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Research Article

Effect of Application of Bio-Fertilizer and Residue under Different Tillage Practices on Soil Carbon Pools at Different Phenological Stages of Rice under Rice-Wheat Cropping System

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Abstract

Rice is the most important food-grain crop for almost a major part of India, from the view-point of, production, income and livelihood. However, the degradation of soil organic carbon due to over-cultivation of land and insufficient incorporation of organic matter, have led to decrease in production. Therefore, clear notion about the suitable management practices to conserve the soil health and restore the soil carbon reserves is very much essential. For the following purpose, an experiment was conducted with 8 treatments, T-1 - ZTR_0B_1, T-2 - ZTR_0B_0, T-3 – ZTR $_1B_1$, T-4 – ZTR $_1B_0$, T-5 - CTR_0B_1, T-6 - CTR_0B_0, T-7 – CTR $_1B_1$, T-8 - CTR_1B_0, where ZT- zero tillage, CT- conventional tillage, B_1- with bio-fertilizer, B_0- without bio-fertilizer, R_1- with residue, R_0- without residue. The effect was observed for two different soil depths, 0-5 cm and 5-10 cm and for different growth stages, i.e., tillering, flowering and harvesting. The results reflected that, the total organic carbon was highest for the treatment T7, for the flowering stage, in the depth of 0-5 cm and 5-10cm, 20.21 g/kg and 17.31g/kg respectively. Higher TOC content was observed in residue added plots in comparison to the plots where there was no addition, value ranged from 6.5% to 18.10 % and the percentage in 5-10 cm ranged from 8.7 % to 17.82 % across the treatments in tillering stages. For bio-fertilizer inoculated plots significant increase in the TOC content to the tune of 12.24 % and 8.37 %, in 0-5cm soil layer of flowering and harvesting stages, were recorded. The highest value of active carbon (AC) was observed in T3, 598.25 mg/kg, in the depth of 0-5cm, during the tillering stage. It can also be understood that with the application of bio-fertilizer along with addition of residues resulted in increase of active carbon, mostly in the zero tillage plots. Highest value of hot water-soluble carbon (HWSC) was recorded in the depth of 0-5 cm, for T2, T1 and T7 respectively for tillering, flowering and harvesting stages, with the values 0.80g/kg, 0.79g/kg and 0.74g/kg respectively. So, it is evident that carbon pool changes with different management practices and in various growth stages.

Keywords: Rice, carbon, growth, stages, soil

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Introduction

Intensive cultivation of land and repeated rotation of cereal crops without addition of sufficient organic matter have resulted in depletion of soil organic carbon. The long-term conventional agricultural practices have often resulted in land degradation. It finally decreases the soil quality and renders the soil infertile. Practice of zero-tillage along with addition of residues resulted in conservation of higher soil organic carbon (SOC). Therefore, it is very much essential to shift our focus from intensive tillage to 'no or reduced tillage' with addition of crop residues. Proper tillage practice can resolve many of the problems related to soil health as it can alter the physical, chemical and biological properties of soil. A proper soil structure and health is required for the sustenance of healthy crops in a long run. In case of no/zero tillage 30 % of the residue cover is left on the surface of the field which leads to increase in soil organic carbon. The rice-wheat cropping system results in generation of about 7-10 t/ha of crop residues annually [1]. Carbon sequestration in soil is largely dependent on the storage of Soil organic carbon (SOC) in the soil. Storage of soil organic carbon in soil is also dependent on several other factors like aggregation, soil texture and cation exchange properties. Some SOC fractions, hot-water extractable carbon and permanganate oxidizable carbon (Active C) are considered as more sensitive indicators to contemplate the changes in soil properties due to the changes in soil management. These labile pools of carbon need to be evaluated to identify the most suitable parameter to conserve the soil organic carbon and how they behave in different phenological stages of plant growth. Keeping this in mind, the above experiment was conducted to evaluate the quantitative changes in labile soil organic carbon (SOC) pools under varying tillage and cultivation management in Rice-Wheat system in different growth stages of Rice.

Materials and Method

The field experiment was conducted during the Kharif season of 2015-2016 at University Farm, Pundibari, Cooch Behar (W.B) of Uttar Banga Krishi Viswavidyalaya. The Farm is situated at 26°19' N latitude, 89°23' E longitude with an altitude 43 m above the sea level. Data was recorded after the harvesting of Rice.Soils used for analyses were composite of sub-samples collected from each treatment plot in the experimental field at 0-5 and 5-10 cm depths in the three-growth stage of tillering, flowering and harvesting of rice in a year under rice – wheat cropping system.The experimental field was laid out in a 3- factor factorial in RBD with three replications for each treatment; plot size for each treatment was 7m x 9m. The experiment had 3 treatment factors and each with two options/levels.

