Biological Forum – An International Journal **14(1): 1103-1110(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Influence of Conservation Agriculture on Soil Microbial Indices Contributing to Soil Carbon Sequestration in Rice Crop

Bhagwan Singh Dhaked*, Geeta Singh and T.K. Das
Division of Microbiology, ICAR-Indian Agricultural Research Institute, New Delhi-12

(Corresponding author: Bhagwan Singh Dhaked)*

(Received 15 November 2021, Accepted 17 January, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: A long term (2008-2020) field experiment was conducted adopting various management approaches in a rice-wheat cropping system. The aim was to understand the impact of alternate tillage and agri -resource management on indices related to soil health namely the microbial biomass Carbon (SMBC), respiration and dehydrogenase enzyme activity. The treatment combinations applied were Zero-Tillage (ZT), Conventional tillage (CT) along with brown manure (BM), crop residues (CR), and moong bean (MB). Soil microbial parameters were studied from soil samples collected from two depth (0-15, 15-30cm) at the wheat flowering and harvest. ZT +CR had maximum soil respiration and minimum dehydrogenase activity. Dehydrogenase, was maximum in ZT +CR+BM. CTR – ZTW had higher SMBC. ZT had lower soil respiration, SMBC and higher dehydrogenase activity. ZT+BM had higher soil respiration, SMBC and lower dehydrogenase activity. ZT+CR had higher soil respiration. ZT+MB had higher soil respiration, SMBC and lower dehydrogenase activity. Soil respiration, beta-glucosidase had higher value at 15-30 cm soil depth than 0-15 cm soil depth. DHA, SMBC had higher value at 0-15 cm soil depth than 15-30 cm soil depth. Soil respiration, DHA, SMBC had higher value at flowering than at harvest.

Keywords: Conservation agriculture, Soil carbon sequestration, tillage, soil microbial indices.

INTRODUCTION

Agricultural sustainability, environmental quality and ultimately, plant, animal and human health, are determined by soil quality (Doran, 1980; Safley, 1999). Soil quality can be described as the integration of the physical, chemical and biological properties of the soil for productivity and environmental quality (Gugino *et al.*, 2009). The numbers, types, and activities of soil microorganisms are important to the productivity of soil through their regulatory effect on soil carbon (C) and nitrogen (N) levels. Soil microorganisms play integral roles in nutrient cycling, soil stabilization, and organic matter decomposition. Soil enzyme activities in particular are increasingly used as indicators of soil quality because of their relationship to decomposition and nutrient cycling, ease of measurement, and rapid response to changes in soil management (Dick, 1994; Dilly *et al.*, 2003). Soil microorganisms are important to agro-ecosystems and involved in key roles, such as soil aggregate formation, soil humus formation, nutrient cycling, decomposition of various compounds and other transformations (Zak *et al.*, 1994; Wu *et al.*, 2011). Dehydrogenases play a significant role in the biological oxidation of soil organic matter (OM) by transferring hydrogen from organic substrates to inorganic acceptors (Zhang *et al.*, 2010). Thus, DHA serves as an indicator of the microbiological redox-systems and could be considered a good and adequate measure of microbial oxidative activities in soil. Therefore, DHA reflects metabolic ability of the soil and its activity is considered to be proportional to the biomass of the microorganisms in soil. The amount of microbial biomass in soil affects the amount of enzymes in soil, which in turn affects the decomposition rates of the respective components of soil organic substances including the components of microbial bodies. With increasing global interest in climate change, there has been increasing interest in the potential for carbon (C) sequestration in agricultural soil. Soil is not only the basis of crop production but is also the key facilitator of C sequestration in terrestrial ecosystems.

The accumulation of SOC is considered to be the best choice for long-term C sequestration in the terrestrial ecosystem. Soil respiration is the CO_2 emission process and is the C flux between the atmosphere and terrestrial ecosystem; furthermore, cropland soil respiration (Rs) also plays an important role in CO_2 transportation.

Approximately 85% to 90% of SOC was decomposed by soil bacteria and soil fungi (Condron *et al.*, 2010). There is a positive correlation between DHA and OM content (Chodak and Niklińska, 2010; Moeskops *et al.*, 2010). Soil respiration is associated to carbon availability in biomass and increased amount of CO_2-C is released at upper layer in NT soil than plowed soil due to increased population and activity of soil microorganisms (Gajda *et al.*, 2013). Soil respiration was higher in conservation agriculture (CA) than in conventional tillage (CT), which indicates more microbial activity and increased mineralization of soil organic carbon for nutrient release (Edralin *et al.*, 2016). The rotation had higher soil carbon sequestration potential. However, the effect of rotations and straw retention on carbon sequestration required continued, long-term monitoring in cropping systems (Kong *et al.*, 2019).

The increase in the C retention in small and large macro-aggregates at top soil layer by reduced soil disturbance coupled with residue retention due to greater aggregate stability and reduced the emissions of CO_2 than conventional tillage without residues retention (Fuentes *et al.*, 2012). Soil microbial biomasses influence the conversion of SOM, and are critical for the cycle of nutrients and energy in the ecosystem (Merino, Pérez-Batallón, and Macías 2004). Thus, conservation tillage, along with some complimentary practices such as soil cover and crop diversity has emerged as a viable option to ensure sustainable food production and maintain environmental integrity. This implies that conservation tillage is a component of conservation agriculture (CA). CA is a method of managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. Crop management practices (tillage systems or cropping sequences) can affect soil health.M

MATERIAL AND METHODS

A. Study site

The long-term field experiment (2008-2020) was conducted at the research farm of the Indian Agricultural Research Institute, New Delhi, India. The experimental site is situated at 28.4° N and 77.1° E at an elevation of 228.6 m above mean sea level (Arabian Sea) New Delhi India. The region is a Trans-Gangetic Plains' agro-climate zone with a semi-arid and sub-tropical climate. The climate is characterized by hot and dry summers (41-48°C) and cold winters (3-7°C). The mean precipitation in the region (650 mm) is mainly received during July-September. The texture of fields oil is a sandy clay loam(typic Ustochrept) with 52.06% s and, 22.54% silt and 25.40% clay (Organic matter 1.25% and a pH 8.18).

