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Response of conservational practices on soil organic carbon and stock in rice-wheat system

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Abstract
Rice-wheat cropping system being predominant system in the Indo-gangetic plains is facing several constraints with the traditional practice of rice and wheat like depletion of soil health, burning of residue and environmental pollution, which affects the sustainability of soil quality besides productivity of rice-wheat system. Thus, to improve the soil health and quality sustainably two years field study was conducted at N.E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) during 2015 to 2017 with 5 establishment methods and 3 weed management practices under strip plot design with three replications. Comparatively higher soil organic carbon was recorded in zero till than conventional transplanted rice. Treatment zero till rice-wheat cropping system with residue retention-*Sesbania* brown manuring resulted in higher values of SOC with stock at 0-15 cm soil depth. Residue retention, brown manuring and zero tillage led to enhancement in SOC with stock. While, weedy check recorded higher values of soil organic carbon content and stock at different depths, after the harvest of rice and wheat crop, among weed management practices under rice-wheat system.

Keywords: Conventional tillage, organic carbon, *Sesbania*, weedy, zero till

Introduction
Rice (*Oryza sativa*)-Wheat (*Triticum aestivum*) system act as the “food bowl” or “food basket” of the Indo-Gangetic plains (IGP) of India, together contributing more than 74% of total cereal production in India, with production of 104.41 and 92.29 million tonnes of rice and wheat, respectively (GOI, 2016) [11]. The traditional practice of rice and wheat resulted in depletion of soil organic carbon (Singh *et al.,* 2007 and Bhattacharyya *et al.,* 2015) [24, 3] by intensive tillage and residue burning. Also, persistent use of conventional practices lead to soil carbonic losses and steadily degrading the soil resource base as soil quality primarily depends soil organic matter, that is not only a source of carbon but also a sink for carbon stock (Liu *et al.,* 2006) [18]. The organic matter decreased with increasing tillage at all depths and was 33% greater with no tillage compared with the average of the other tillage treatments in the surface 0 to 5 cm (Roldán *et al.*, 2004) [23]. Alternately, soil organic carbon is a key element affecting soil quality that affects crop productivity proportionally (Lal, 2006 and Pan *et al.*, 2009) [17, 21]. Zero tillage can enhance organic carbon contents in the surface layers and result in higher stability of soil aggregates (Chauhan *et al.,* 2002) [6]. Stock of organic carbon in soils occurs if the organic carbon input is greater than the soil organic matter loss caused by microbial decomposition. Soil carbon stock is influenced by many factors, such as agricultural practice, and climatic and soil conditions. A number of studies reported that soil organic carbon levels increase under practices of balanced fertilization, organic amendments, cropping rotations, conservative tillage (Bhattacharyya *et al.*, 2007 and Tong *et al.*, 2009) [2, 26]. To eliminate the limitations being encountered in the existing mode, researchers need to find an alternative production system that may be achieved through appropriate crop rotations, inclusion of organic material, conservation tillage methods like direct seeding of rice and zero till wheat with residues retention and integrated fertility management (Srinivasarao *et al.,* 2012) [25]. Thus, conservation agriculture may be an option for improving the soil quality besides improving productivity of the rice-wheat system in IGP of India (Dey *et al.,* 2016 and Jat *et al.,* 2016) [8, 14] as it refers to the system of raising crops with minimal disturbance to the soil while retaining crop residue on the soil surface. From a paradigm shift to conservation agriculture from that of conventional, the performance of crop with soil health may vary. Some

Some improvement in organic C was reported with residue retained on soil surface with ZT (Neugschwandtner *et al.*, 2014 and Islam *et al.*, 2015) [19, 13]. Thus, some practices are required to enhance the sustainability of this system, by reducing the intensity of tillage and inclusion of organic material that improves soil quality and overall enhancement of resources-use efficiency. Considering above facts, a 2 years field study was conducted to evaluate soil health under different establishment methods in rice-wheat cropping system.

Materials and Methods

The 2 years field study was conducted at N.E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) during 2015 to 2017. The site is situated at 29°N latitude and 79.32°E longitude having an altitude of 243.8 m above the mean sea level. The soil of the experimental field was clay loam with pH 7.86 having high organic carbon (0.76%), low available nitrogen (212.6 kg/ha), medium available phosphorus (17.2 kg/ha) and available potassium (203.1 kg/ha).

The experiment was carried out in similar manner as discussed in research paper by Paliwal *et al.*, 2017 [20]. Soil organic carbon was determined by Modified Walkley and Black method (Walkley and Black, 1934) [27] and soil organic carbon stock was determined at different soil depth using the formula given by Joa Carlos *et al.,* 2001 [15].

