

Original Research Article

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Conservation of Agriculture in the Western Indo-Gangetic Plains' Irrigated Cotton–Wheat and Guar-Wheat System

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ABSTRACT

Conserving natural capital and optimizing factor productivity in semi-arid regions has been a great challenge in achieving sustainability of the production system. Cotton-wheat and guar-wheat based cropping system plays a predominant role under evolving climatic scenarios by sustainable conservation of natural resources. In the present study, the effect of long-term zero-tillage practices on selected physico-chemical and microbiological properties was determined in different cropping system at 0-15 and 15-30 cm soil depth in Mahendergarh (Tigra) district of Haryana (latitude- 28.03⁰N and longitude- 76.10⁰E) during the year 2006. The composition of soil samples from traditional and zero-tillage farms had been sandy. After harvesting of wheat in 2017, triplicate soil samples from undisturbed and disturbed soil were obtained for determination of pH, electrical conductivity (EC), soil organic carbon (SOC), total N, P and K content, microbial biomass carbon and nitrogen (MBC and MBN), enzymatic activities and viable count of microbes and results showed that EC and pH were not significantly affected by tillage systems. Results indicated that SOC (0.31 %) under ZT was relatively higher at the surface layer compared to CT (0.28 %) under guar-wheat cropping system. The long-term zero-tillage practices resulted that relatively higher soil total nitrogen, phosphorous and potassium contents, MBC and MBN dehydrogenase, alkaline phosphatase, cellulase and urease activities and bacterial and fungal count at the 0-15 cm depth than conventional tillage under guar-wheat cropping pattern. The zero-tillage practices thus enhanced soil's physico-chemical as well as microbiological properties, which can contribute to increased crop yield and soil health. Hence, Haryana's growing system of cotton-wheat and guar-wheat under irrigated conditions in this area due to its potential for increased production, competitiveness and resource conservation.

Keywords

Crop-rotation, Microbiological properties, Soil health and Zero-tillage

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Introduction

Wheat (*Triticum aestivum* (L.) and other crops are grown sequentially on approximately 2.5 M ha in irrigated, double crop pattern in the state of Haryana (North-

West India). The annual sequences of rotation used are cotton (*Gossypieae*)–wheat (*Triticum aestivum* (L.) in the western part of the state and cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.)–wheat (*Triticum aestivum* L.) in the SW regions of Haryana. Cotton-wheat

cropping system is South Asia's second most effective wheat-based system (4.5 M ha) and India (2.6 M ha) and contributes significantly to food security in the region (Das *et al.*, 2014). Cotton, an important fiber crop, is grown throughout India on an area of 9.5 million hectares (M ha) under both rainfed and irrigated conditions (Mayee *et al.*, 2008). Wheat is grown on 29 M ha and meets a number of people's dietary requirements. Both of these crops contribute to the subsistence of a significant number of Indians. Developing short-term early maturing cotton varieties and increasing irrigation facilities has led to the cultivation of a cotton-wheat rotation system in northwestern India. Therefore, the cotton-wheat cropping method in the states of Punjab, Haryana and Rajasthan occupies approximately 1.7 M ha (Monga *et al.*, 2009) but cotton production has shown a declining trend in recent years (Mayee *et al.*, 2008).

Cluster bean, known locally as guar, is an important legume cash crop, and is grown as an industrial crop particularly in India's semi-arid and arid regions, because of its seeds (guar gum) containing gelling agent, guar cultivation is now gaining ground for a few days, thus having significant industrial use. This crop is a source of nutrient replenishment, particularly nitrogen from soils with low fertility and can withstand the stress of moisture.

Wheat is the most important strategic cereal crop cultivated during the rabi season following semi-arid harvesting of cluster bean. Although these crops are grown under improved irrigation practices coupled with better crop management practices, over the years, the productivity of individual factors has declined (Rajanna *et al.*, 2016).

Water is an abundant natural resource and a gift from the god to sustain all life forms, food production, economic growth and

general well-being. To feed ever-increasing population coupled with scarcity and steady reduction in the share of agricultural water. The only one option is to produce more food per unit of water available (Abdin and Salem, 2009). In future, due to competing demands for non-agricultural sectors, the share of water in agriculture will be further reduced by 2050 to approximately 72 to 75 per cent (IWMI, 2002). From which, by non-process depletion, about 52 per cent of the water used by agricultural crops and the remaining 48 per cent is lost.

Minimizing these losses would improve water efficiency considerably through efficient technologies and strategies. Over-exploitation and inadequate groundwater management in many parts of the region has contributed to reduced water level and adverse impacts on the climate. Many persistent problems in the area are the deterioration of land quality due to various types of soil degradation and excess residue burning (Bhattacharyya *et al.*, 2013a,b; Das *et al.*, 2013). Potential resource management technique (RCTs) such as zero tillage, minimal tillage and furrow irrigated raised bed planting (FIRB) which can play a major role in saving scarce natural resources such as water (Hari *et al.*, 2010).