Table 1 Details of treatment combinations used in rice (Figure 3 & 4)

Sl. No.	Combined form of Treatment	Component of treatments for rice
1.	T-1 - ZTR_0B_1	Zero tillage + residue removed+ bio-inoculation
2.	T-2 - ZTR_0B_0	Zero tillage + residue removed+ no bio-inoculation
3.	T-3 – ZTR_1B_1	Zero tillage + residue added+ bio-inoculation
4.	T-4 – ZTR_1B_0	Zero tillage + residue added+ no bio-inoculation
5.	T-5 - CTR_0B_1	Conventional Tillage + residue removed+ bio-inoculation
6.	T-6 - CTR_0B_0	Conventional Tillage + residue removed+ no bio- inoculation
7.	T-7 – CTR_1B_1	Conventional Tillage + residue added+ bio-inoculation
8.	T-8 - CTR_1B_0	Conventional Tillage + residue added+ no bio-inoculation

Total Organic Carbon- TOC was estimated by wet oxidation method of Walkley and Black Method [2].
Hot water extractable carbohydrates- 1g air dried soil was mixed 10 ml of hot distilled water (850 C) and heated for 2.5 h. All the soil suspension was centrifuged at 5000 rpm for 15 min [3]. Colour development of supernatant solution using phenol – sulphuric acid method of [4], glucose used as standard.
Permanganate oxidizable Carbon (Active C)- 2.5g air dried soil in a tube containing 18 ml deionised water and 2ml of 0.2M $KMnO_4$ shaken for 2 minutes, after 10 min of settling time, 0.5ml of supernatant in 49.5 ml of water was added, pink colour measured at 550 nm in spectrophotometer [5].
The experimental design was Randomized Complete Block design with factorial arrangement (2_3) with three replications. Mean separations for different treatments under different parameters were performed using Least Significant Difference comparison (P< 0.05). Normality assumption of residual under analysis of variance was also verified using PROC UNIVARIATE statement in SAS.

Results and Discussion

Effect of tillage, residue and bio-fertilizer on Total organic carbon (TOC) in soil of rice under Rice-Wheat cropping system

In a long run, reduced tillage and application of crop residues increases organic carbon content of soil [6]. However, short term tillage effects on soil organic dynamics are often variable and complex.

The results indicated that the effect of direct seeding through zero-tillage was significantly higher in 0-5 cm soil depth only at tillering stage. But in all other stages TOC was higher in conventionally tillage rice plots in comparison to direct seeded plots. In all the growth stages, application of residues resulted in significant increase in TOC concentration in all the soil layers. In tillering and harvesting stages, TOC was higher in plots where residues were added in comparison to the plots where residues were not added and the range varied from 6.5% to 18.10 % in 0-5 cm and the percentage increased from 8.7 % to 17.82 % across all the treatments in 5-10 cm layer [7] (Table- 3a and 3b). Addition of residues, along with litter fall and microbial activities may have resulted in increased stabilization of soil carbon and increase in values were recorded probably due to this phenomenon [8]. Higher amount of lignin and phenol in organic matter which forms complexes with protein resulted in increase of total organic carbon in some plots where residues were added [9].

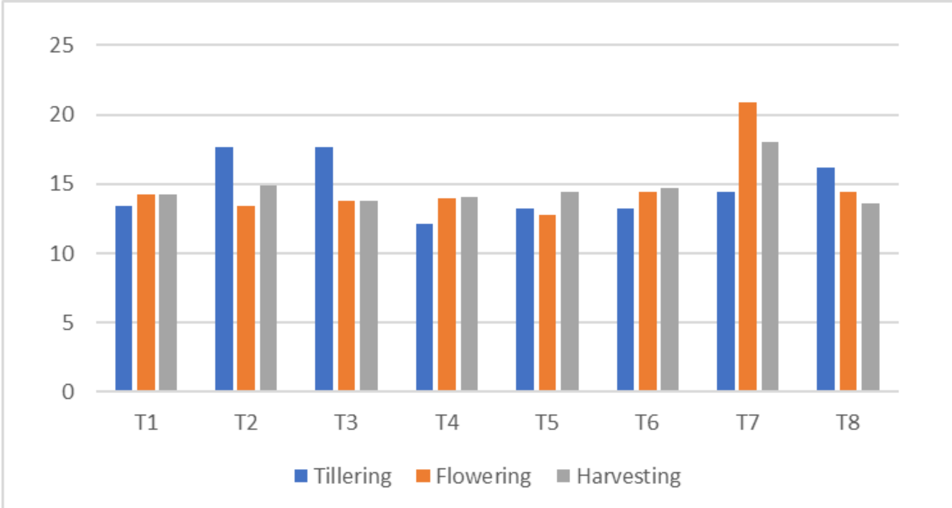

Figure 1 Status and Distribution of Total organic carbon in 0-5 cm soil depth during stages of Rice growth as influenced by tillage, crop residue and bio-fertilizer practices (g/kg)

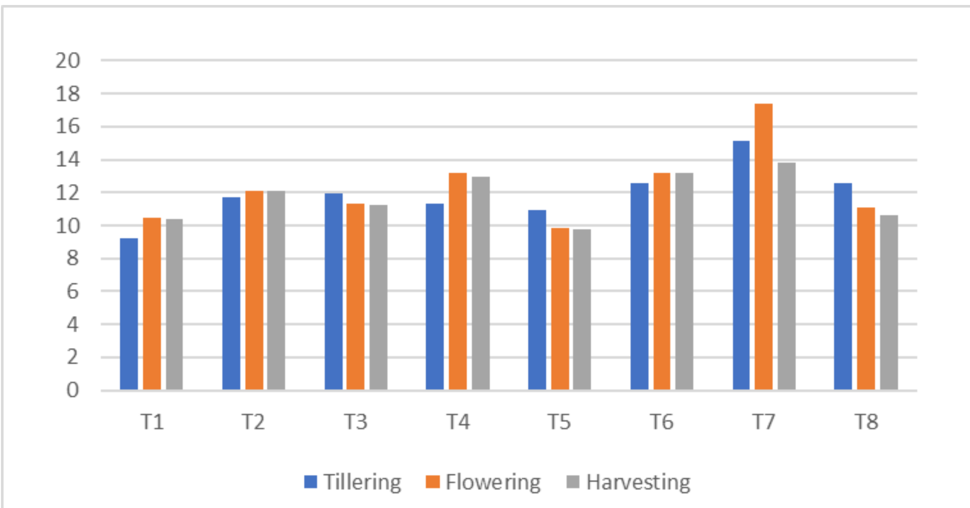

Figure 2 Status and Distribution of Total organic carbon in 5-10 cm soil depth during stages of Rice growth as influenced by tillage, crop residue and bio-fertilizer practices (g/kg)

