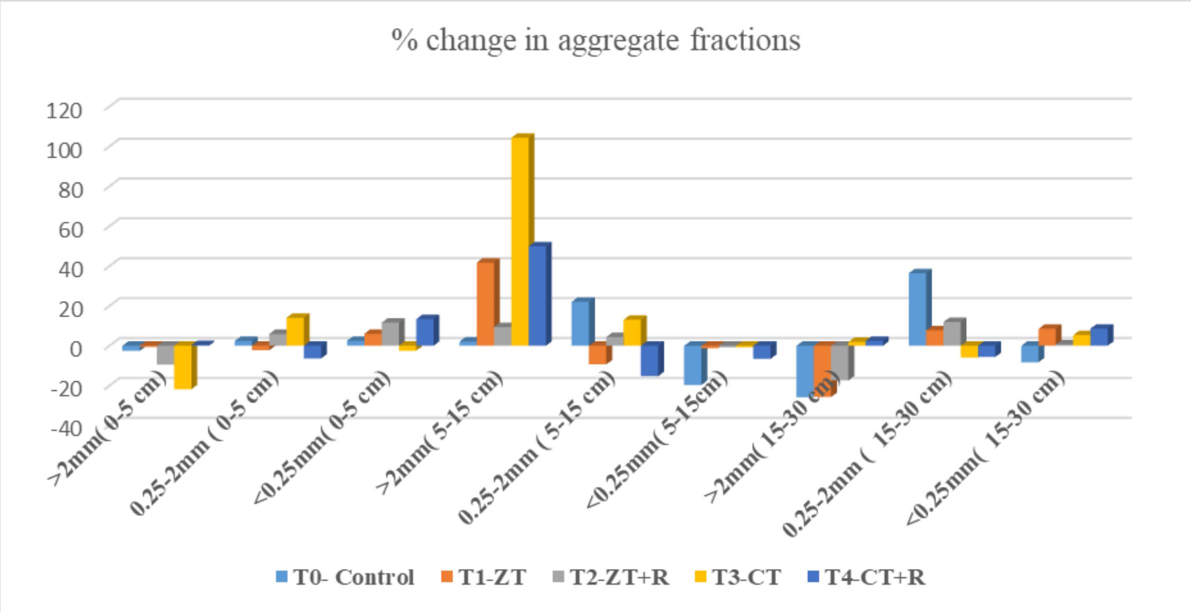

Fig 1: % change in aggregate size fractions observed between Post-Wheat soil 2018 and Post-Rice 2019

Fig 1 indicates that the aggregate size fractions of >2mm in upper soil layer (0-5 cm) was found to be significantly reduced for the treatment where only conventional tillage (T3) was practiced due to breakdown of macro-aggregates. On the other hand, the aggregate size fraction of 0.25-2mm was found to increase significantly for the treatment with practice of conventional tillage (T3). But the aggregate size fractions of <0.25 mm in the upper soil layers seemed to be higher for the treatment with zero-tillage with application of residues (T2) and conventional tillage without application of residues (T4). For 5-15 cm of soil depth, fractions greater than 2mm showed highly positive and significant percentage of change that was observed in the treatment with conventional tillage practices (T3). Significant increase was observed in 0.25-2mm fractions for the control plot and the treatment with conventional tillage practices and application of residues (T4). Whereas significantly high fractions of aggregates less than 0.25mm was observed in the treatment with conventional tillage and residue incorporation (T4). On contrary to the upper soil layers, the lower layer of 15-30 cm showed significant increase in greater than 2mm fractions in control (T0) and the treatment with zero-tillage and no application of residues (T1). Greater increase in the aggregate size fractions of 0.25-2 mm was observed in the control plot (T0). Whereas, in the case of lower soil layers, fractions less than 0.25 mm, decreased for control plot and increased for treatment where only zero-tillage was practiced (T1) and for treatment with practice of conventional tillage and residue application (T4). The mechanical forces during tillage leads to the disruption of large macro-aggregates. Formation of aggregates were to get enhanced as tillage is reduced and the formation large macro-aggregates is more predominant than the smaller size macro-aggregates (Ashagrie *et al*, 2007; Zhang *et al*, 2012). But a decrease in the proportion of aggregates were observed in >2mm fractions by 49.4 to 77.5% in treatment with cropping system and 54.9 to 81.1% in bare-land over uncultivated grassland (Yuan *et al*, 2021) which can also be observed in our experiment. According to some scientists 1-2 mm fractions of dry-stable aggregates is the determinant of aggregate stability because medium macro-aggregates are important in retaining C, N and biological activity and stabilizing soil against erosion (Franzluebbers, 2022).