These factors contribute to consideration of agriculture (CA) conservation for sustained production, profitability and soil quality (Kassam *et al.*, 2011). Conservation agriculture has the following four principles: (i) reducing mechanical soil disruption and seeding directly into tilled soil to enhance the quality and health of soil organic matter (SOM); (ii) enhancing the use of SOM to cover crops and/or crop residues (mainly residue retention) (iii) crop diversification in partnerships, sequences and rotations to improve system resilience and (iv) regulated soil compaction traffic. Generally speaking, the benefits of zero tillage derive from the

three main principles: decreased soil disturbance, enhanced soil cover from crop residues and increased diversity of species by crop rotation (Taroll *et al.*, 2019). The improvement of the chemical and microbiological properties of soil such as SOC, total N, P and K, enzymatic activities and microbial counts under zero tillage therefore obey these principles (Pareja-Sanchez *et al.*, 2017).

CA technologies involving zero-tillage practices, residue management advances (mainly residue retention) to avoid straw burning and crop diversification have potential to increase productivity and soil quality, primarily through SOM build-up (Bhattacharyya *et al.*, 2013a,b). Soil organic carbon is an indicator of soil quality and gives soil matrix structural stability. Under the traditional tillage (CT) method, however, the rate of buildup and potential depletion is significantly reduced (Omara *et al.*, 2017 and 2019). Thus, CA enhances soil organic carbon (SOC) quality, increases efficiency in input usage and has the potential to minimize greenhouse gas emissions (Bhattacharyya *et al.*, 2012 a, b).

The goal of this study was therefore to determine the change in the physico-chemical and microbiological properties associated with the conversion from conventional tillage to zero tillage.

Materials and Methods

Site and preparation of soil samples

An experiment on the cotton–wheat and guar-wheat cropping system was conducted during 2018 at the research farm of Tigra in Mahendergarh (latitude 28.03°N and longitude 76.10°E) after the harvesting of wheat and experimental trials initiated in 2006 to assess the impact of different tillage

systems under different crop rotations in Mahendergarh.

The collected soil samples were screened for specific analysis via 2 mm sieve and stored at $4\pm 1^{\circ}\text{C}$. In order to establish microbial biomass and microbial activity, the soil was moistened to 60% water holding capacity (WHC) and incubated for 10 days at 30°C to enable uniform rewetting and to enable microbial activity to stabilize after initial disturbances.

Analytical methods:

Soil texture

The texture class of the soil was calculated using the textural triangle suggested by the International Society of Soil Sciences (ISSS) from the relative proportion of fractions of sand, silt and clay in the sample.

Soil pH and Electrical Conductivity (EC)

Five-gram soil was combined with 12.5 ml distilled water to test the pH and EC of different soil samples. It was shaken for 30 minutes and the pH of soil suspension was measured with Systronics 331 pH meter at room temperature, and EC was measured with Naina electrical conductivity meter.

Soil organic carbon

The organic carbon content in different soil samples was determined by the method of Kalemossa and Jenkinson (1973).

Total N, P and K

Total nitrogen, phosphorous and potassium content in different soil samples was estimated by Kjeldhal's method (Bremner and Mulvaney, 1982), John (1970) and Knudsen *et al.*, (1982).

Microbial biomass carbon and nitrogen

Microbial biomass carbon was estimated by method described by Vance *et al.*, (1987) and microbial biomass N was estimated by method described by Pruden *et al.*, (1985).

Soil enzyme activities

Soil dehydrogenase activity was determined by the method of Casida *et al.*, (1964), alkaline phosphatase activity was determined by the method given by Tabatabai and Bremner (1969), cellulase activity was determined by method of Deng and Tabatabai (1995) and soil urease activity was measured by the method of Tabatabai and Bremner (1972).

Enumeration of microorganisms

Viable counts of bacteria and fungi in different soil samples were determined by serial dilution making and plating on respective media.

Statistical analysis

To assess the effects of different tillage practices on the soil properties, the RBD statistical programme was used for three way analysis of variance (ANOVA). Computation and preparation of graphs were done using Microsoft Excel 2007 Program.

Results and Discussion

Soil texture

The texture of soil samples collected from conventional and conservation tillage plots was sand and mechanical composition of soil under conventional tillage was 92% sand, 5% silt and 3% clay, while under conservational tillage respective values were 89%, 6% and 5%.

Chemical properties

EC, pH and soil organic carbon

The data presented in Fig. 1 and 2 on EC and pH of soils under conventional and zero-tillage systems under different crop rotations suggested that not much difference was observed in EC and pH of soil at different depths when switching from conventional to zero-tillage. In this research, conservation tillage had little effect on the EC content of Mahendergarh soils at depths of 0-15 and 15-30 cm compared to traditional tillage, which may be due to the buffering ability of soils based on carbonate content that resisted soil changes in EC during organic matter decomposition under conservation tillage.