Figure 3 Sowing at conventional tillage plot (T6)

Figure 4 Zero-tillage plot (T2)

Table 2(a) Effect of tillage, residue and Bio-fertilizer on Total organic carbon at tillering stage of rice in 0-5cm and 5-10cm soil depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	17.61a	13.04c	15.32	11.74dc	11.32dc	11.53	13.42c	17.62a	15.52	9.22e	11.96dbc	10.59	15.51a	15.33a	15.19	10.48c	11.64b	11.06
CT	13.2bc	16.14a	14.57	12.53b	12.58bc	12.55	13.2c	14.47c	13.83	10.1d	15.1a	12.6	13.2b	15.3a	14.25	11.71b	13.84a	12.95
Mean	15.41	14.54	15.00	12.13	11.95	12.04	13.31	16.04	14.68	9.66	13.53	11.50	14.36	15.31	14.72	11.09	12.74	12.00

0-5cm	**Tillage**	**Residue**	**Bio-fertilizer**	**T*R**	**T*B**	**R*B**	**T*R*B**
LSD (0.05)	0.72	NS	NS	S	NS	S	S
5-10 cm							
LSD (0.05)	0.60	NS	NS	NS	S	S	NS

In flowering and harvesting stages there was significant variation in TOC concentration due to bio-fertilizers in all the soil layers (Table- 3b and c). Significant increase in TOC content of 12.24 % and 8.37 % in 0-5cm soil layer was observable in plots with addition of bio-fertilizes in comparison to plots with no inoculation of biofertilizers (Table 3b and 3c). In zero-tillage plots without residues, higher TOC content was recorded and in CT plots with residues incorporated higher TOC was recorded. Addition of residues recorded higher TOC content in both CT and ZT plots in flowering and post-harvest stages in soil. In transplanted plots TOC content was significantly higher in all the stages and through all the depths except 0-5 cm interval in tillering stage. Similar results were obtained in long term experiments by other scientists [10]. According to Ghosh et al (2021) straw with NPK, sequestered the highest total soil organic carbon [11].

Interaction of tillage with residue was found to be significant which focused on the fact that during tillering stage TOC was found high in ZT plots without residues. Whereas, in CT plots TOC was higher in those treatments in which residues were incorporated. In case of soil taken after flowering and harvesting stages, both the ZT and CT plots was found to be higher in TOC content in those treatments where residues were given. TOC concentration was significantly higher in conventionally transplanted rice plots than direct seeded plots in all the stages with exception in 0-5 cm soil interval of tillering stage. In conventionally tilled plots inoculated with bio-fertilizer, interaction between tillage and bio-fertilizer resulted in higher TOC content. However nearly same results were observed in bio-inoculated and non-bio-inoculated plots in case of zero-tillage. Therefore, from the results it is quite clear that inoculation of seedings with bio-fertilizers was much effective in case of transplanted rice than that of direct seeded rice throughout all the depths than in those plots in which residues are removed [12].

Table 2(b) Effect of tillage, residue and Bio-fertilizers on Total organic carbon at flowering stage of rice in 0-5cm and 5-10 cm soil depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	13.37bc	14.01bc	13.69	11.79c	13.17b	12.48	14.22b	14.13b	14.17	10.46ed	11.29c	10.87	13.8bc	14.04b	13.93	11.12c	12.23b	11.67
CT	13.43bc	14.43b	13.93	12.83b	11.80cd	11.95	12.76c	20.91a	16.84	9.83e	17.35a	13.59	13.09c	17.67a	15.38	11.33c	14.21a	12.77
Mean	13.40	14.22	13.81	12.31	12.13	12.21	13.49	17.52	15.50	10.15	14.24	12.23	13.44	15.87	14.65	11.22	13.22	12.22

0-5cm	Tillage	Residue	Bio-fertilizer	T*R	T*B	R*B	T*R*B
LSD (0.05)	0.66	00.70	0.66	0.66	S	S	S
5-10 cm							
LSD (0.05)	S (0.35)	S (0.35)	S (0.35)	S	S	S	S

Table 2(c) Effect of tillage, residue and Bio-fertilizers on Total organic carbon at harvesting stage of rice in 0-5cm and 5-10 cm soil depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	14.88b	14.03b	14.46	12.12cb	12.97ab	12.55	14.24bc	14.36b	14.03	10.41ed	11.27cd	10.84	14.56b	14.19b	14.37	11.27bc	12.12ab	11.70
CT	13.33b	14.15bc	13.74	12.51b	10.63ed	11.57	14.45b	18.06a	16.26	9.78e	13.82a	11.80	13.89b	16.11a	15.00	11.14ab	12.22a	11.68
Mean	14.10	14.09	14.10	12.31	11.80	12.05	14.35	15.94	15.28	10.10	12.55	11.32	14.22	15.15	14.68	11.20	12.17	11.68

