

IMPACT OF TILLAGE PRACTICES ON PHYSICO-CHEMICAL AND FUNCTIONAL DIVERSITY IN PEARL MILLET-WHEAT CROPPING SYSTEM

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Abstract: Conservation agriculture based tillage practices mainly zero-tillage (ZT) considered as major component of sustainable agriculture that involves reducing the tillage operations retaining at least 30% of plant parts/crop-residues at the soil surface and including crop-rotation in the existing cropping system. More research is needed for better understanding of tillage effects on soil physico-chemical and microbiological properties. Thus, the impact of two tillage systems: no-tillage (NT) and conventional tillage (CT) with different crop-rotations *i.e.* Conventional Tillage Wheat-Conventional Tillage Pearl millet (CTW-CTPM), Conventional Tillage Wheat-Zero Tillage Pearl millet (CTW-ZTPM), Zero Tillage Wheat-Conventional Tillage Pearl millet (ZTW-CTPM) and Zero Tillage Wheat-Zero Tillage Pearl millet (ZTW-ZTPM) on physico-chemical and functional diversity of soil was evaluated in the present investigation at CCSHAU, Regional Research Station (RRS) at Bawal during 2014 year. After harvesting of wheat in 2017, triplicate soil samples from undisturbed and disturbed soil were obtained from two different depths (0-15 cm and 15-30 cm), for determination of CaCO₃, Total N, P and K content and Functional diversity of microbes. Physico-chemical properties and functional diversity were recorded relatively higher under ZTW-ZTPM system at surface (0-15 cm) layer. SOC was recorded higher at surface layer under ZTW-ZTPM (0.29 %) as compared to CTW-CTPM (0.26 %) and the respective values at subsurface layer were 0.25 and 0.23%. In nutshell, NT treatments promoted better physico-chemical and functional diversity of the soil relative to the CT treatment.

Keywords: Functional diversity, Nutrient release pattern, Tillage systems

INTRODUCTION

Tillage is one of the fundamental agriculture operation because it influences on crop growth, soil properties (physical, chemical and biological) and environment and optimization of tillage practices lead to improvement in soil health. Intensive agricultural practices often lead to changes in soil health governing properties like, soil structure, aggregation, infiltration, bulk density, soil carbon content, microbial biomass and their activities (Allen *et al.*, 2011). Soil with better health and quality will be able to produce higher crop yield under favorable as well as extreme climatic conditions (Congreves *et al.*, 2015), and soil health acts as a critical component for adaptation and mitigation of climate change effects by the crops (Congreves *et al.*, 2015). Therefore, it is important to apply appropriate tillage practices that avoid the degradation of soil structure, maintain crop yield as well as ecosystem stability.

Pearl millet-wheat has been most important cropping system because it is a staple diet for the vast majority of poor farmers and also forms an important fodder crop for livestock. Resource degradation problems are manifesting in the present-day agriculture, necessitating for development of more innovative conservation-based technologies in place of the conventional agriculture systems. In recent years, interest of farmers in conservation agriculture (CA) has increased because of escalation of capital and

production costs. Various on farm participatory trials have revealed little or no difference in yields of crops under zero-tillage system, compared with conventional tillage (Krishna and Veetil 2014). The CA specifically aims to address the problems of soil degradation due to water and wind erosion, depletion of organic matter and nutrients from soil, runoff losses of water, and, moreover, it purports to address the negative consequences of climate change on agricultural production. Relatively less attention has been paid on the use of conservation agriculture in the arid and semi-arid tropics, although a lot of information is available from humid and sub-humid regions globally (Jat *et al.*, 2012). But region specific CA options need to be identified for implementation by resource-poor farmers. Crop residues have competing uses like fodder because of dominance of livestock in these areas. Therefore, it is necessary that suitable amount should be App. to improve crop productivity and soil health in a cost-effective manner. It is hypothesized that zero tillage with residue retention improves soil physical, chemical and biological properties compared to conventional tillage in pearl millet – wheat cropping system.