These results are supported by Roldan *et al.*, (2005)'s observations that EC was not influenced by tillage practices although, while in contrast, Khan *et al.*, (2017) reported increased EC under NT, which may be attributed to decreased nutrient leaching along with water and increased availability of nutrients under NT. Non-significant effect of ZT or CT was observed by Singh *et al.*, (2015) in loam sand and sandy loam soil, but in contrast to these results Gholami *et al.*, (2014) stated that ZT had the highest EC value compared to CT because the lower electrical conductivity of the soil under the ZT system compared to CT related to the increased movement of water in the soil which improved soil aggregate growth. Kumar *et al.*, (2018) found a decrease in soil EC under CT that could be attributed to the opening and aeration of the top soil layers that resulted in increased leaching on the surface soil. In the practice of zero tillage, maximum EC was reported under direct seeded rice with residue application and minimum in traditional tillage practice under transplanted condition (Kevat *et al.*, 2019).

In present study, not much differences were observed in pH of soil under CT and ZT at 0-15 and 15-30 cm depth and the pH of soils under CT was 8.0, 8.1 and 7.6, 7.6 at surface and subsurface layer, under cotton-wheat and guar-wheat cropping pattern, respectively, and upon adoption of zero-tillage the values were 8.2, 8.7 and 7.7, 7.6 at 0-15 and 15-30 cm depth, respectively (Fig. 2). Many researchers have made similar findings. Asenso *et al.*, (2018) found no significant difference under zero-tillage in soil pH at 0–40 cm depth which may be attributed to the fact that no liming material was added as part of the procedure. In contrast, Kumar *et al.*, (2018) documented a significant impact of tillage on soil pH and observed the highest pH in zero tillage at the surface layer compared to traditional tillage method, this may be due to the fact that the experiment continued on dry soil agriculture for many years as part of the long term. Tillage does not affect soil pH directly, but its impact on pH may depend on the prevailing climate, soil quality, and management factors.

Soil organic matter (SOM) is the material formed by living organisms which are returned to the soil and are decomposed (Bot and Benites, 2005). This increases the soil's physical, chemical, and biologic properties. SOM serves as a source of plant nutrients and water absorbent, and can increase soil productivity by increasing the quality and quantity of organic carbon (SOC) (Lal, 2004). A large amount of literature is available that supports long-term tillage practices that substantially increase soil organic carbon over traditional crop / crop systems (Safeer *et al.*, 2013; Islam *et al.*, 2015; Asenso *et al.*, 2018; Jat *et al.*, 2018; Kumar *et al.*, 2018). In present study, soil organic carbon was relatively higher at 0-15 cm depth than bottom layer 15-30 cm depth with the values 0.28 and 0.26 % in conventional tillage, respectively, while respective values under

ZT were 0.31% and 0.28% (Fig. 3) in guar-wheat rotation. Individually, crop-rotation, tillage and depth affected organic carbon content significantly and our findings are consistent with those of Naresh *et al.*, (2015) and Song *et al.*, (2019) that tillage management practices have a major impact on the overall soil organic carbon (SOC) content at the surface (0-15 cm) layer relative to CT due to residue preservation, limited disruption and accumulation of organic carbon at the soil surface layer in ZT. Asenso *et al.*, (2018) recorded the highest organic C below ZT at a depth of 0–40 cm which could be attributed to undisturbed land resulting in increased soil organic matter accumulation indicating a reduced rate of leaching in the soil surface profile. The findings of other workers' experiences are also endorsed (Hati *et al.*, 2014; Jat *et al.*, 2018; Kaushik *et al.*, 2018; Kumar *et al.*, 2018; Zuber *et al.*, 2018).

Total N, P and K

Total nitrogen (N), phosphorus (P) and potassium (K) content of different cropping systems is important for maintaining crop productivity and food safety, and a large volume of literature is available to support the fact that long-term ZT increases the total N, P and K soil content at the surface layer as compared to CT under different cropping systems (Neugschwandtner *et al.*, 2014; Islam *et al.*, 2015; Zuber *et al.*, 2015). In present study, conservational tillage at different locations was found to affect total N, P and K content under different crop-rotations and higher total N, P and K content was observed under ZT system. There was significant influence of tillage and depth on total N, P and K content at both 0-15 and 15-30 cm depth (Fig. 4). Comparison of nutrient status in two farming systems revealed that the total N, P and K content under ZT was 0.049, 0.33 and 0.44% at surface layer while at subsurface layer the respective values were

0.042, 0.28 and 0.39% under guar wheat cropping system and under CT the respective values were 0.044, 0.25 and 0.41% and 0.040, 0.18 and 0.35%.