0-5cm	Tillage	Residue	Bio-fertilizer	T*R	T*B	R*B	T*R*B
LSD (0.05)	0.50	0.50	0.50	S	S	S	NS
5-10 cm							
LSD (0.05)	NS	0.61	0.61	NS	S	S	S

The interaction of residue and bio-fertilizer during the flowering stage of rice was found to be significant in all the stages and in all the soil depth. This interaction resulted in higher TOC concentration in plots where both residue and bio-fertilizers were added**.**

The conventional plots, mostly, have got higher soil carbon throughout its depth due to incorporation of residues, may be because of the changes in physical, chemical and biological properties of saturated soil influencing the growth of micro-organisms. Also, mechanical breakdown of soil organic matter is encouraged by tillage. The spontaneous growth of blue-green algae in puddled soil can also be a significant factor in breaking down the soil organic matter [13].

Effect of tillage, residue and bio-fertilizer on active carbon (AC) in soil of rice under Rice-Wheat cropping system

The potassium permanganate oxidizable C (Active-C) which is one of the labile pools of carbon is one of the sensitive indicators to measure the changes in soil carbon due to management practices adopted in Rice-Wheat cropping system. In this study the effect of Zero-tillage in rice resulted in significant increase in active C concentration.

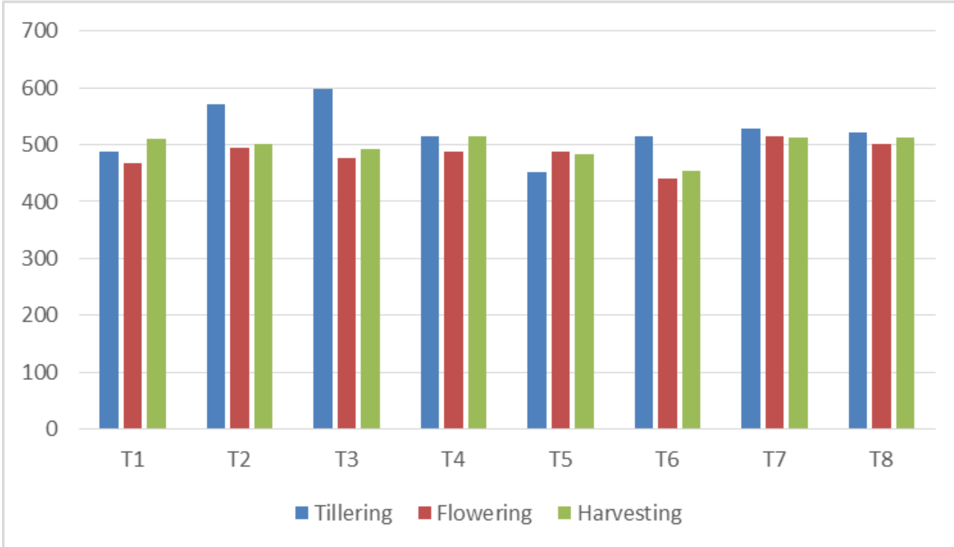

Figure 5 Status and Distribution of Active carbon in 0-5 cm soil depth during stages of Rice growth as influence by tillage, crop residue and bio-fertilizer practices (mg/kg)

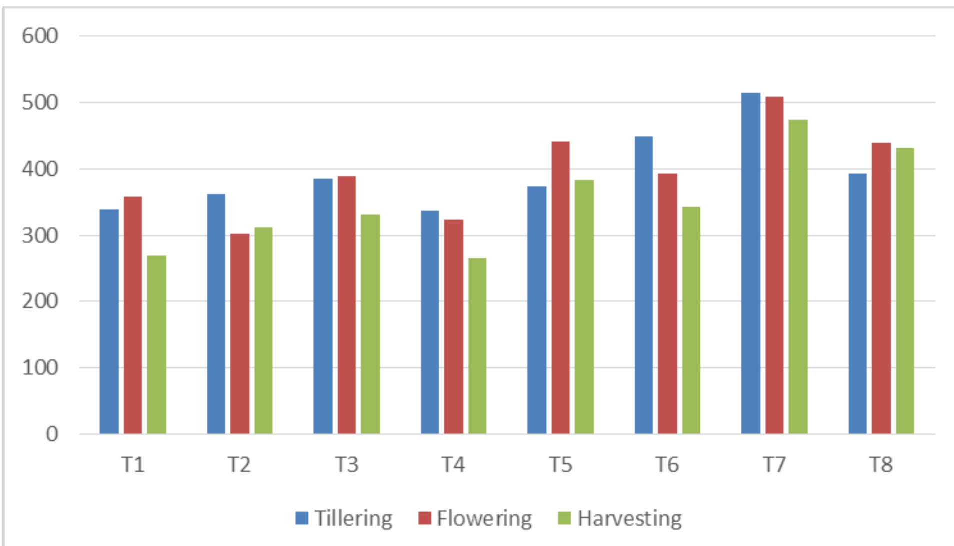

Figure 6 Status and Distribution of Active carbon in 5-10 cm soil depth during stages of Rice growth as influence by tillage, crop residue and bio-fertilizer practices (mg/kg)