MATERIALS AND METHODS

Study Site and Soil Sampling

The study site was located at CCSHAU, Regional Research Station, Bawal, District- Rewari (Haryana)

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and no-tilled and conventionally tilled plots were established in 2014. The soil samples collected during 2017 after wheat harvest from surface and subsurface soil profile from five random spots/tillage plots were sieved through 2 mm sieve and stored at $4\pm 1^\circ\text{C}$. For determination of microbial activities, the soil was moistened to 60 % water holding capacity (WHC) and incubated at 30°C for 10 days to permit uniform rewetting and allow microbial activity to equilibrate after the initial disturbances. Sub-samples were air-dried and ground for chemical analysis.

Characterization of Soil Physical and Chemical Properties

CaCO₃ and Soil organic carbon

Calcium carbonate content in different soil samples was determined by the rapid titration method (Puri, 1949). The organic carbon content in different soil samples was determined by the method of Kalemhassa 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).

Functional diversity of different microorganisms using CLPP

Biolog microplate comprising of 22 different sugars and 9 amino-acids as a substrate and a control well without a carbon source was used to study functional diversity of different microorganisms. Serial dilution of each soil sample was made and 100 μl of diluted soil sample was added in a well of microtitre plate having sugar basal medium and the plates were incubated at $20\pm 2^\circ\text{C}$ in dark. Development of color from blue to yellow was measured after every 24 h for 5 days using an Elisa plate reader at 592 nm and substrate utilization was calculated.

Statistical analysis

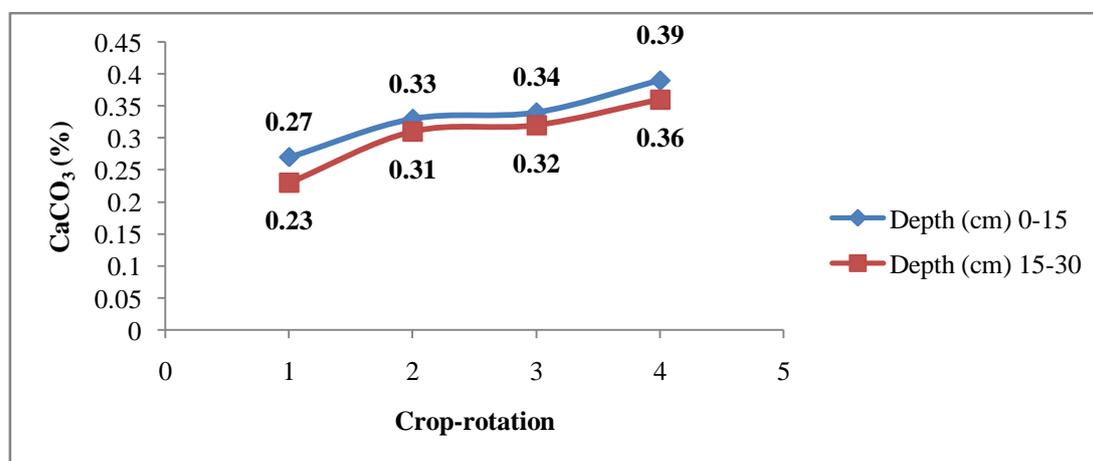
The significance of treatment effects was analyzed using two factorial RBD analysis, using OP Stat software, at CCS HAU, Hisar.

RESULTS AND DISCUSSION

CaCO₃ and Soil organic carbon

Zero-tillage (ZT) affects the chemical properties of the soil in entirely different patterns to as that of what CT did. No-tillage can also lead to improvements in soil quality by improving soil structure and enhancing soil biological activity, nutrient cycling, soil water holding capacity, water infiltration and water use efficiency (Hobbs *et al.*, 2008). The data on CaCO₃ of soils under conventional and zero-tillage systems under pearl millet-wheat crop rotation presented in Fig. 1 indicated that on shifting from conventional to zero-tillage, not many differences were observed in CaCO₃ content of the soil at different depths.