Soil organic carbon stock (t/ha) = Soil organic carbon (%) X BD (Mg/m3) X Depth (cm)

The statistical analysis adapted was statistical package CPCS-1, designed and developed by Punjab Agricultural University, Ludhiana (Cheema and Singh, 1991) [7].

Results

Organic carbon (%)

Significant influence was noticed with the soil organic carbon after the harvest of rice and wheat under different establishment methods during both the years, except at 15-30 cm soil depth after the harvest of rice (Table 1). Significantly high soil organic carbon was recorded under ZTR+R-ZTW+R-ZTS during both the years after the harvest of rice and wheat, being significantly at par with ZTR-ZTW-ZTS at 0-15 cm soil depth after rice harvest and at 15-30 cm soil depth, during 2016-17 after wheat harvest. While, after harvest of rice, at 15-30 cm soil depth, DSR-CTW-ZTS recorded higher content of soil organic carbon, along with TPR-ZTW-ZTS, during 2016.

Variations in the soil organic carbon at different depths after the harvest of rice and wheat owing to weed management practices were found significant during both the years (Table 1). Weedy check recorded significantly highest soil organic carbon content at different soil depth. It was at par with IWM practice, except 0-15 cm, during 2015 after rice harvest and except at 15-30 cm, during 2015-16 after wheat harvest.

Establishment methods of rice and wheat with weed management practices showed non-significant interaction effect on soil organic carbon at different depths after harvest, during both the years.

Soil organic carbon stock (t/ha)

The soil organic carbon stock after the harvest of rice and wheat owing to different establishment methods was influenced significantly during both the years, at 0-15 and 15-30 cm soil depth (Table 2). Significantly high soil organic carbon stock was recorded under ZTR-ZTW-ZTS and ZTR+R-ZTW+R-ZTS, during both the years of study, being at par with each other at 0-15 cm soil depth after rice harvest and at 0-15 cm, during 2015-16 and 15-30 cm soil depth, during 2016-17 after wheat harvest. While, at 15-30 cm, after rice harvest, higher stock of soil organic carbon was recorded with TPR-CTW and TPR-ZTW-ZTS, being at par to each other, during both the years.

Different weed management practices significantly influenced the soil organic carbon stock at different depths after the harvest of rice and wheat during both the years (Table 2). Weedy check recorded significantly highest organic carbon stock of soil at different depths, being significantly superior to IWM practices and sole application of bispyribac-Na 20 g/ha in rice and clodinafop + MSM 64 g/ha in wheat.

Establishment methods of rice and wheat with weed management practices showed non-significant interaction effect on soil organic carbon stock at different depths after harvest, during both the years.

Table 1: Soil organic carbon as influenced by establishment methods and weed management practices in rice-wheat system after harvest at different soil depths during two years (2015 to 2017)

Treatment	Organic carbon (%)							
	0-15 cm				15-30 cm			
	After rice harvest		After wheat harvest		After rice harvest		After wheat harvest	
	2015	2016	2015-16	2016-17	2015	2016	2015-16	2016-17
Establishment Methods								
TPR-CTW	0.77	0.77	0.80	0.80	0.82	0.82	0.80	0.81
TPR-ZTW-ZTS	0.79	0.79	0.81	0.83	0.82	0.84	0.82	0.82
DSR-CTW-ZTS	0.85	0.85	0.79	0.80	0.83	0.84	0.81	0.80
ZTR-ZTW-ZTS	0.93	0.94	0.89	0.88	0.82	0.83	0.87	0.88
ZTR+R-ZTW+R-ZTS	0.95	0.95	0.95	0.94	0.81	0.82	0.89	0.89
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
LSD (P=0.05)	0.03	0.03	0.03	0.03	NS	NS	0.02	0.02
Weed Management								
Bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat	0.83	0.84	0.83	0.83	0.78	0.79	0.82	0.83
IWM (bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat fb 1 HW at 45 DAS/DAT)	0.86	0.86	0.85	0.85	0.84	0.84	0.84	0.84
Weedy check	0.88	0.89	0.87	0.87	0.85	0.86	0.85	0.86
SEm±	0.01	0.01	0.005	0.003	0.01	0.01	0.003	0.003
LSD (P=0.05)	0.04	0.02	0.01	0.01	0.02	0.02	0.01	0.01