In bio-fertilizer inoculated plots, active C increased in all the stages except in tillering stage in 0-5cm soil depth. The difference between the active C concentration in the depth of 5-10 cm was higher in bio-fertilizer inoculated plots as compared to bio-fertilizer non-inoculated plots (Table-5a). The results are almost in accordance to the values as reported by Rudrappa et al (2006), Purakayastha et al. (2008), and Moharana et al. (2012) [14-16]. In case of those treatments where only residues were applied in case of zero-tillage resulted in higher concentration of Active C than those where there was no application of residues (Table-4 and 5a). All the treatments having bio-innoculation resulted in increased Active C concentration except in 0-5 cm layers for all the treatments (Table-5a). In both zero and conventionally tilled plots where residues were added there was increase in concentration of active C. In treatment 4 and 8, there was relatively higher concentration of Active C (Table- 4). In case of tillering and harvesting stage of rice in 0-5 cm soil layer there was 6.42% and 4.20% increase in active C in direct seeded plots in comparison to transplanted plots (Table-5 a & c). All the growth stages, application of residues had resulted in increase of Active C concentration throughout all the depths

Study reported that effect of conservation agricultural practices on soil organic fractions in two types of soil resulted in statistically higher AC values in conservation tillage treatments than the conventional tillage treatments [17]. The present study revealed that both zero-tillage treatments with and without bio-fertilizers and zero-tillage combined with residues and bio-fertilizers have led to higher active C concentration in comparison to the conventional plots without incorporation of residues or addition of bio-fertilizers in 0-5 cm of soil depth. Addition of residues along with bio-fertilizers.

Table 3(a) Effect of tillage, residue and Bio-fertilizers in Rice soil on Active carbon at tillering stage of rice in 0-5 cm and 5-10 cm soil depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	498.05ab	515.4aa	506.73	330.61c	264.83d	297.72	511.21a	519.13a	515.17	269.6d	340.96c	305.28	504.78a	517.31a	511.05	300.1c	302.89c	301.50
CT	453.42c	512.31a	482.87	342.02c	431.94ab	386.98	483.66b	512.31a	497.99	383.4cb	473.32a	428.36	468.54b	512.31a	490.43	362.71b	452.63a	407.67
Mean	475.74	513.86	494.80	336.32	348.39	342.35	497.44	515.72	506.58	326.50	407.14	366.82	486.66	514.81	500.74	331.41	377.76	354.58

0-5cm	Tillage	Residue	Bio-fertilizer	T*R	T*B	R*B	T*R*B
LSD(0.05)	10.91	10.91	NS	S	NS	NS	NS
5-10 cm							
LSD(0.05)	10.91	10.91	NS	S	NS	S	S

Table 3(b) Effect of tillage, residue and Bio-fertilizers in Rice soil on Active carbon (mg/kg) at flowering stage of rice in 0-5 cm and 5-10 cm soil depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	498.05ab	515.4aa	506.73	330.61c	264.83d	297.72	511.21a	519.13a	515.17	269.6d	340.96c	305.28	504.78a	517.31a	511.05	300.1c	302.89c	301.50
CT	453.42c	512.31a	482.87	342.02c	431.94ab	386.98	483.66b	512.31a	497.99	383.4cb	473.32a	428.36	468.54b	512.31a	490.43	362.71b	452.63a	407.67
Mean	475.74	513.86	494.80	336.32	348.39	342.35	497.44	515.72	506.58	326.50	407.14	366.82	486.66	514.81	500.74	331.41	377.76	354.58

0-5cm	Tillage	Residue	Bio-fertilizer	T*R	T*B	R*B	T*R*B
LSD (0.05)	10.91	10.91	NS	S	NS	NS	NS
5-10 cm							
LSD (0.05)	10.91	10.91	NS	S	NS	S	S

However, application of residue plus bio-fertilizers and only residues, improved active C content in conventional tillage also and the concentrations were comparable. In 5-10cm soil layer however, active C concentrations were higher in conventionally tilled plots than the ZT plots. In lower layer reserve trend was prominent because ploughing promotes microbial activity by increasing contact between soil and decomposing plant material or because ploughing exposed frees organic matter surface to microbial attack [18].

Effect of tillage, residue and bio-fertilizer on hot extractable carbohydrate (HWC) in soil after rice in Rice-Wheat cropping system

Higher HWC was recorded in direct seeded plots in comparison to conventionally transplanted rice in the soil depth of 0-5 cm and 5-10 cm in both the tillering and flowering stages [19]. The direct seeded plots showed enhanced concentration of HWC in tillering stage, i.e., 46% in 0-5cm and 44.44% in 5-10cm (Table-7a). In flowering and harvesting stage, HWC content increased in 5-10 cm of soil depth as a result of addition of residues. The increase was noted to be 31.25% in 5-10cm soil depth, 30.4% in 0-5cm and 25.64% in 5-10cm during harvesting stage (Table-7b and 7c) [20]. Soil collected after flowering and harvesting showed increase in concentration of HWC in 0-5 cm of soil layer when seedlings were inoculated with bio-fertilizers. Due to bio-fertilizer inoculation the increase was found to be 23.64% (flowering stage) 12% (0-5cm) and 12.2% (5-10cm) in post-harvest soils.