Greater availability of total N, P and K content associated with the zero-tillage at surface layer is closely related to soil organic matter build up. Dorr de Quadros *et al.*, (2012) documented significantly higher total N and P content in the no tillage system due to high microbial diversity and high soil organic matter accumulation. In contrast to our findings, Islam *et al.*, (2015) found a non-significant interaction impact of tillage on the total N, P and K content of the surface and subsurface layers, but comparatively higher values under zero tillage treatment at the surface layer than the subsurface layer, may be due to an increase in soil organic matter. Similarly, in a comparative study of traditional tillage and no-tillage carried out by Zuber *et al.*, (2015), higher total N under no-tillage was reported compared to CT because losses of N in the form of nitrates leaching and denitrification gaseous losses can offset the addition of N to the soil and the return of greater crop residue is an important factor in the greater total nitrogen under crop rotation which more frequently incorporates these crops.

Microbiological properties

No-tillage or conservation tillage preserves or enhances soil quality by maintaining soil structure and moisture, growing soil organic matter, and supplying soil microbes with a home. Most notably it is the bacteria that's why soil microbes are the earth's workhorses.

Microbial biomass carbon and nitrogen

Soil microbial biomass is a microbial community indicator, *i.e.* related to soil organic matter quality. In the present study,

tillage and depth affected microbial biomass carbon and nitrogen in various soil samples and relatively higher values were observed at the surface layer. MBC and MBN were higher in zero-tillage system as compared to conventional system but the values decreased with depth. The impact of tillage practices on microbial biomass C and N in sandy textured soils is shown in Fig. 5. The major affect produced by no-tillage was on MBC and MBN at surface layer under CT and ZT.

In present study, the MBC of soils under cotton-wheat and guar-wheat cropping system were 107, 102 and 111, 105 mg/kg soil at surface and subsurface layer, respectively, under CT and upon adoption of zero-tillage the values were 116, 113 and 124, 116 mg/kg soil at 0-15 and 15-30 cm depth, respectively. Results of our study are consistent with the findings of Lopez *et al.*, (2013) that microbial biomass carbon under ZT was substantially higher than conventional tillage because tillage conservation resulted in the accumulation of crop residues and organic carbon content at the surface layer. In zero tillage treatment, Chaudhary and Sharma (2019) recorded higher microbial biomass carbon (MB-C) than traditional tillage in the rice-wheat cropping system, showing an increase of 103% and 46.6% in MB-C compared to conventional tillage.

During present investigation, the MBN of soils under cotton-wheat and guar-wheat cropping system were 18.1, 15.1 and 19.6 and 16.4 mg/kg soil at surface and subsurface layer, respectively, under CT and upon adoption of zero-tillage the values were 19.8, 16.5 and 22.5, 17.4 mg/kg soil at 0-15 and 15-30 cm depth, respectively. Individually, the effects of crop-rotation, tillage and depth on MBC and MBN were significant.

Kabiri *et al.*, (2016) determined the carbon and nitrogen content of soil microbial

biomass at a depth of 0–20 cm and reported higher levels of MBC (25–43%), MBN (7–13%), MBC / MBN (17%) compared to conventional tillage. Belmonte *et al.*, (2018) observed the impact of long-term soil management on microbial activity in a vineyard and found higher levels of microbial biomass carbon and nitrogen (106.42 and 13.94 mg/kg) in S+NT (sown cover crop and no-tillage) followed by UV (under-vine zone with no vegetation and tillage) and least in S+T (sown cover crop and tillage) for *Vicia faba* L., *Pisum sativum* L., *Triticum aestivum*

L. Kabiri *et al.*, (2015) and (2016) found that higher microbial biomass carbon and nitrogen contents under no-tillage due to the increased SOM (C and N) level probably improved aggregation of soil and higher content of microbial biomass. In contrary, Zuber *et al.*, (2018) found that rotation did not affect microbial biomass C and N (MBC, MBN) while conventional tillage reduced MBN at 10–20 cm compared to NT may be due to soil-wide dispersion of N fertilizers and MBN was greater in NT than CT because of SOM accumulation under no-tillage (Table 1–5).

Table.1

Factors	Organic carbon
A (crop-rotations)	0.009
B (Tillage)	0.009
A X B	NS
C (Depth)	0.009
A X C	NS
B X C	NS
A X B X C	NS

C.D. at 5%

Table.2

Chemical properties	Factors						
	A (Crop-rotations)	B (Tillage)	A X B	C (Depth)	A X C	B X C	A X B X C
Total N	0.002	0.002	0.003	0.002	NS	0.003	NS
Total P	0.015	0.015	0.022	0.015	NS	NS	0.031
Total K	0.016	0.016	NS	0.016	NS	NS	NS

C.D. at 5%

Table.3

Factors	MBC	MBN
A (Crop-rotations)	4.007	4.007
B (Tillage)	4.007	4.007
A X B	NS	NS
C (Depth)	4.007	4.007
A X C	NS	NS
B X C	NS	NS
AXB X C	NS	NS

C.D. at 5%

Table.4

Chemical properties	Factors						
	A (Crop-rotations)	B (Tillage)	A X B	C (Depth)	A X C	B X C	AXB X C
Dehydrogenase	0.395	0.395	0.558	0.395	0.558	0.558	0.79
Alkaline phosphatase	5.925	5.925	8.379	5.925	8.379	6.729	11.85
Cellulase	0.003	0.003	NS	0.003	NS	NS	NS
Urease	0.365	0.365	0.516	0.365	NS	NS	NS