CaCO₃ content of different soil samples varied between 0.27-0.39 % at 0-15cm depth and 0.23-0.36 % at 15-30 cm depth under different tillage practices whereas with the adoption of zero-tillage wheat system, CaCO₃ content increased to 0.39 % at surface soil which decreased upto 0.36 % at subsurface soil under ZTW-ZTPM system. Individually, CaCO₃ content was significant with depth and interaction of tillage and depth was also significant. The CaCO₃ content of soil samples was affected by pearl millet-wheat crop rotation under conventional and zero-tillage to different extent, in present study and similar findings have been reported in literature also. Neugschwandtner *et al.* (2014) reported increased calcium carbonate at 30–40 cm depth because the loss of CaCO₃ was reduced by conservation tillage due to greater retention of water in the soil profile. Celik *et al.* (2017) observed that calcium carbonate content of the soil was not significantly different within 0-30 cm depth, might be due to the tillage practices did not cause to accumulate calcium carbonate content within 30 cm of the soil surface. Reduction of Ca content in the tillage practices reported by Nta *et al.* (2017) can be explained due to the rapid breakdown and mineralization in soil organic carbon in mechanically tilled plot.



1= CTW-CTPM, 2= CTW-ZTPM, 3= ZTW-CTPM, 4= ZTW-ZTPM

Fig. 1: Effect of conventional and zero tillage on soil CaCO₃

Zero-tillage (ZT) affects the chemical properties of the soil in an utterly diverse pattern to as that of what conventional tillage did. Zero-tillage can also lead to improvements in soil quality by improving soil

constitution and enhancing soil biological activity, nutrient cycling, soil water holding capacity, water infiltration and water use efficiency (Hobbs *et al.*, 2008).

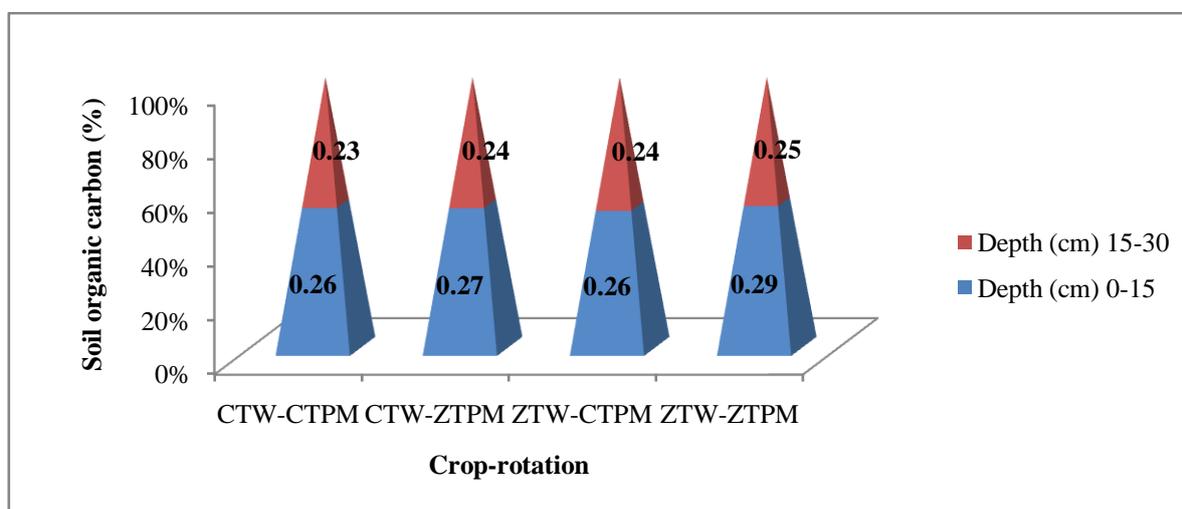


Fig. 2: Effect of conventional and zero tillage on soil organic carbon

Locations	Chemical properties	A (Tillage)	B (Depth)	A X B
		C.D. at 5%		
RRS, Bawal (Rewari)	CaCO ₃	NS	0.013	0.019
	SOC	0.008	0.008	0.012

Soil organic carbon is vital marker of soil health as it affects almost all the physico-chemical properties. The soil organic carbon in sandy soil was higher at surface layer than subsurface layer with the values 0.26-0.29 % in surface layer and 0.23-0.25 % in subsurface layer and organic carbon was relatively higher with the adoption of ZTW-ZTPM (0.29%) at surface layer (Fig. 2). Individually, as well as interaction of tillage and depth was significant under pearl millet-wheat systems. Asenso *et al.* (2018) reported highest organic C under ZT at 0–40 cm depth that may be due to the undisturbed land resulting an increased buildup of soil organic matter which reflected a reduced rate of leaching in the soil surface profile. The results are also supported by the observations of other workers (Jat *et al.*, 2018; Kaushik *et al.*, 2018; Kumar *et al.*, 2018; Zuber *et al.*, 2018).