Table 1: Soil physiochemical properties of the experimental field.

Property value	
A. Mechanical composition	
1. Sand(%)	52.06
2. Silt(%)	22.54
3. Clay(%)	25.40
Textural class	Sandy clay loam
B. Chemical composition and physical properties	
1. pH(1:2.5 soil: water ratio)	8.16
2. Electrical conductivity (dSm21258C)	0.79
3. Cation exchange capacity (C.molkg 21 soil)	14.73
4. Organic C (gkg21 soil)	5.20
5. Total Kjeldahl N (mgkg21 soil)	580
6. 0.5M $NaHCO_3$ extractable P (mg/kg soil)	8.42
7. Neutral 1NNH_4OAC extractable K(mg /kgsoil)	187
8. Bulk density (Mg /m^3)	1.50
9. Field capacity at 1/3 atmospheric tension (%)	24.57

The experimental field was laser-levelled during September 2018. A uniformity trial on wheat was under taken during winter 2018–20 to ensure uniform soil fertility in the entire field. Finally, the experiment was started during monsoon 2018. Eleven treatments (Table1) were laid out in a completely randomized block design. The individual plot size was 14.0 m × 9.0 m. Crop management : Rice hybrid PRH 10 and wheat cv. HD 2895were used in all plots.

Treatments:

1. ZT100%N,
2. ZT100%N+BM,
3. ZT100%N+CR,
4. ZT100%N+CR+BM,
5. ZT100%N+MB,
6. ZT100%N+MB+CR,
7. CTR–ZTW100%N and
8. CT100%N. ZTDSR

Zero till direct seeded rice, ZTW = Zero till wheat, CTW: Conventional till wheat, Brown manuring: Brown manuring of *Sesbania*, TPR: Transplanted rice, Recommended dose of fertilizer nitrogen 120Kg/h; RDF=120N:60P:40K.

A. Collection of soil samples

Two sets of soil samples were collected from crop field at 2depths (0-15and15-30cm) with a core sampler (7.5cm diameter) according to treatments (11inwheat) in cropping system (Rice-Wheat) using a soil auger at two stages *viz.*, flowering and harvest. 1. Soilrespiration: Soil respiration was estimated by the standard protocol (Anderson and Domsch,1973). Soil enzyme dehydrogenase was determined according to Casida *et al.,* (1964). Microbial biomass carbon in each treatment was estimated according to fumigation extraction method (Powlson *et al.*,1987).

B. Collection of soil samples

Two sets of soil samples were collected from crop field at 2 depths (0-15 and 15-30cm) with acore sampler(7.5cm diameter) according to treatments (11 in wheat) in cropping system (Rice-Wheat) using a soil auger at two stages *viz*. flowering and harvest.

1. Soil respiration: Soil respiration was estimated by the standard protocol (Anderson and Domsch,1973). Soil enzyme dehydrogenase was determined according to Casida *et al.,* (1964). Microbial biomass carbon in each treatment was estimated according to fumigation extraction method (Powlson *et al.,*1987).

C. Soil respiration

Soil samples were collected at two soil depth (0-15 and 15-30 cm) at flowering and harvest from rice crop field. Weigh 100 gm fresh soil sample from different treatments and put it in 1 liter bottle. Pour 10 ml N/10 NaOH in test tube and put it in same bottle in slanting position containing soil samples and cap the bottle. Incubate the bottles for 24 hours. After incubation remove the each tubes one by one and add few drops of $BaCl_2$ in each tubes containing NaOH. The white precipitate of $BaCO_3$ was come. Then add few drops of Phenolphthalein indicator in white precipitate of $BaCO_3$. The pink color was developed after addition of Phenolphthalein indicator. Then titrate it with N/10 HCl till white ppt was come. Then note down the volume of HCl was consumed (Anderson and Domsch, 1973).

D. Soil microbial biomass carbon

Microbial biomass carbon in soil was determined by the chloroform fumigation and extractionmethod (Vance *et al*., 1987) for two soil depth (0-15 and 15-30 cm) at flowering and harvest from rice-wheat cropping system from different tillage treatments in rice crop. Organic biomass was measured on three replicate portions of moist soil, having two sets of fresh soil sample each containing 17.5 gm soil. The soil sample was exposed to $CHCl_3$ (1 ml) for 24 h, the fumigant was removed and the soil then extracted with 0.5 M K_2SO_4 (7.0 ml), a non-fumigated control was also extracted under the same conditions at the start of fumigation. Organic carbon (C) in the extracts are estimated by spectrophotometer (O.D 280 nm).

E. Soil dehydrogenase activity

Soil samples were obtained for two soil depth (surface, 0-15 and sub-surface, 15-30 cm) at flowering and harvest from rice-wheat cropping system from different tillage treatments (8 in rice). 1gm of fresh soil was taken in a screw-cape test tube. The soil was then mixed with pinch of calcium carbonate ($CaCO_3$) and 1 ml of 3 % TTC solution. The mixture was then shaken and plugged with a rubber stopper and incubated at 37° C for 24 hours in an incubator. Three replicates were maintained in each case and blank also maintained without soil sample. Then add 10 ml of methanol to each tube, mix the content thoroughly. Incubate the tubes in dark for overnight. Filter the supernatant and the optical density of the red color filtrate was read at 485 nm on spectrophotometer, using a blank. The activity was representing in terms of concentration of Formazan, which was calculated by a standard curve of triphenyl formazan in methanol. Dehydrogenase activity per gram dry soil was expressed in terms of milligram formazan per gram dry soil per hour.