C.D. at 5%

Table.5

Chemical properties	Factors						
	A (Crop-rotations)	B (Tillage)	A X B	C (Depth)	A X C	B X C	AXB X C
Bacteria	NS	0.04	0.057	0.04	0.057	0.057	0.081
Fungi	0.035	0.035	0.05	0.035	0.05	0.05	0.071

C.D. at 5%

Fig.1 Effect of conventional and zero tillage on EC content under different cropping systems

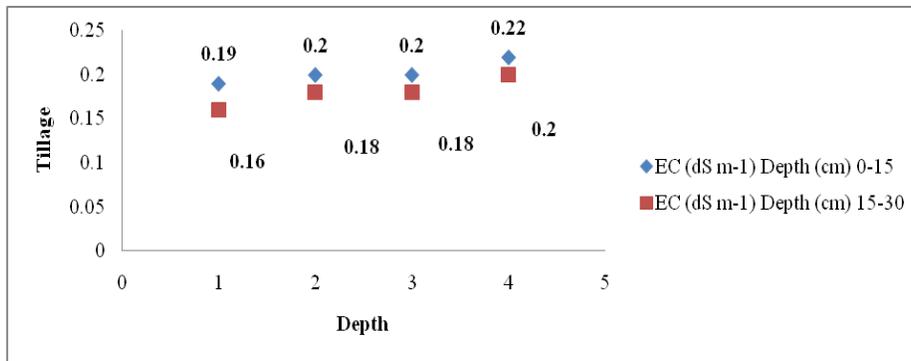


Fig.2 Effect of conventional and zero tillage on pH content under different cropping systems

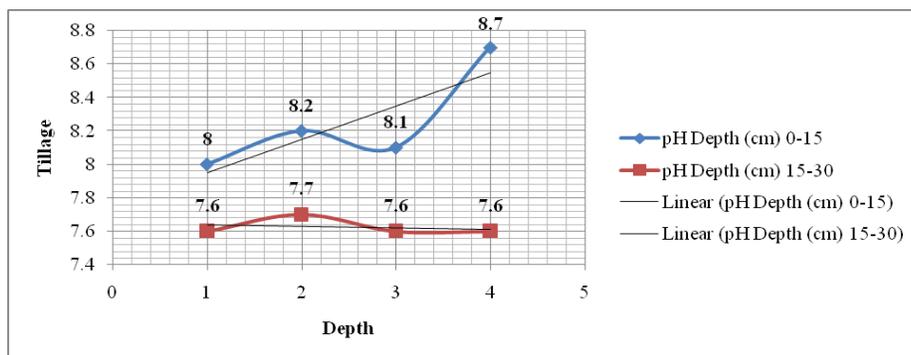


Fig.3 Effect of conventional and zero tillage on soil organic carbon content under different cropping systems