Transplanted rice-Conventional till wheat (TPR-CTW); Transplanted rice-Zero till wheat-*Sesbania* green manuring (TPR-ZTW-ZTS); Direct seeded rice-Conventional till wheat-*Sesbania* incorporation (DSR-CTW-ZTS); Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue removed) (ZTR-ZTW-ZTS); and Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue retained) (ZTR+R-ZTW+R-ZTS)

Table 2: Soil organic carbon stock as influenced by establishment methods and weed management practices in rice-wheat system after harvest at different soil depths during two years (2015 to 2017)

Treatment	Organic carbon stock (t/ha)							
	0-15 cm				15-30 cm			
	After rice harvest		After wheat harvest		After rice harvest		After wheat harvest	
	2015	2016	2015-16	2016-17	2015	2016	2015-16	2016-17
Establishment Methods								
TPR-CTW	15.8	15.9	16.1	16.1	42.9	42.5	34.5	34.6
TPR-ZTW-ZTS	15.7	15.8	16.5	16.8	41.5	42.3	35.0	34.6
DSR-CTW-ZTS	17.8	17.6	15.7	15.8	39.8	39.8	34.0	34.0
ZTR-ZTW-ZTS	20.4	20.5	18.8	18.8	38.3	38.2	37.3	37.7
ZTR+R-ZTW+R-ZTS	20.0	20.1	19.4	19.3	37.2	37.5	37.5	37.7
SEm±	0.24	0.15	0.12	0.15	0.42	0.23	0.23	0.22
LSD (P=0.05)	1.0	0.6	0.5	0.6	1.8	1.0	1.0	0.9
Weed Management								
Bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat	17.2	17.4	16.8	16.9	37.8	30.0	35.1	35.0
IWM (bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat fb 1 HW at 45 DAS/DAT)	17.7	17.7	16.9	17.0	37.8	39.6	34.9	35.0
Weedy check	19.0	18.8	18.1	18.2	42.2	42.5	37.1	37.1
SEm±	0.35	0.14	0.24	0.12	0.64	0.43	0.23	0.32
LSD (P=0.05)	1.1	0.4	0.7	0.4	2.0	1.3	0.7	1.0

Transplanted rice-Conventional till wheat (TPR-CTW); Transplanted rice-Zero till wheat-*Sesbania* green manuring (TPR-ZTW-ZTS); Direct seeded rice-Conventional till wheat-*Sesbania* incorporation (DSR-CTW-ZTS); Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue removed) (ZTR-ZTW-ZTS); and Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue retained) (ZTR+R-ZTW+R-ZTS)

Discussion

Results on soil organic carbon and its stock revealed that maximum was recorded under zero till rice and wheat with retention of residues followed by *Sesbania* brown manuring during both the years of study at 0-15 cm soil depth (Table 1 and 2). This might be due to zero tillage which enhances organic carbon content (Gosai *et al*., 2009; Ghosh *et al*., 2010 and Punia *et al*., 2016) [12, 9, 22]. Also, some improvement in organic C was reported with retained residue on soil surface with ZT (Neugschwandtner *et al.,* 2014 and Islam *et al.,* 2015) [19, 13], as conventional till plots recorded lower values of organic matter due to the inversion of top soil during ploughing which shifts less fertile subsoil to the surface in addition to possible leaching reported by Ali *et al.* (2006) [1]. However, at 15-30 cm, higher stock of soil organic carbon was recorded with TPR with as well as without *Sesbania* as green manure as it is a function of soil organic carbon and bulk density (Table 2). While, in wheat, zero till rice and wheat with retention of residues followed by *Sesbania* brown manuring recorded higher stock of soil organic carbon under sub surface condition also (Table 1). The organic matter decreased with increasing tillage at all depths (Roldán *et al.*, 2004) [23]. Soil organic carbon concentration was significantly better under conservation tillage than CT (Gianessi, 2013 and Busari *et al.,* 2015) [10, 5]. No till reduces soil disturbance, improve SOC maintenance and benefits soil quality (Bhattacharyya *et al.,* 2006 and Kahlon and Singh, 2014) [4, 16].

Among weed management practices, the results of soil organic carbon and stock at different depths after the harvest of rice and wheat revealed that weedy check recorded highest organic carbon content with stock during both the years (Table 1 and 2). This might be due to more weeds which results in high underground biomass and increase the organic carbon content and stock with this treatment.

Conclusion

Based on the two years study, it can be concluded that zero till practice and weedy condition considerably improved the soil health by increasing the organic carbon and stocking it in the soil as retention of residues and its decomposition into the soil leads to increase in the organic carbonic status of soil.

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