RESULTS AND DISCUSSION

A. Soil respiration in rice crop

ZT +CR had significantly higher soil respiration (4.61±1.88 $\mu mol^{-1} m^{-2} s^{-1}$ than ZT and CT (132.82% higher than ZT and 48.70% higher than CT). ZT had significantly lower (56.56%) soil respiration than CT. ZT+BM had significantly higher (132.32%) soil respiration than without BM. ZT+CR had significantly higher (132.82%) soil respiration than without crop residue. ZT+MB had significantly higher (60.60%) soil respiration than without MB in crop rotation. Implying that the soils under ZT release lower amounts of carbon di oxide than the CT soils.

Table 2: Soil respiration (µmol/ms)in rice crop.

	Soil respiration (µmol/ms)			
	Soil depth (cm)			
	Soil respiration at flowering		**Soil respiration at harvest**	
Treatments	**0-15**	**15-30**	**0 -15**	**15-30**
ZT100%N	1.98 ± 1.01^{bc}	1.61 ± 0.78^{d}	1.16 ± 0.54^{c}	1.84 ± 1.01^{b}
ZT100%N +BM	1.90 ± 0.77^{bc}	4.60 ± 1.77^{a}	1.90 ± 0.77^{b}	1.61 ± 0.88^{bc}
ZT100%N +CR	3.65 ± 1.76^{a}	4.61 ± 1.88^{a}	2.12 ± 0.89^{b}	3.16 ± 1.49^{a}
ZT100%N +CR+BM	3.45 ± 0.67^{a}	2.30 ± 0.81^{cd}	0.71 ± 0.39^{cd}	0.46 ± 0.25^{d}
ZT100%N +MB	1.73 ± 0.86^{c}	3.18 ± 1.21^{bc}	0.99 ± 0.52^{cd}	1.14 ± 0.46^{bcd}
ZT100%N +MB +CR	0.94 ± 0.55^{d}	1.95 ± 1.10^{d}	0.47 ± 0.28^{d}	1.86 ± 0.95^{b}
CTR – ZTW 100%N	1.49 ± 0.82^{cd}	3.49 ± 1.36^{b}	0.46 ± 0.29^{d}	0.93 ± 0.52^{cd}
CT100%N	2.50 ± 0.85^{b}	0.46 ± 0.25^{e}	3.10 ± 1.23^{a}	0.46 ± 0.22^{d}
CD(0.01)	**0.891**	**1.301**	**0.804**	**1.06**

However, input of external sources like crop residue, brown manure or inclusion of legumes like moong bean significantly enhances the carbon di oxide release from these soils. Soil respiration had significantly higher value (48.70%) at 15-30 cm soil depth than 0-15 cm. Soil respiration had significantly higher value at flowering than at harvest.

We observed that, the value of soil respiration is ranged from 0.46±0.22μmol $m^{-2}s^{-1}$ to 4.61±1.88μmol$m^{-2}s^{-1}$ in rice crop. The growing of legume (mungbean) in ZT was significantly increased soil respiration than without MB in crop rotation in rice crop due to increased amount of nutrient and organic matter, resulting higher microbial activity. The crop residues (wheat, rice residues) in ZT increased the decomposable organic matter was showed significantly increased soil respiration than without crop residue in rice crop. The decreased amount of CO_2 evolution was found in ZT than CT in rice crop.

The mean soil respiration were more than 10 times greater in zero tillage with crop rotation because of variation in land utilization, tilled soil, cropping operations, soil fertilization and rainfall (Yang *et al.,* 2017). The wheat plus summer soybean (WS) rotation had lower mean soil respiration than from soils under the winter wheat with summer maize (WM), and / or summer fallow (WF) rotation during the growing seasons. A legume crop, soybeans, compared with maize had inferior activity of CO_2 evolution, and had capability to fix atomspheric nitrogen symbiotically reducing the requirement of nitrogen fertilization application. Therefore, growing soybeans allow farmers to consrve energy and lower release of greenhouse gas (GHG) (Kopkeand Nemecek, 2010).

Under lower rainfall conditions, total microbial biomass, bacterial abundance, soil organic carbon, soil respirstion are significantly reduced. The increased soil water filled pore space decreased soil respiration.Straw-return significantly promoted soil CO_2 emissions due to the abundance of carbon in the straw, releasing carbon in the putrefaction and decomposition processes of the straw. The promoting effect of straw-return on soil CO_2 emissions attributed to increased soil microorganisms because the respiration of soil microorganisms can promote soil CO_2 emissions (Wang *et al.,* 2003) indicating that the soil MB-C content affected by the activity of soil microorganisms. The increased soil moisture and soil temperature showed inhibiting effect of NT on soil CO_2 emissions. The soil CO_2 emission rate was positively and significantly correlated with soil temperature and negatively and significantly correlated with soil moisture. However, there were no significant correlation between soil CO_2 emissions and soil MB-C content. These results indicate that tillage and straw-returning affected soil CO_2 emission by regulating the temperature and moisture of the soil.

In our study, we observed that soil depth affect the microbial activity at surface soil due to higher organic matter, resulting increase soil respiration and decreasing trend with increasing soil depth due to the reduction in soil aeration in deeper layer. We found that soil respiration showed significantly higher value at surface soil than 15-30 cm (sub-surface) in wheat crop. The soil respiration was showed increased amount of soil CO_2 flux at sub-surface than surface in rice crop.