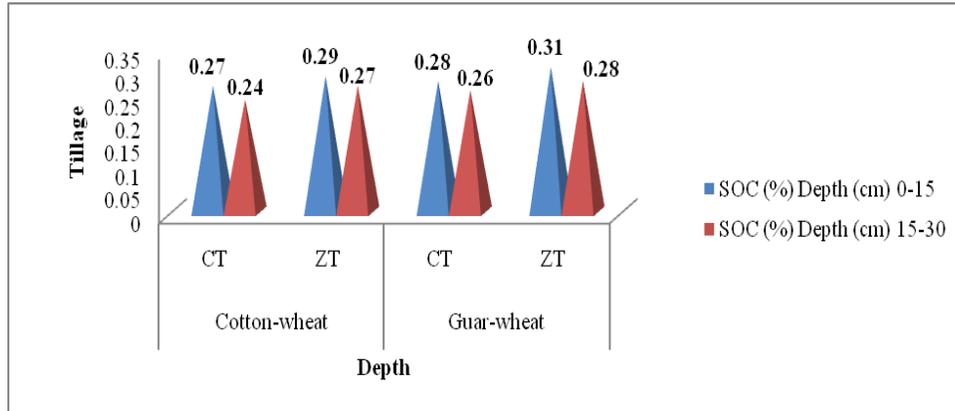


Fig.4

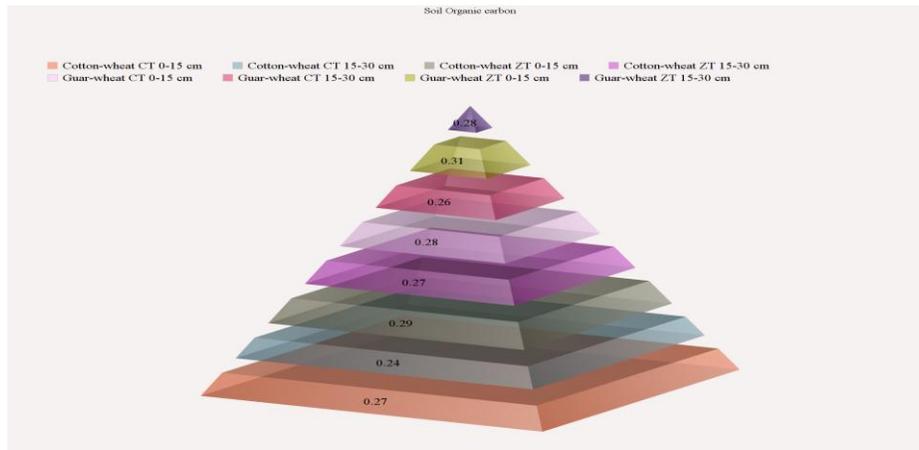


Fig.5 Effect of conventional and zero tillage on Total N, P and K content under different cropping systems

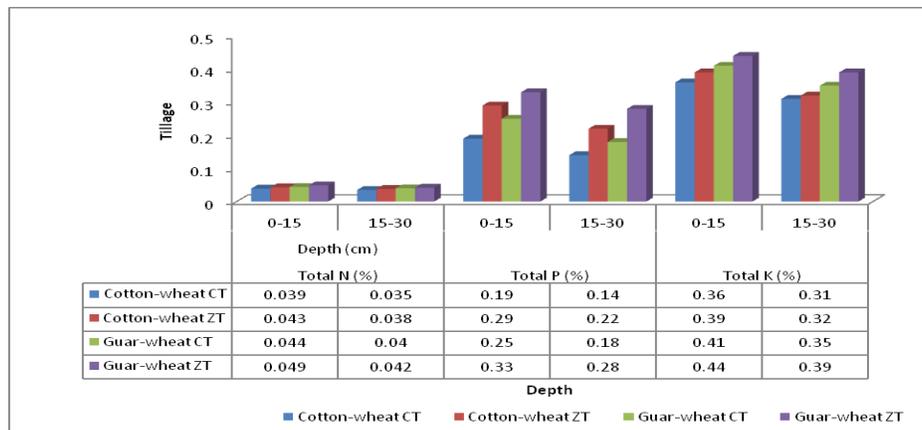


Fig.6 Effect of conventional and zero tillage on microbial biomass carbon and nitrogen content under different cropping systems

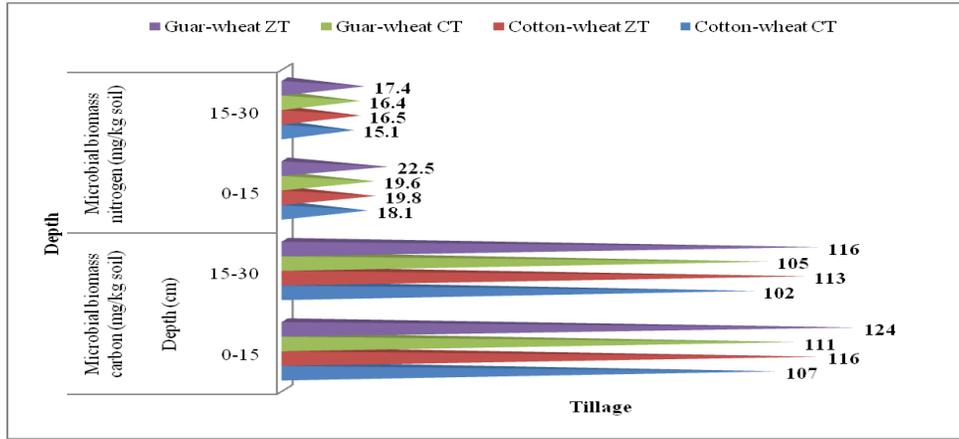


Fig.7 Effect of conventional and zero tillage on enzymatic activity under different cropping systems