Table 3(c) Effect of tillage, residue and Bio-fertilizers in soil on Active carbon at harvesting stage of rice in 0-5 cm and 5-10 cm depth soil depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	564.7a	515.5b	540.10	361.91cd	337.24d	349.58	486.84c	579.81a	533.33	339.63d	385.78c	362.71	525.77b	547.65a	536.71	350.77c	361.51c	356.14
CT	513.9b	522.65b	518.28	448.65b	392.15c	420.40	452.63d	528.22b	490.43	374.64cd	513.9a	444.27	483.26c	525.44b	504.35	411.64b	453.02a	432.33
Mean	539.3	519.08	529.19	405.28	364.70	384.99	469.74	554.02	511.88	357.14	449.84	403.49	504.52	536.55	520.53	381.21	407.27	394.24

0-5cm	Tillage	Residue	Bio-fertilizer	T*R	T*B	R*B	T*R*B
LSD(0.05)	10.91	10.91	10.91	NS	S	S	S
5-10 cm							
LSD(0.05)	22	NS	NS	NS	NS	S	S

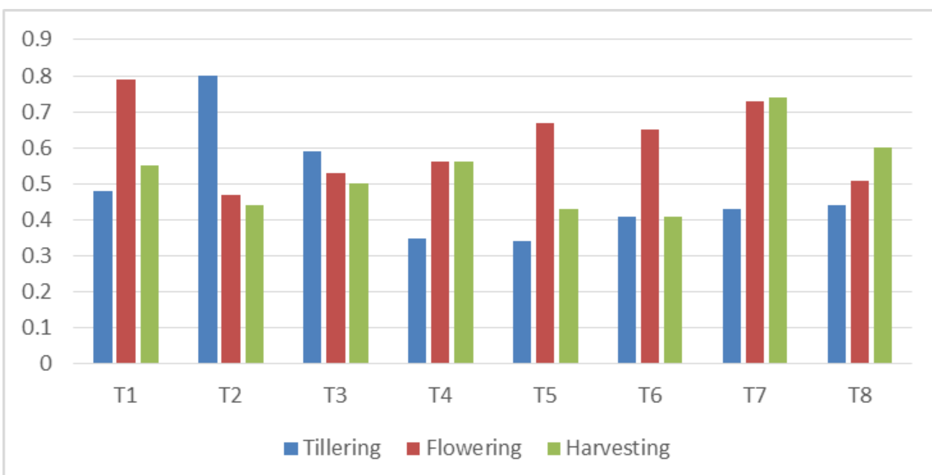

Figure 7 Status and Distribution of Hot-water extractable carbohydrate (g/kg) 0-5 cm soil depth during stages of Rice growth as influence by tillage, crop residue and bio-fertilizer practices

Therefore, the above results showed that application of bio-fertilizer increased HWC in in 0-5cm soil layer. Bio-fertilizer application helps in improving the HWC concentration as it helps in mineralization of different organic substances in soil [21] and also helps in improvement of rhizospheric environment and enhances the growth of microbial population in soil.

Interaction of tillage and residue in the present study showed higher concentration of HWC in zero tillage plots without residue and conventional tillage plots with residue in tillering stage of rice. In plots without residues, high concentration of HWC was recorded in both ZT and CT in 0-5 cm during flowering stage. Plots with application of residues in case of both ZT and CT showed higher concentration of HWC in flowering stage of rice. Interaction of tillage and bio-fertilizer revealed that HWC concentration was higher in both ZT and CT without addition of biofertilizers in 0-5 and 5-10 cm of soil layers in tillering stage. In case of flowering stage and in harvesting stage, in 0-5 cm soil depths, the concentration of HWC was higher than in other stages.

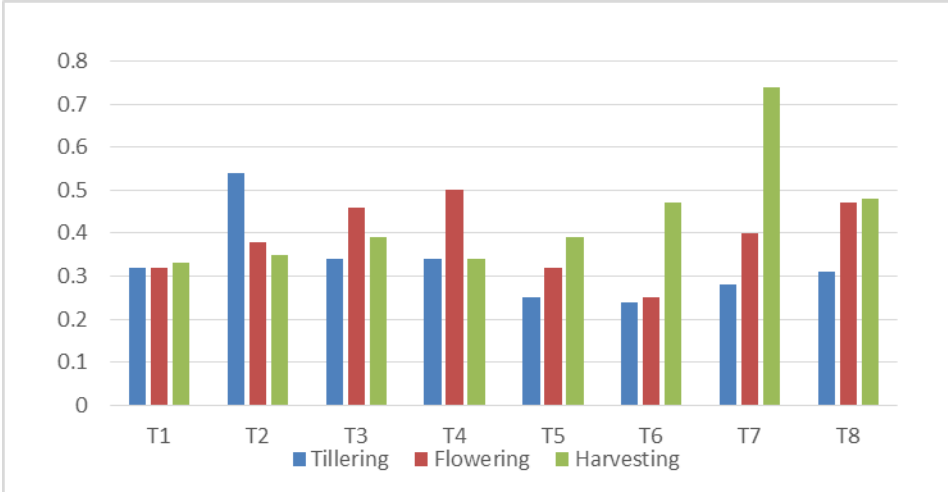

Figure 8 Status and Distribution of Hot-water extractable carbohydrate (g/kg) 5-10 cm soil depths during stages of Rice growth as influence by tillage, crop residue and bio-fertilizer practices

Table 4(a) Effect of tillage, residue and Bio-fertilizer on Hot-Water carbohydrate (g/kg) at tillering stage of rice in 0-5 cm and 5-10 cm depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	0.8a	0.35f	0.58	0.54a	0.34b	0.44	0.48c	0.59b	0.54	0.32bc	0.34b	0.33	0.64a	0.47b	0.56	0.43a	0.34b	0.39
CT	0.41e	0.44d	0.43	0.24e	0.31c	0.28	0.34f	0.43d	0.39	0.25e	0.28d	0.27	0.37d	0.43c	0.40	0.24d	0.29c	0.27
Mean	0.61	0.40	0.50	0.39	0.33	0.36	0.41	0.51	0.46	0.29	0.31	0.30	0.51	0.45	0.48	0.34	0.32	0.33