Microbial biomass does not provide information on microbial activity. The microbial biomass turnover, such as soil respiration (SR), reflected the availability of carbon for microbial maintenance. SR measure the total activity of the soil microbial community affected by nutrient management and its interaction with the cropping system.

The significantly increased soil respiration was found in ZT with BM than without BM in rice crop. However, input of organic nutrient sources significantly improved the SR activity. Leguminous crop fixes atmospheric nitrogen and improved the soil N status, lowering the C:N ratio. The organic amendments showed significant increase in SR. The addition of CR stimulated the soil CO_2 emission. The SR increased significantly by the residue incorporation and the effect was more apparent where the manure either singly or in combination with CR are applied (Singh *et al.,* 2015). In general, we found that the growth stages of crop significantly affect soil respiration due to higher activity of microbes at active phase (flowering) than other stages (harvest). Soil respiration was increased at flowering than crop harvest in wheat crop. Soil respiration was significantly increased at flowering than at harvest in rice crop. Similarly, the peak at sowing was induced by the soil tillage, and at the joint and grain filling stages by the soil temperature and soil moisture.

However, the low emissions in last sampling also due to the result of low temperatures. The temperature is a regulating factor for organic matter break down, with lower temperatures resulting in lower rates of decomposition (Aon *et al.,* 2001). The higher CO_2 emissions in the warmer months associated with root respiration, because plant growth are also much higher in those months. The annual crops root contributions to soil respiration are higher during the growing season but low during dormant periods. For cereals it has been estimated that about 16% of the C translocated to the roots is lost as respiration and exudates before flowering, and then decreased due to the increasing sink by reproductive organs (Jensen, 1994).

B. SMBC in rice crop

CTR – ZTW 100%N had significantly higher SMBC (2008.89±12.35 mg kg $soil^{-1}$ as compared to ZT and CT (404.74% higher than ZT and 110.18% higher than CT). ZT had significantly lower value (140.14%) of SMBC than CT. ZT +BM had significantly lower (40.54%) SMBC than without BM and higher value than CT. ZT +CR had significantly higher value (180.16%) SMBC than without CR.ZT +MB had significantly higher (24.91%) SMBC than without MB in crop rotation. SMBC had significantly higher (26.64%) value at 0-15 cm soil depth than 15-30 cm soil depth. SMBC had significantly higher at flowering than at harvest.

Table 3: SMBC (mg kg soil^{-1}) in rice crop.

	SMBC in rice (mg kg soil^{-1}) in rice			
Treatments	**Soil depth (cm)**			
	SMBC at flowering		**SMBC at harvest**	
	0-15	**15-30**	**0 -15**	**15-30**
ZT100%N	398±7.86^{e}	132.75±6.64^{g}	286.13±8.94^{d}	124.86±9.18^{f}
ZT100%N +BM	283.19±1081^{g}	53.10±10.81^{h}	198.37±10.09^{f}	45.89±9.62^{g}
ZT100%N +CR	1115.06±8.79^{b}	300.89±10.77^{e}	815.97±11.7^{b}	289.36±10.24^{d}
ZT100%N +CR+BM	787.62±19.43^{c}	380.54±11.31^{d}	529.46±10.78^{c}	284.36±9.24^{d}
T5 ZT100%N +MB	495.58±9.97^{d}	176.99±8.77^{f}	273.65±12.46^{de}	157.16±9.04^{e}
ZT100%N +MB +CR	353.99±7.31^{f}	407.09±9.76^{c}	258.24±10.27^{e}	389.43±10.94^{b}
CTR – ZTW 100%N	2008.89±12.35^{a}	1070.82±9.39^{a}	1586.25±12.07^{a}	726.19±10.22^{a}
CT100%N	292.04±10.83^{g}	955.77±11.16^{b}	154.37±6.14^{g}	365.49±11.73^{c}
CD(0.01)	**28.17**	**16.993**	**26.656**	**25.472**

The greater degree of biological activity was found soil under no-tillage due to the increased levels of the soluble C fractions. The positive correlationswas found between the soluble C fractions and microbial biomass. Soil respiration by CO_2 evolution reflected the SMBC, giving an estimate of microbial decomposition activities and carbon cycling in the soil (Doran and Parkin 1996).

The soil biological activity of microbial community in soil was characterized by bacteria to fungal ratio (B/F) ratio. The highest values of B/F ratio in soil under direct sowing (DS) and reduced tillage (RT), the lowest values in soil under conventional tillage was found. The higher values of B/F ratio indicate the weaker development of fungi population in soil, while the lower values suggest stronger development of fungi, as compared to bacteria population in soil.

The increased microbial biomass carbon (MBC) was found at increased soil organic matter (SOC) amount. The 94.8% variation of MBC due to SOC showing significant and positive correlation (Kandeler *et al.,* 2006; Mullen *et al.,* 1998 and Singh *et al.,* 2009). The elevated moisture content, increased soil aggregation, increased SOC and total nitrogen (TN) content, and lower disturbance, providing a balanced source of SOC and total nitrogen (TN) to maintain microbial community near soil surface, having increased microbial biomass carbon (MBC) and microbial biomass (N) under no tillage (NT) than permanent bed (PT).

Consistently, our data suggest that crop residues incorporations was also beneficial in ZT (ZT +CR) as a significant gain of SMBC content was observed over the ZT soils not receiving CR in wheat crop.The content of SMBC were ranged from 45.89±9.62 mg /kg soil to 2008.89±12.35 mg /kg soil in rice crop. Conventional transplanted rice-zero tillage wheat (CTR – ZTW) significantly show increased SMBC as compared to ZT and CT in rice crop. ZT had significantly lower value of SMBC than CT in rice crop. ZT +MB show significantly increased SMBC than without MB in crop rotation in rice crop. There were increased SMBC in ZT +CR than without CR in rice crop.