3.3. Change in total carbon, total nitrogen and C/N ratio in different aggregate size fractions in post-wheat and post-rice soils

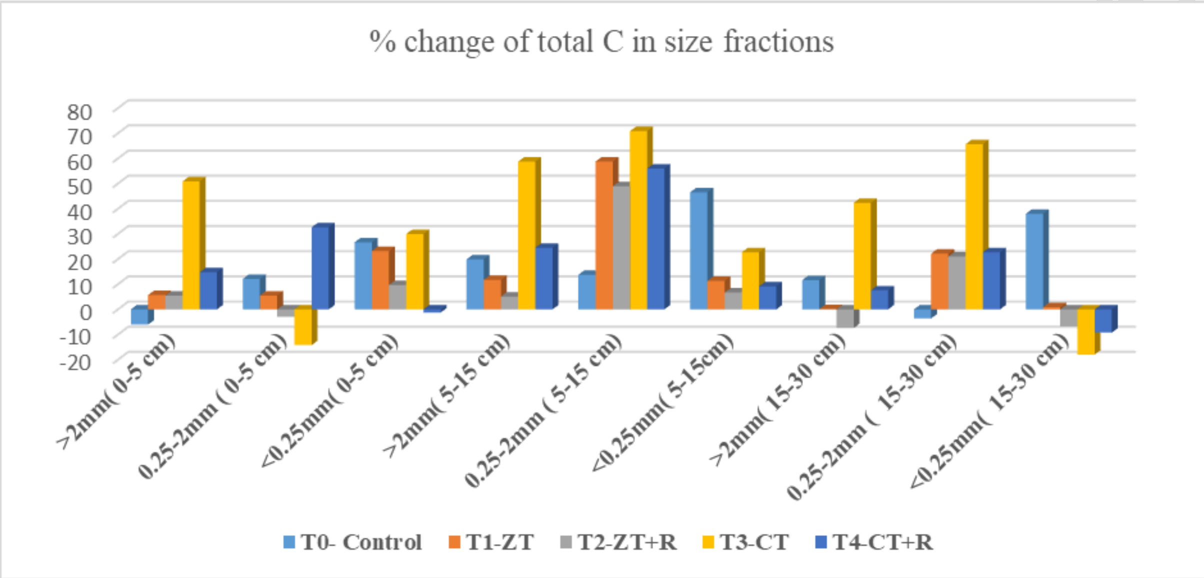

Fig 2: % change of total carbon in aggregate size fractions observed between Post-Wheat soil 2018 and Post-Rice 2019

Fig 2 represents the change in carbon for the different aggregate size fractions over the period from post-wheat of 2018 to post-rice 2019. Interestingly, for the upper soil layer of 0-5 cm, the carbon in the large aggregates of greater than 2mm were found to have been significantly increased for the treatment where only conventional tillage was practiced (T3). The carbon in the aggregate fractions comprising of 0.25-2mm size classes seemed to be increasing significantly for the treatment following conventional tillage practices and residue incorporation. However, carbon in the fractions <0.25 mm showed increase in the control and treatment following zero-tillage (T1) as well as conventional tillage (T3). Similar to the trend in the upper soil layers of 0-5 cm, the soil layer of 5-15 cm also showed significant increase of carbon content in >2mm fractions for treatment with conventional tillage practices when compared with other treatments. In the fraction of 0.25-2 mm, increase in the carbon content was observed for all the treatments except in the control and the increase was highest in the treatment with conventional tillage without application of residues. The carbon content in the fractions less than 0.25mm, was found to have positive and significant increase in control over other treatments. For 15-30 cm depth of soil, both the fraction of >2mm and 0.25-2mm showed positive and significant increase in carbon content for the treatment with practice of conventional tillage when compared with other treatments. Similar to the upper depth, for fractions less than 0.25mm control plot showed the maximum increase in carbon content. When soybean was continuously grown, it was observed that C concentrations were highest in all fractions like 2mm, 2-1mm and <0.053 mm (Yuan *et al*, 2021). But in cropping systems with continuous cultivation of soybean, maize, wheat and maize-soybean-wheat rotation showed decreased carbon concentration in 0.5-0.25 and 0.25-0.053 mm fractions but the concentration increased in 2-1 mm fractions (Yuan *et al*, 2012) which was also observed in this experiment mainly for the upper 0-5 cm soil layer. In the same experiment it was also observed that, >5 mm, 2–1 mm and <0.25 mm aggregate size-fractions had higher organic carbon content in no-tillage treatments when compared with rotary tillage treatments.