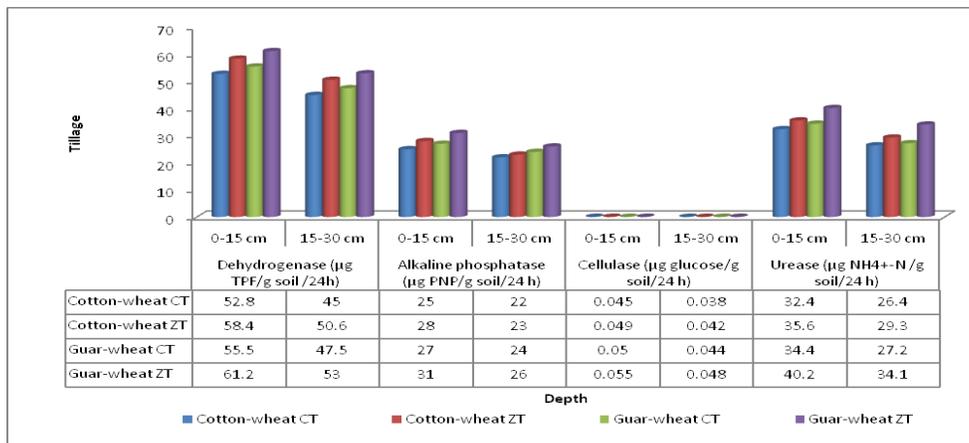
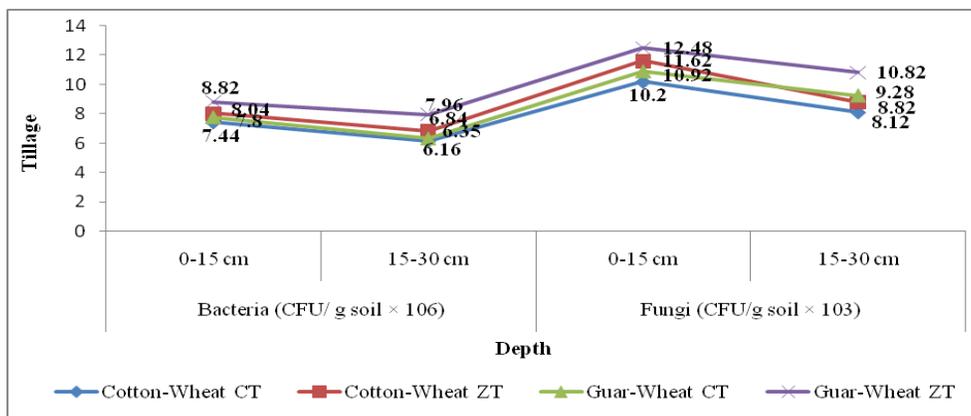


Fig.8 Effect of conventional and zero tillage on microbial count under different cropping systems



Enzyme activity

Soil microbial processes are regulated by different enzymes and are influenced by many factors of physical, chemical and environmental significance. Enzymes in soil are biologically important because they affect plant nutrient availability and all microbial activities are directly linked to the various enzymatic activities produced extracellularly by specific microorganisms or plant roots. In soil, the principal sources of enzymes are microorganisms, active roots, and dead cells. Soil enzymatic activity is a delicate marker of the impact on microbial functions of ecological factors. In this study, the effect of soil management practices on different enzymatic activities under different crop-rotations at different locations *viz.* Dehydrogenase, alkaline phosphatase, cellulase, and urease were studied, and different enzyme activity was observed higher in the 0-15 cm layer compared to the 15-30 cm layer.

Measurement of dehydrogenase activity (DHA) is one of the analyzes of the overall soil condition, being a highly sensitive indicator of environmental changes (Gałązka *et al.*, 2017). It is closely related to the cycles of carbon and nitrogen, and the biological oxidation of organic soil (Błońska *et al.*, 2016). The activity of dehydrogenase represents the complete oxidizing activity of soil microflora and in present study, DHA was affected with different tillage practices under two cropping systems at 0-15 and 15-30 cm depth. DHA activity of different soil samples were 52.8, 45.0, 55.5 and 47.5 $\mu\text{g TPF/g soil /24 h}$ under the conventional tillage system and increased up to 58.4, 50.6 61.2 and 53.0 $\mu\text{g TPF/g soil /24 h}$ at surface and subsurface soil in zero-tillage system, respectively (Fig. 6). Individually and interaction of crop-rotation, tillage and depth was significant. Our results are similar with

the findings of Janušauskaite *et al.*, (2013) that the highest dehydrogenase activity at a depth of 0-10 cm under no-tillage may be attributed to high NT microbial biomass and nutrients than CT. Similarly, Majchrzak *et al.*, 2016 and Bhaduri *et al.*, 2017 observed substantial effect of tillage systems on DHA, which was substantially higher under NT due to accumulation of organic matter and nutrients at the surface layer of soil under no-tillage.

During present investigation, long term impact of conservational tillage affected the alkaline phosphatase activity in soil. Upon the adoption of zero tillage system, alkaline phosphatase activity was relatively higher under guar-wheat cropping system 31 and 28 $\mu\text{g PNP/g soil/ 24 h}$ at surfaces and subsurface layer, respectively (Fig. 6). Individually and interaction of crop-rotation, tillage and depth was significant. The explanation for increased alkaline phosphatase activity in the surface layer may be due to high concentrations of inorganic phosphate released from organic matter under zero tillage, resulting in increased alkaline phosphatase activity in the surface layer, the results are supported by the findings of that Acosta-Martinez *et al.*, (2003), Mathew *et al.*, (2012) and Gajda *et al.*, (2013).