SMBC showed significantly increased value at flowering than at harvest in rice crop.Conventionally managed soil contained a smaller amount of microbial biomass C pool (about 20%) than RT soil. Microbial biomass C contents were smaller at 15-30 cm depth than at 0-15 cm depth in both CT and RT soil, by about 20% and 30%, respectively (Acosta-Martinez *et al.,* 2008; Bulluck *et al.,* 2002; Doran *et al.,* 1998; Liebig and Doran, 1999; Marinari *et al.,* 2006). The labile carbon (C) and nitrogen (N) decreased with increase in soil depth. The MBC is the most labile pools of organic matter and important reservoir of plant nutrients, such as N and P (Marumoto *et al.,* 1982). This enrichment was generally related with SOC and water soluble carbohydrates (WSC) contents (Garcia-Gil *et al.*, 2000), and these two parameters were positively correlated with the MBC.

The increased in microbial biomass carbon (MBC) and Microbial biomass nitrogen (MBC) are relay on increased in c associated inputs, residues maintenance, and reduced tillage (RT) (Wang *et al.,* 2012) under zero tillage-rice-wheat-mungbean (ZT-R-W-Mb) and zero tillage-maize-wheat-mungbean (ZT-M-W-Mb). Microbial diversity, density, and growth are affected due to the diverse type of crops provides diverse types of crop residues and secreting diverse root exudates. The tillage and crop rotations were significantly affected (MBC) at 0-30 cm soil layer.

CA practices had increased surface amount of soil organic matter (SOM) from accumulation of crop residues due to higher dissolved organic carbon (DOC) concentration on the surface from SOM decomposition and increased MBC which relayed on DOC in no tillage and minimum tillage (Melero *et al.,* 2009). The dissolved organic carbon (DOC) and MBC contents are significantly showed higher value in straw return than no straw return. (Wang *et al.,* 2016).

Crop straw Energy and nutrients are supplied for soil microbial growth (Breulmann *et al.,* 2014). The lignocellulose of crop straw are decomposed by actinomycetes by encouraging their growth in straw return (Tang *et al.,* 2014). Short term straw return allowed the bacteria to grow faster than gungi, thus fungal abudance are changes slowly. (Zhang *et al.,* 2013). The SMBC rised with reduction in soil depth (at 0-90 cm soil depth) due to the presence of more amount of microbial biomass and organic matter contents. We found that, soil depth influenced the SMBC content, with higher biomass content in the top soils due to higher organic matter inputs than the sub soil in wheat crop. The higher value of SMBC was significantly found at 0-15 cm soil depth than 15-30 cm soil depth in rice.

At 0-5 cm soil layer, MBC and MBN were significantly increased than 5-15 and 15-25 cm layers under no tillage. As occurred with SOC, MBC decreased with soil depth (Madejon *et al.,* 2007). At 0-5 cm soil layer, the increased MBC of bulk soil, >0.25 mm aggregates, and <0.25 mm aggregates are found due to the increased organic matter and improved environmental conditions for soil microbial community (Zhang *et al.,* 2013). In our study, a positive effect of brown manure input in ZT soils (ZT +BM) was observed on SMBC by recording an increase over the ZT soils without BM in wheat. We observed that brown manure input in ZT soils was significantly decreased SMBC than without BM in rice crop. In general, two legumes (chickpea and sesbania) in conservation agriculture, zero tillage-maize-chickpea-soybean (ZT-M-C-S) increased SOC, with increased microorganism actions and microbial biomass carbon (MBC). The different microbial activities are found in the different constitution of lignin and carbon ratio (C:N ratio) (cereals, oilseeds and legumes) (showed different microbial activities

C. Soil Dehydrogenase activity during rice crop growth

Dehydrogenase was significantly high and the maximum in ZT +CR+BM (30.05±4.88ugTPF/g soil/24 hours) as compared to CT and ZT (10.11% higher than ZT and 43.91% higher than CT). ZT had significantly higher value (30.69%) of dehydrogenase activity than CT. ZT + BM had significantly lower (21.88%) dehydrogenase activity than without BM. ZT +CR had significantly lower value (31.26%) of dehydrogenase activity than without CR. ZT + MB had significantly lower (2.40%) dehydrogenase activity than without MB in crop rotation. This indicates that DHA had significantly higher value (5.04%) at 0-15 cm soil depth than 15-30 cm soil depth and. DHA had significantly higher value at flowering at harvest.

Dehydrogenase was significantly high and the maximum in ZT + CR + BM as compared to CT and ZT in rice crop. ZT + CR had significantly lower value of dehydrogenase activity than without CR in rice crop. BM in ZT had significantly higher dehydrogenase activity than without BM in wheat crop. ZT + BM had significantly lower dehydrogenase activity than without BM in rice crop. Tillage practices had significant effect on DHA, conservation tillage improved (13-17%) the dehydrogenase activity, while conventional tillage decreased the dehydrogenase activity and (total organic carbon) TOC and total nitrogen N (Roldan *et al.,* 2005). The dehydrogenase (DHA) had increased (9.11) activity in ZT than CT in the rhizosphere soil. (Bastida *et al.,* 2006; Melero *et al.,* 2008; Truu *et al.,* 2008). The increased activity of DHA was significantly found at suface soil soil than sub-surface soil in rice crop. Similarly, the tillage practices affect the dehydrogenase activity at all depths.

Table 4: Dehydrogenase in rice (ugTPF/g soil/24 hours.