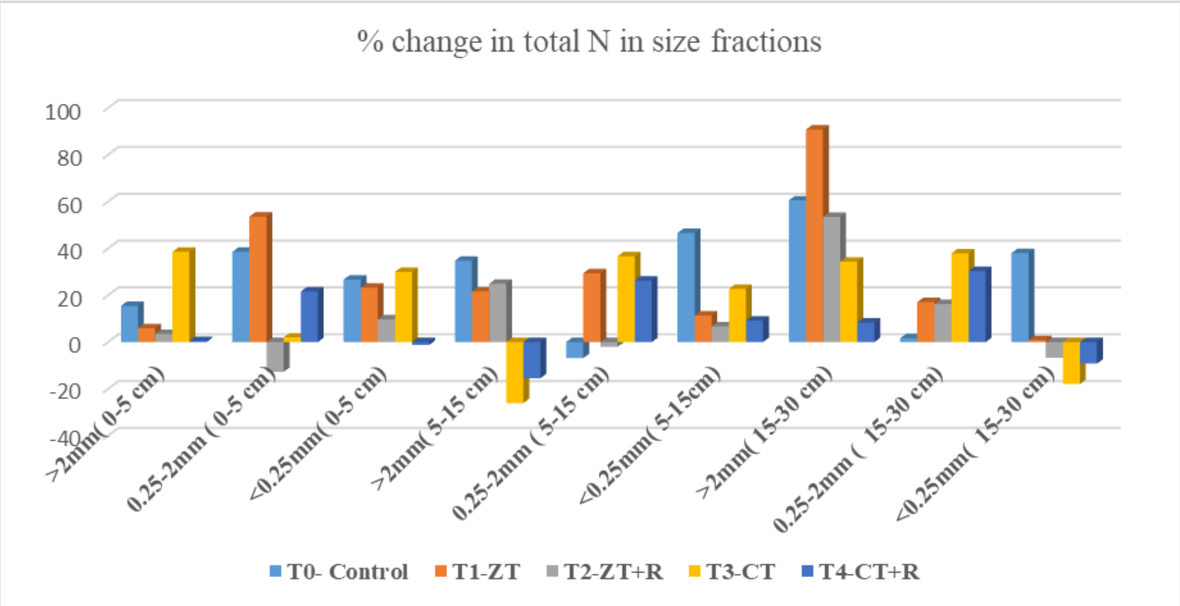

Fig 3: % change of total nitrogen in aggregate size fractions between Post-Wheat soil 2018 and Post-Rice 2019

In Fig 3, for the upper soil layer of 0-5 cm, the total nitrogen in the fraction >2mm was found to increase significantly in the treatment with conventional tillage practices (T3). Treatment with only zero-tillage with no incorporation of residues (T1) showed highest increase in total N when compared with other treatments. But in the case of fractions less than 0.25 mm, the control along with treatments with zero-tillage (T1) and with conventional tillage (T3) showed increase in total N over other treatments. Increase in total N was observed in control, zero-tillage (T1) and treatment with zero-tillage and residue incorporation (T2) for fractions greater than 2mm in 5-15 cm of soil depth. In the fractions of 0.25-2mm increase in percentage of total N was observed for treatment with zero-tillage (T1), conventional tillage (T3), and conventional tillage without residue incorporation (T4). The total N content in the fractions less than 0.25mm was found to be significantly higher in the control over other treatments. In the depth of 15-30 cm soil depth, the total N in fraction of >2mm was found to increase at a significantly higher rate for the control plot, the treatment with zero-tillage (T1), zero-tillage with incorporation of residues (T3) and treatment with conventional tillage practices (T3). But the highest increase was observed in the treatment with zero-tillage (T1). An increase in total N content was observed in the fraction of 0.25-2mm for the treatment with conventional tillage (T3) as well as conventional tillage with residue application (T4). Significant increase in total N content was observed in the control plot in the fractions less than 0.25mm. In an experiment conducted by Zhang *et al* (2021), that with application of biochar and recommended NPK doses the total N levels increased by 44.87–50.35% in 2–0.25 mm fraction of soils. Also in comparison with control the total N in the fractions > 2 mm and 0.25–0.053 mm was higher for the treatment with NPK and biochar. In this experiment only recommended dose of NPK and application of residues showed the similar results.