0-5cm	Tillage	Residue	Bio-fertilizer	T*R	T*B	R*B	T*R*B
LSD (0.05)	0.01	0.01	0.01	S	NS	S	S
5-10 cm							
LSD (0.05)	0.01	0.01	0.01	S	S	S	S

Table 4(b) Effect of tillage, residue and Bio-fertilizer on Hot-Water carbohydrate (g/kg) at flowering stage of rice in 0-5 cm and 5-10 cm depth

Tillage	No application of bio-fertilizer						Application of bio-fertilizer						Mean					
	0-5 cm			5-10 cm			0-5 cm			5-10 cm			0-5 cm			5-10 cm		
	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean	Removed residue	Added residue	Mean
ZT	0.47h	0.56e	0.52	0.38d	0.5a	0.44	0.79a	0.53f	0.66	0.32e	0.46b	0.39	0.63b	0.55d	0.59	0.35c	0.41a	0.38
CT	0.65d	0.51g	0.58	0.25f	0.47b	0.36	0.67c	0.73b	0.70	0.32e	0.4c	0.36	0.66a	0.62c	0.64	0.29d	0.43b	0.36
Mean	0.56	0.54	0.55	0.32	0.49	0.40	0.73	0.63	0.68	0.32	0.43	0.38	0.65	0.59	0.62	0.32	0.42	0.37

0-5cm	Tillage	Residue	Bio-fertilizer	T*R	T*B	R*B	T*R*B
LSD(0.05)	NS	NS	NS	S	S	S	S
5-10 cm							
LSD(0.05)	NS	NS	NS	S	S	S	S

Table 4(c) Effect of tillage, residue and Bio-fertilizer on Hot-Water carbohydrate (g/kg) at harvesting stage of rice in 0-5 cm and 5-10 cm depth

Tillage	**No application of bio-fertilizer**						**Application of bio-fertilizer**						**Mean**					
	0-5 cm			**5-10 cm**			**0-5 cm**			**5-10 cm**			**0-5 cm**			**5-10 cm**		
	Removed residue	**Added residue**	**Mean**	**Removed residue**	**Added residue**	**Mean**	**Removed residue**	**Added residue**	**Mean**	**Removed residue**	**Added residue**	**Mean**	**Removed residue**	**Added residue**	**Mean**	**Removed residue**	**Added residue**	**Mean**
ZT	0.44de	0.56bc	0.50	0.35cd	0.34cd	0.35	0.55bc	0.5dc	0.53	0.33d	0.39c	0.36	0.5b	0.53b	0.52	0.34c	0.36c	0.35
CT	0.41e	0.6b	0.51	0.47b	0.48b	0.48	0.43de	0.74a	0.59	0.39c	0.74a	0.57	0.42c	0.67a	0.55	0.43b	0.61a	0.52
Mean	0.43	0.58	0.50	0.41	0.41	0.41	0.49	0.62	0.56	0.36	0.57	0.46	0.46	0.60	0.53	0.39	0.49	0.44

0-5cm	**Tillage**	**Residue**	**Bio-fertilizer**	**T*R**	**T*B**	**R*B**	**T*R*B**
LSD(0.05)	NS	0.04	0.04	S	NS	NS	S
5-10 cm							
LSD(0.05)	0.03	0.03	0.03	S	S	S	S

In flowering stage (0-5cm) and harvesting stage the HWC was more in both ZT and CT with bio-fertilizers as compared to plots where no such inoculations were made. Residue and bio-fertilizer combination did not improve HWC concentration in rice. The data presented in Table 6 and 7 reveals that HWC concentration was more in conventionally tilled plots than ZT plots. Further, the effect of residue or bio-fertilizers was more pronounced in CT

Conclusion

It was quite evident from the above research that the effect of zero tillage on total organic carbon was significantly higher in 0-5 cm depth for tillering stage only. Other stages showed higher TOC in transplanted plots. Application of residues notably increased total organic carbon concentration in all the soil layers and in all stages mostly in conventionally tilled plots. The range of increase in TOC content in residue added plots in 0-5 cm soil depth was 6.54 % to 18.10 % and from 8.7 % to 17.82 % in soil depth of 5-10 cm in all the treatments under consideration. Significant increase in TOC was observed in 0-5 cm soil depth in the tune of 12.24 % and 8.37 % in both flowering and harvesting stages in treatments where inoculation of bio-fertilizers was done.

Active C concentration in 0-5 cm soil layer was 6.42% and 4.20% in tillering and harvesting stage respectively in direct seeded plots than conventionally tilled plots. Active C significantly increased in rice due to application of residue in all the stages. Bio-fertilizer inoculation increased the active C concentration in rice in 0-5 cm soil layer, in all stages, except in tillering stage. But the active C concentration was found significantly higher in non-inoculated plots in upper layers, whereas in 5-10cm soil layer, there was little increase in active C concentration due to bio-fertilizer inoculation.