	Dehydrogenase in rice (ugTPF/g soil/24 hours			
Treatments	**Soil depth (cm)**			
	DHA at flowering		**DHA at harvest**	
	0-15	**15-30**	**0 -15**	**15-30**
ZT100%N	**27.29±4.59**^{b}	21.26±3.07	15.40±3.17d^{e}	10.20±2.82^{bc}
ZT100%N +BM	**22.39±4.22**^{d}	21.07±4.86	13.51±3.14^{f}	9.17±2.74^{bc}
ZT100%N +CR	**20.79±4.41** ^{e}	17.39±3.22	12.66±3.43^{f}	7.46±2.28^{c}
ZT100%N +CR+BM	**30.05±4.88** ^{a}	**22.11±3.73**	**25.98±4.77**^{a}	14.74±3.37^{a}
T5 ZT100%N +MB	**26.65±5.28** ^{c}	16.63±3.21	20.13±4.35^{b}	11.72±3.49^{ab}
ZT100%N +MB +CR	21.07±3.79 ^{e}	19.84±4.49	17.86±4.68^{c}	**15.31±2.92**^{a}
CTR – ZTW 100%N	21.54±4.87 ^{e}	17.67±3.46	16.54±4.57^{d}	10.68±3.35^{bc}
CT100%N	**20.88±4.71** ^{e}	18.52±4.35	14.74±4.46^{e}	8.41±2.73^{bc}
CD(0.01)	**1.119**	**NS**	**1.707**	**5.083**
CV		**15.336**		

Conservation tillage had increased enzyme activities in the surface soil (1-10 cm soil depth) due to reduced soil disturbance than conventional tillage (CT). The dehydrogenase activities increased (10 to 190%) at 0 to 7.5 cm soil depth in no-till systems than conventional systems. The DHA activity decreased (2-3 times) at the lower layer (15-30 cm) than the upper soil. The Decreased DHA activity of soil with soil depth due to the increased total organic carbon (TOC) of the top soil, showing positive correlations between TOC and dehydrogenase activity (Doran, 1980; Dick, 1984).

In our study, the rotation with legume (mungbean) in rice-wheat cropping system influenced the DHA activity due to the residue and nutrient availability for succeeding crop. ZT +MB show significantly decreased dehydrogenase activity than without MB in crop rotation in rice crop. The interactions of tillage and crop rotations affect the soil DHA activity at top soil layer. The DHA had stable soil health and increased microbial activity. The 84.0% variation in the DHA due to MBC (Madejon *et al.,* 2007; Tao *et al.,* 2009). DHA value varied from 77.07 to 122.35 µg TPF g^{-1} day^{-1} at surface layer for conventional tillage (CT), reduced tillage (RT) and no tillage (NT). The difference in DHA activity among no tillage (NT) and/or reduced tillage (RT) soil andtraditional tillage (TT) soil are due to either a positive effect (organic fertilizers) or a negative effect (inorganic fertilization) applied mostly into soil under conservation tillage system.

We found that the growth stages during growing period had significant effect on DHA activity at flowering stage. We reported that the active phase of crop, flowering recorded higher magnitude of DHA relative to the wheat harvest. DHA had significantly higher value at flowering than at harvest in rice crop. Soil microbial communities in agro-ecosystems affected by seasonal changes (Schloter *et al.*, 2003). The seasonal variation of biochemical parameters used as indicators of soil responses to specific treatments. The active carbon (AC), water stable carbon (WSC), DHA did not showed a seasonal pattern due to input of available carbon sourcesat flowering and crop harvest, through root exudates and root and crop residues in the soil after harvest (Feng *et al.*, 2003).

SUMMERY AND CONCLUSION

Soil microbial parameters were studied from soil samples collected from two depth (0-15, 15- 30cm) at the wheat flowering and harvest. ZT +CR had maximum soil respiration and minimum dehydrogenase activity. Dehydrogenase, was maximum in ZT +CR+BM. CTR – ZTW had higher SMBC. ZT had lower soil respiration, SMBC and higher dehydrogenase activity. ZT+BM had higher soil respiration, SMBC and lower dehydrogenase activity. ZT+CR had higher soil respiration. ZT+MB had higher soil respiration, SMBC and lower dehydrogenase activity. Soil respiration, beta-glucosidase had higher value at 15-30 cm soil depth than 0-15 cm soil depth. DHA, SMBC had higher value at 0-15 cm soil depth than 15-30 cm soil depth. Soil respiration, DHA, SMBC had higher value at flowering than at harvest.

Acknowledgement. The author wishes to thank the ICAR-Indian Agricultural Research Institute (IARI) for all the support during research as well as the facility to carry out the experimental work.

Conflict of Interest: None.

REFERENCES

Acosta-Martinez, V., Acosta-Mercado, D. I. M. A. R. I. S., Sotomayor-Ramirez, D. & Cruz-Rodríguez, L. (2008). Microbial communities and enzymatic activities under different management in semiarid soils. *Applied Soil Ecology*, *38*(3): 249-260.

Anderson, J. P. E., & Domsch, K. H. (1973). Quantification of bacterial and fungal contributions to soil respiration. *Archiv für Mikrobiologie*, *93*(2): 113-127.

Aon, M. A., Sarena, D. E., Burgos, J. L. & Cortassa, S. (2001). (Micro) biological, chemical and physical properties of soils subjected to conventional or no-till management: an assessment of their quality status. *Soil and Tillage Research*, *60*(3-4): 173-186.

Bastida, F., Moreno, J. L., Hernandez, T. & García, C. (2006). Microbiological activity in a soil 15 years after its devegetation. *Soil Biology and Biochemistry*, *38*(8): 2503-2507.