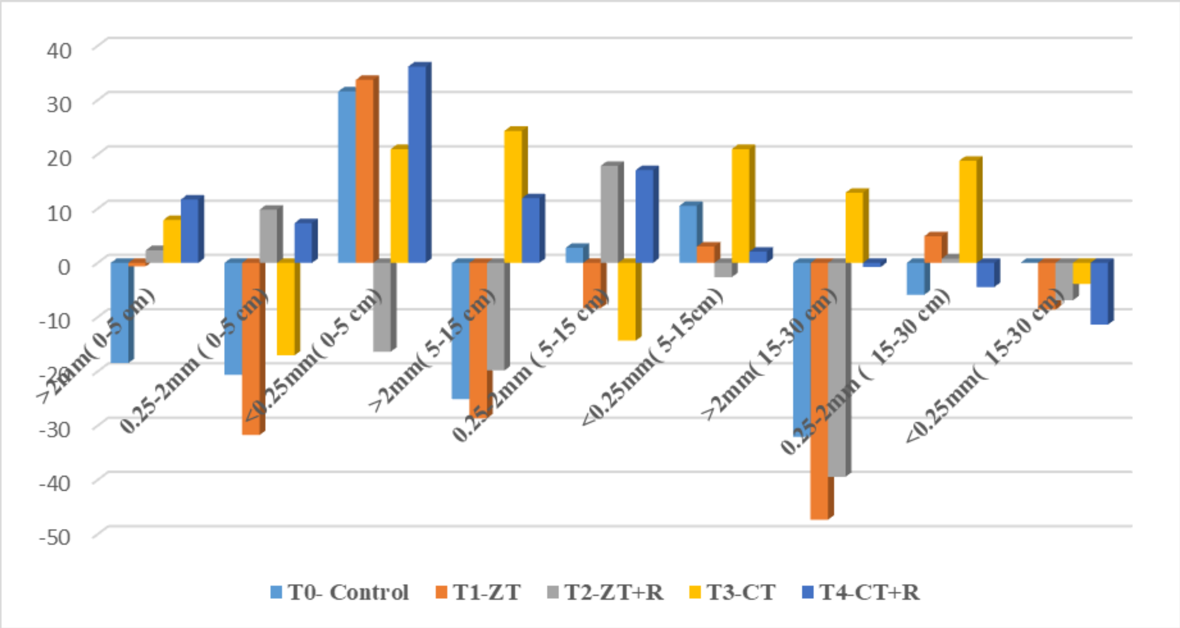

Fig 4: % change of C/N ratio in aggregate size fractions between Post-Wheat soil 2018 and Post-Rice 2019

Fig 4 represents, that in the upper soil layers of 0-5cm, due to tillage and residue management there was increase in C/N ratios of treatments T2, T3 and T4 for fractions greater than 2mm. But significant decrease was noticed in C/N ratio in the control plot. Whereas, in the case of 0.25-2mm fractions of soil, the decrease in C/N ratio was maximum for treatment with zero-tillage practice (T1). For the fractions less than 0.25mm significant increase was observed in C/N ratios in the control, treatment with zero-tillage (T1) and zero-tillage with residue incorporation (T4). In the depth of 5-15 cm the C/N ratio in the fractions greater than 2mm showed significantly high increase for T3 and the decrease in C/N was maximum for the treatment with zero-tillage (T1). The C/N ratio in the 0.25-2mm fractions was found to have significant increase in the treatment following zero-tillage along with incorporation of residues (T2) and also conventional tillage with incorporation of residues (T4). Whereas, significant decrease in C/N ratio in the fraction was observed in treatment with conventional tillage (T3). In the fractions less than 0.25mm, the treatment with conventional tillage (T3) showed the highest increase in C/N ratio. In the lower soil depths of 15-30 cm, the C/N ratio in fractions of >2mm showed significant decrease in control and treatment following zero-tillage (T1) and zero-tillage with application of residues (T2). But the highest decrease was observed in the treatment with zero-tillage (T1). The C/N ratio in fractions of 0.25-2mm was observed to be significantly high in the treatment with conventional tillage (T3). In the fractions less than 0.25mm, C/N ratio was found to be higher in treatment with conventional tillage and incorporation of residues (T4). Decrease in C/N ratio indicates availability of nitrogen for immediate crop use. In an experiment, the aggregate fraction of 1-2mm, the corn-soybean cropping system had the C/N ratio of 9.9 while corn-soybean-wheat system had the C/N ratio of 10.5 respectively (Shuster *et al*, 2000).

4. CONCLUSION

The above experiment indicates that with suitable management of tillage and residue incorporation practices, the quality of the soil can be enhanced. The storage of carbon and nitrogen along with the formation of soil organic matter can help in regulating the C/N ratio that helps in maintaining soil health and increase productivity. In order to reduce the loss of soil carbon and nitrogen it is essential to follow the conservation agricultural practices in a long term basis. Even if the carbon in the fractions can increase in a short-span for conventional tillage practices, if not managed properly, the carbon can get destroyed and can be released into the atmosphere as carbon dioxide. Therefore, it is essential to increase the soil aggregation to maintain the C/N ratio with the help of conservational agricultural practices.

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