In present study, cellulase activity in soil under different tillage practices is shown in Fig. 6. Cellulase activity was found higher in guar-wheat cropping pattern at 0-15 cm depth (0.055 $\mu\text{g glucose/g soil/24 h}$) and (0.048 $\mu\text{g glucose/g soil/24 h}$) at 15-30 cm depth under zero-tillage and cotton-wheat cropping pattern had lower enzymatic activity at surface and subsurface layer 0.049 $\mu\text{g glucose g}^{-1}\text{ soil 24 h}^{-1}$ and 0.042 $\mu\text{g glucose/g soil/24 h}$, respectively, with same tillage and the similar trend was observed under conventional tillage. The findings of present study on relatively higher cellulase activity under ZT

system are contrary to the observation of Mina *et al.*, (2008) and Bini *et al.*, (2014) that no-tillage cellulase production was lower than traditional tillage due to increased organic matter inputs into the soil due to CT plowing and harrowing, which made organic C pools more vulnerable to microbial and soil enzyme attacks. However, Balota *et al.*, (2003) reported 90% increase in cellulase activity under no-tillage as compared with CT in wheat based cropping systems may be due to high microbial biomass in no-till soils which contained more nutrients than microbial biomass in CT systems.

In present study, urease activity was relatively higher in guar-wheat cropping system at surface soil (40.2 $\mu\text{g NH}_4^+\text{-N}$ released /g soil/ 24 h) which further decreased in subsurface soil (34.1 $\mu\text{g NH}_4^+\text{-N}$ released /g soil/ 24 h) under zero tillage but with conventional tillage system respective values were (34.4 $\mu\text{g NH}_4^+\text{-N}$ released /g soil/ 24 h) and (27.2 $\mu\text{g NH}_4^+\text{-N}$ released /g soil/ 24 h) the similar trend was observed in cotton-wheat crop-rotation under conventional tillage (Fig. 6). The findings of the present study on urease activity under various systems are similar to the observations of Raiesi and Kabiri (2016) that higher urease activity recorded under reduced tillage practices compared to CT practices may be due to high soil organic carbon accumulation under no-tillage. In comparison, Asenso *et al.*, (2018) found the highest enzyme activity under subsoiling (SS) treatment relative to ZT treatment since SS treatment loosened the soil and resulted in higher organic C added to the soil, increasing the abundance of soil microorganisms resulting in increased soil enzyme activity due to increased substratum and oxygen availability.

Microbial count

The microbial count in soil samples was determined to know the total viable count of

bacteria and fungi for studying the impact of tillage practices under different cropping patterns. Compared with traditional tillage, the microbial population increased by implementing zero-tillage and was higher in surface soil under both systems. Bacteria and fungi are a very significant functional group of soil species and involved in many biogeochemical processes. They are responsible for mineralizing organic matter, circulating elements, synthesizing proteins and nucleic acids, as well as transforming phosphorous forms.

In present study the effect of tillage practices on microbial groups under different cropping patterns was studied and population of bacteria and fungi was observed relatively higher in zero tilled soil at 0-15 cm depth compared to conventional tilled soil and bacteria were most abundant under all systems. The effect of tillage practices on total bacterial population is presented in Fig. 7 revealed that bacterial population remained higher at surface soil and maximum in guar-wheat surface soil 8.82×10^6 cfu/g soil which further decreased up to 7.96×10^6 cfu/g at subsurface layer under zero-tillage practices and cotton-wheat cropping pattern had lower bacterial population at surface and subsurface layer 8.04×10^6 cfu/g and 6.84×10^6 cfu/g, respectively, with same tillage. Similar trend was observed for total microbial count at different depths under two cropping pattern in conventional tillage.

The fungal population in conventional as well as in zero-tillage systems is shown in Fig. 7. There was significant increase in fungal count and maximum in guar-wheat cropping system at surface layer (12.42×10^3 cfu/g) which further decreased up to subsurface layer (10.48×10^3 cfu/g) upon adoption of zero tillage practices while cotton-wheat cropping pattern had lower count at surface and subsurface layer 11.62×10^3 cfu/g and 8.82×10^3 cfu/g respectively and similar trend

was observed under two cropping pattern at surface and subsurface layer in conventional tillage (Fig. 8).

Such findings are consistent with Dorr de Quadros *et al.*, (2012)'s observations that microbial diversity in the no-tillage environment was substantially higher, as soil management affected soil biodiversity and abundance of individual organisms. Under the conservational agriculture method, Dongre *et al.*, (2017) attributed comparatively higher bacterial and fungal counts at 0-15 cm depth to submerged conditions in a deeper layer. Schmidt *et al.*, (2018) recorded higher total bacterial number in cover cropped plots at different depths, while no-till treatments showed higher number at surface layer compared to standard tillage because farming practices and depths favored distinctly different microbial life strategies.

In conclusion the soil physico-chemical and microbiological properties were improved as a consequence of decreased disturbance and crop residue cover on the surface in ZT system. Zero tillage significantly affected the microbial community's functioning as reflected by an increased enzyme activity and in addition, long-term ZT practice resulted in increased organic carbon, microbial count and aeration status in soils. The study concludes that the practice of ZT in wheat under various semi-arid IGP crop system in Haryana can be adopted in order to preserve the system's productivity, but the practice must be encouraged in fine textured soils.

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