Breulmann, M., Masyutenko, N. P., Kogut, B. M., Schroll, R., Dörfler, U., Buscot, F. & Schulz, E. (2014). Short-term bioavailability of carbon in soil organic matter fractions of different particle sizes and densities in grassland ecosystems. *Science of the total environment*, *497*: 29-37.

BulluckIii, L. R., Brosius, M., Evanylo, G. K. & Ristaino, J. B. (2002). Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Applied soil ecology*, *19*(2): 147-160.

Casida Jr, L. E., Klein, D. A. & Santoro, T. (1964). Soil dehydrogenase activity. *Soil science*, *98*(6): 371-376.

Chodak, M. & Niklińska, M. (2010). Effect of texture and tree species on microbial properties of mine soils. *Applied Soil Ecology*, *46*(2), 268-275.

Condron, L., Stark, C., O'Callaghan, M., Clinton, P. & Huang, Z. (2010). The role of microbial communities in the formation and decomposition of soil organic matter. *In Soil microbiology and sustainable crop production* 81-118.

Dick, R. P. (1994). Soil enzyme activities as indicators of soil quality. *Defining soil quality for a sustainable environment*, *35*: 107-124.

Dick, W. A. (1984). Influence of long-term tillage and crop rotation combinations on soil enzyme activities. *Soil Science Society of America Journal*, *48*(3): 569-574.

Dilly, O., Blume, H. P., Sehy, U., Jimenez, M. & Munch, J. C. (2003). Variation of stabilised, microbial and biologically active carbon and nitrogen in soil under contrasting land use and agricultural management practices. *Chemosphere*, *52*(3): 557-569.

Doran, J. W. (1980). Soil microbial and biochemical changes associated with reduced tillage. *Soil Science Society of America Journal*, *44*(4): 765-771.

Doran, J. W. & Parkin, T. B. (1996). Defining and assessing soil quality. *Defining soil quality for a sustainable environment*, *35*: 1-21.

Doran, J. W., Elliott, E. T. & Paustian, K. (1998). Soil microbial activity, nitrogen cycling, and long-term changes in organic carbon pools as related to fallow tillage management. *Soil and Tillage Research*, *49*(1-2): 3-18.

Edralin, D. I. A., Sigua, G. C. & Reyes, M. R. (2016). Dynamics of soil carbon, nitrogen and soil respiration in farmer's field with conservation agriculture, Siem Reap, Cambodia. *International Journal of Plant & Soil Science*, 1-13.

Feng, Y., Motta, A. C., Reeves, D. W., Burmester, C. H., Van Santen, E. & Osborne, J. A. (2003). Soil microbial communities under conventional-till and no-till continuous cotton systems. *Soil Biology and Biochemistry*, *35*(12): 1693-1703.

Fuentes, M., Hidalgo, C., Etchevers, J., De Leon, F., Guerrero, A., Dendooven, L. & Govaerts, B. (2012). Conservation agriculture, increased organic carbon in the top-soil macro-aggregates and reduced soil CO_2 emissions. *Plant and Soil*,*355*(1): 183-197.

Gajda, A. M., Przewloka, B. & Gawryjolek, K. (2013). Changes in soil quality associated with tillage system applied. *International Agrophysics*, *27*(2).

Garcıa-Gil, J. C., Plaza, C., Soler-Rovira, P. & Polo, A. (2002). Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. *Soil Biology and biochemistry*, *32*(13): 1907-1913.

Gugino, B. K., Abawi, G. S., Idowu, O. J., Schindelbeck, R. R., Smith, L. L., Thies, J. E. & Van Es, H. M. (2009). Cornell soil health assessment training manual. Cornell University College of Agriculture and Life Sciences

Janzen, H. H., Campbell, C. A., Brandt, S. A., Lafond, G. P. & Townley-Smith, L. (1994). Light-fraction organic matter in soils from long-term crop rotations. *Soil Science Society of America Journal*, *56*(6): 1799-1806.

Kandeler, E., Mosier, A. R., Morgan, J. A., Milchunas, D. G., King, J. Y., Rudolph, S. & Tscherko, D. (2006). Response of soil microbial biomass and enzyme activities to the transient elevation of carbon dioxide in a semi-arid grassland. *Soil Biology and Biochemistry*, *38*(8): 2448-2460.

Kong, D., Liu, N., Wang, W., Akhtar, K., Li, N., Ren, G. & Yang, G. (2019). Soil respiration from fields under three crop rotation treatments and three straw retention treatments. *PloS one*, *14*(9): e0219253.

Kopke, U. & Nemecek, T. (2010). Ecological services of faba bean. *Field crops research*, *115*(3):217-233.

Liebig, M. A., & Doran, J. W. (1999). Impact of organic production practices on soil quality indicators.

Madejon, E., Moreno, F., Murillo, J. M. & Pelegrin, F. (2007). Soil biochemical response to long-term conservation tillage under semi-arid Mediterranean conditions. *Soil and Tillage Research*, *94*(2): 346-352.

Marinari, S., Mancinelli, R., Campiglia, E. & Grego, S. (2006). Chemical and biological indicators of soil quality in organic and conventional farming systems in Central Italy. *Ecological Indicators*, *6*(4): 701-711.

Marumoto, T., Anderson, J. P. E. & Domsch, K. H. (1982). Mineralization of nutrients from soil microbial biomass. *Soil Biology and Biochemistry*, *14*(5): 469-475.

Melero, S., Lopez-Garrido, R., Murillo, J. M. & Moreno, F. (2009). Conservation tillage: Short-and long-term effects on soil carbon fractions and enzymatic activities under Mediterranean conditions. *Soil and Tillage Research*, *104*(2): 292-298.