In tillering and flowering stage, in the depths of 0-5cm and 5-10cm soil layer, the direct seeded plots recorded higher HWC than the conventionally tilled plots. During tillering stage, in 0-5 cm depth the HWC concentration was found to be 46% and in 5-10cm soil depth it was recorded to be 44.44% (Table 20 a& b). In all the other cases HWC was generally higher in CT than in ZT. HWC content increased in 5-10cm of flowering stage due to the effect of addition of residues. During harvesting stage, the increase was 30.4% in 0-5cm and 25.64 % in 5-10cm. In flowering stage, bio-fertilizer inoculation of seeds/ seedlings increased HWC in 0-5 cm of soil layer. Both the two layer of soil depths showed increase in HWC in post-harvest soils. The increase in flowering stage was 23.64%. Whereas, in post-harvest soils the percentage of increase was 12% (0-5cm) and 12.2% (5-10cm) due to bio-fertilizer inoculation.

Therefore, the experiment provided us the notion that, conservation agricultural practices can increase soil carbon pools significantly, imparting a positive effect on soil health and encouraging the growth of micro-organisms.

References

[1] K.G. Mandal, et al. Rice residue-management options and effects on soil properties and crop productivity. Journal of Food Agriculture and Environment, 2004, 2: 224-231.

[2] R. Mrabet, et al. Total, particulate organic matter and structural stability of a Calcixeroll soil under different wheat rotations and tillage systems in a semi-arid area of Morocco. Soil & Tillage Research, 2001, 57: 225-235.

[3] J.K. Adesodun, J.S.C. Mbagwu, N. Oti. Structural stability and carbohydrate contents of an ultisol under

different management systems. Soil & Tillage Research, 2001, 60: 135-142.
[4] M. Dubois, et al. Colorimetric method for determination of sugars and related substances. Analytical chemistry, 1956, 28.3: 350-356.
[5] R. Weil, et al. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use. American Journal of Alternative Agriculture, 2003, 3-17.
[6] S. B. Dikgwatlhe, Z. D. Chen, R. Lal, H. L. Zhang, F. Chen. Changes in soil organic carbon and nitrogen as affected by tillage and residue management under wheat–maize cropping system in the North China Plain. Soil and Tillage Research, 2003, 144:110-118.
[7] M. Ghosh, W. Ashiq, H. Bhogilal Vasava, D.N.V. Gamage, P.K. Patra, A. Biswas. Short-Term Carbon Sequestration and Changes of Soil Organic Carbon Pools in Rice under Integrated Nutrient Management in India. Agriculture, 2021, 11, 348.
[8] H. Liu, G.M. Jiang, H.Y. Zhuang, K.J. Wang. Distribution, utilization structure and potential of biomass resources in rural China: With special references of crop residues. Sustain. Energy Rev. 2007, 12:1402–1418.
[9] G. Tian, B. Kang, L. Brussaard. Biological effects of plant residues with contrasting chemical composition under humid tropical conditions decomposition and nutrient release.1992.
[10] D. S. Jenkinson, D. E. Adams, and A. Wild. Model estimates of CO 2 emissions from soil in response to global warming. Nature, 1991, 351.6324:304-306.
[11] M. Ghosh, W. Ashiq, H. Bhogilal Vasava, D.N.V. Gamage, P.K. Patra, A. Biswas. Short-Term Carbon Sequestration and Changes of Soil Organic Carbon Pools in Rice under Integrated Nutrient Management in India. Agriculture, 2021, 11, 348.
[12] Y. Singh, et al. Long-term effects of organic manuring and crop residues on the productivity and sustainability of rice-wheat cropping system in north-west India. Long-term soil fertility experiments in rice-wheat cropping systems, 2000, pp-149-62.
[13] P. R. Gajri, S. P. Majumdar, P. K. Sharma, Fundamentals of Soil Science. Indian Society of Soil Science, Indian Agricultural Research Institute, New Delhi, 2002, pp-125-132.
[14] L. Rudrappa, et al. Long-term manuring and fertilization effects on soil organic carbon pools in a Typic Haplustept of semi-arid sub-tropical India. Soil and Tillage Research, 2006, 88.1-2: 180-192.
[15] T. J. Purakayastha, et al. Long-term impact of fertilizers on soil organic carbon pools and sequestration rates in maize–wheat–cowpea cropping system. Geoderma, 2008, 144.1: 370-378.
[16] P. C. Moharana, et al. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year-old pearl millet–wheat cropping system in an Inceptisol of subtropical India. Field Crops Research, 2012, 136: 32-41.
[17] S. Melero, et al. Conservation tillage: Short- and long-term effects on soil carbon fractions and enzymatic activities under Mediterranean conditions. Soil & Tillage Research, 2009, 104: 292–298.
[18] D. S. Powlson. The effects of grinding on microbial and non-microbial organic matter in soil. Journal of Soil Science, 1980, 31.1: 77-85.
[19] S. Hazarika, R. Parkinson. Hot water extractable soil carbohydrate-A sensitive measurement for determining the impact of long-term tillage and residue management. Journal of the Indian Society of Soil Science, 2011, 59(1):60-66.
[20] S. Hazarika, R. Parkinson. Hot water extractable soil carbohydrate-A sensitive measurement for determining the impact of long-term tillage and residue management. Journal of the Indian Society of Soil Science, 2011, 59(1):60-66.
[21] S. B. Latake, D. B. Shinde, D. M. Bhosale. "Effect of inoculation of beneficial microorganisms on growth and yield of pearl millet. Indian Journal of Agricultural Research, 2009, 43.1:61-64.

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