Melero, S., Vanderlinden, K., Ruiz, J. C. & Madejon, E. (2008). Long-term effect on soil biochemical status of a Vertisol under conservation tillage system in semi-arid Mediterranean conditions. *European journal of soil biology*, *44*(4): 437-442.

Merino, A., Perez-Batallin, P. & Macıias, F. (2004). Responses of soil organic matter and greenhouse gas fluxes to soil management and land use changes in a humid temperate region of southern Europe. *Soil Biology and Biochemistry*, *36*(6): 917-925.

Moeskops, B., Buchan, D., Sleutel, S., Herawaty, L., Husen, E., Saraswati, R.& De Neve, S. (2010). Soil microbial communities and activities under intensive organic and conventional vegetable farming in West Java, Indonesia. *Applied Soil Ecology*, *45*(2): 112-120.

Mullen, M. D., Melhorn, C. G., Tyler, D. D. & Duck, B. N. (1998). Biological and biochemical soil properties in no-till corn with different cover crops. *Journal of Soil and Water Conservation*, *53*(3): 219-224.

Powlson, D. S., Prookes, P. C. & Christensen, B. T. (1987). Measurement of soil microbial biomass provides an early indication of changes in total soil organic matter due to straw incorporation. *Soil biology and biochemistry*, *19*(2): 159-164.

Roldan, A., Salinas-Garcia, J. R., Alguacil, M. M., Diaz, E. & Caravaca, F. (2005). Soil enzyme activities suggest advantages of conservation tillage practices in sorghum cultivation under subtropical conditions. *Geoderma*, *129*(3-4): 178-185.

Safley, M. (1999). Defining and assessing soil health and sustainable productivity. *Biological indicators of soil health*, 1-28.

Schloter, M., Dilly, O. & Munch, J. C. (2003). Indicators for evaluating soil quality. *Agriculture, Ecosystems & Environment*, *98*(1-3): 255-262.

Singh, G., Marwaha, T. S. & Dinesh, K. (2009). Effect of resource-conserving techniques on soilmicrobiological parameters under long-term maize *(Zea mays*)-wheat (*Triticum aestivum)* crop rotation. *Indian Journal of Agricultural Sciences*, *79*(2): 94-100.

Singh, G., Kumar, D. & Sharma, P. (2015). Effect of organics, biofertilizers and crop residue application on soil microbial activity in rice–wheat and rice-wheat mungbean cropping systems in the Indo-Gangetic plains. *Cogent Geoscience*, *1*(1): 1085296.

Tang, H. M., Xiao, X. P., Tang, W. G., Wang, K., Sun, J. M., Li, W. Y. & Yang, G. L. (2014). Effects of winter cover crops straws incorporation on CH4 and N2O emission from double-cropping paddy fields in southern China. *PLoS One*, *9*(10): e108322.

Tao, J., Griffiths, B., Zhang, S., Chen, X., Liu, M., Hu, F. & Li, H. (2009). Effects of earthworms on soil enzyme activity in an organic residue amended rice–wheat rotation agro-ecosystem. *Applied Soil Ecology*, *42*(3): 221-226.

Truu, M., Truu, J. & Ivask, M. (2008). Soil microbiological and biochemical properties for assessing the effect of agricultural management practices in Estonian cultivated soils. *European Journal of soil biology*, *44*(2): 231-237.

Vance, E. D., Brookes, P. C. & Jenkinson, D. S. (1987). An extraction method for measuring soil microbial biomass C. *Soil biology and Biochemistry*, *19*(6): 703-707.

Wang, W. J., Dalal, R. C., Moody, P. W. & Smith, C. J. (2003). Relationships of soil respiration to microbial biomass, substrate availability and clay content. *Soil biology and biochemistry*, *35*(2): 273-284.

Wang, X., Yang, G., Feng, Y., Ren, G. & Han, X. (2012). Optimizing feeding composition and carbon–nitrogen ratios for improved methane yield during anaerobic co-digestion of dairy, chicken manure and wheat straw. *Bioresource technology*, *120*: 78-83.

Wu, J., Liu, Z., Chen, D., Huang, G., Zhou, L. & Fu, S. (2011). Understory plants can make substantial contributions to soil respiration: Evidence from two subtropical plantations. *Soil Biology and Biochemistry*, *43*(11): 2355-2357.

Yang, S., Xu, Z., Wang, R., Zhang, Y., Yao, F., Zhang, Y. & Li, H. (2017). Variations in soil microbial community composition and enzymatic activities in response to increased N deposition and precipitation in Inner Mongolian grassland. *Applied Soil Ecology*, *119*: 275-285.

Zak, J. C., Willig, M. R., Moorhead, D. L. & Wildman, H. G. (1994). Functional diversity of microbial communities: a quantitative approach. *Soil Biology and Biochemistry*, *26*(9): 1101-1108.

Zhang, S., Li, Q., Lu, Y., Zhang, X. & Liang, W. (2013). Contributions of soil biota to C sequestration varied with aggregate fractions under different tillage systems. *Soil Biology and Biochemistry*, *62*: 147-156.

Zhang, Y. L., Chen, L. J., Chen, Z. H., Sun, C. X., Wu, Z. J. & Tang, X. H. (2010). Soil nutrient contents and enzymatic characteristics as affected by 7-year no tillage under maize cropping in a meadow brown soil. *Revista de la ciencia del suelo y nutrición vegetal*, *10*(2): 150-157.

How to cite this article: Bhagwan Singh Dhaked, Geeta Singh and T.K. Das (2022). Influence of Conservation Agriculture on Soil Microbial Indices Contributing to Soil Carbon Sequestration in Rice Crop. *Biological Forum – An International Journal*, *14*(1): 1103-1110.