Total N, P and K

Long-term field experiments are important for explaining tillage and rotation effects on soil fertility and to develop nutrient management strategies. Soil total nitrogen (TN) is one of the main factors for determining soil fertility. Traditional activities, such as cropping methods and field management, play an essential role in the accumulation of N in soil for agricultural sustainability. Changes in total N, P and K content of soils under different treatments are shown in Fig. 3-5. In general, the total N, P and K

content was higher in surface layer in CT as well as ZT. The total N, P and K content of sandy soil was relatively higher in ZTW-ZTPM (0.044, 0.24 and 0.36 %, respectively) at 0-15 cm depth and corresponding values were 0.037, 0.18 and 0.34 % at subsurface soil, while lowest total N, P and K content were found under CTW-CTPM, with values 0.039, 0.16 and 0.31 %, respectively, at 0-15 cm depth and respective values were 0.033, 0.13 and 0.28 %, respectively, at 15-30 cm depth. Individually, total N, P and K content was significant but the interaction of tillage with depth was however, significant only for total P content.

In present study, conservational tillage was found to affect total N, P and K content under pearl millet-wheat crop-rotation in sandy texture soil and higher total N, P and K content was found under ZT system at surface layer. Greater availability of total N, P and K content associated with the conservational tillage at surface layer is closely related to SOM build up as reported elsewhere. Dorr de Quadros *et al.* (2012) reported significantly higher total N and P content in the no- tillage system because of high microbial diversity and high accumulation of soil organic matter. In contrast to our findings, Islam *et al.* (2015) reported non-significant interaction effect of tillage on total N, P and K content at surface and subsurface layer but relatively higher values under zero-tillage treatment at surface layer than subsurface layer, might be due to increase in soil organic matter.

Similarly, in a comparative study of conventional 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 leaching of nitrates 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 that incorporate these crops more frequently.

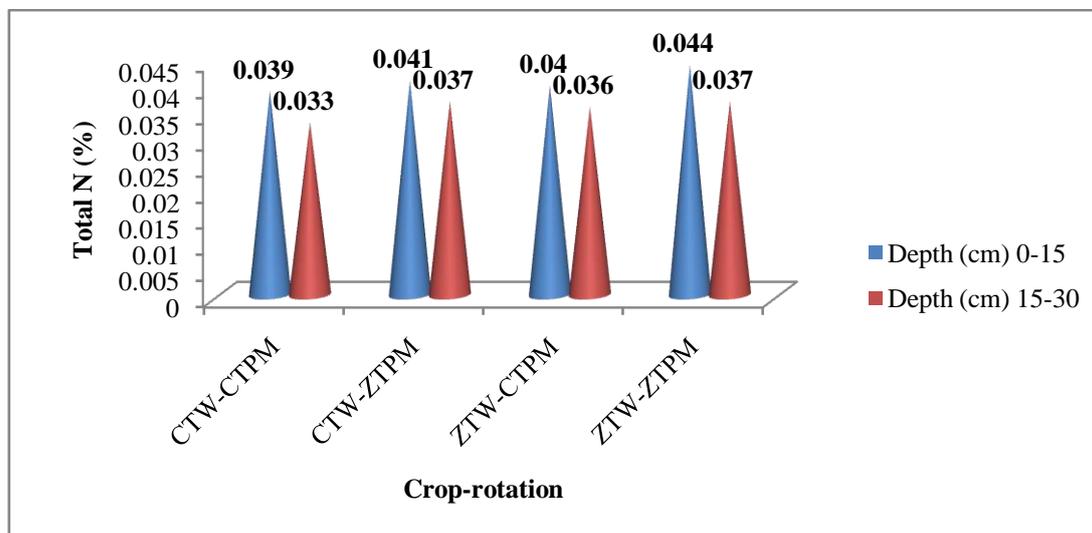


Fig. 3: Effect of conventional and zero tillage on total N content of soil

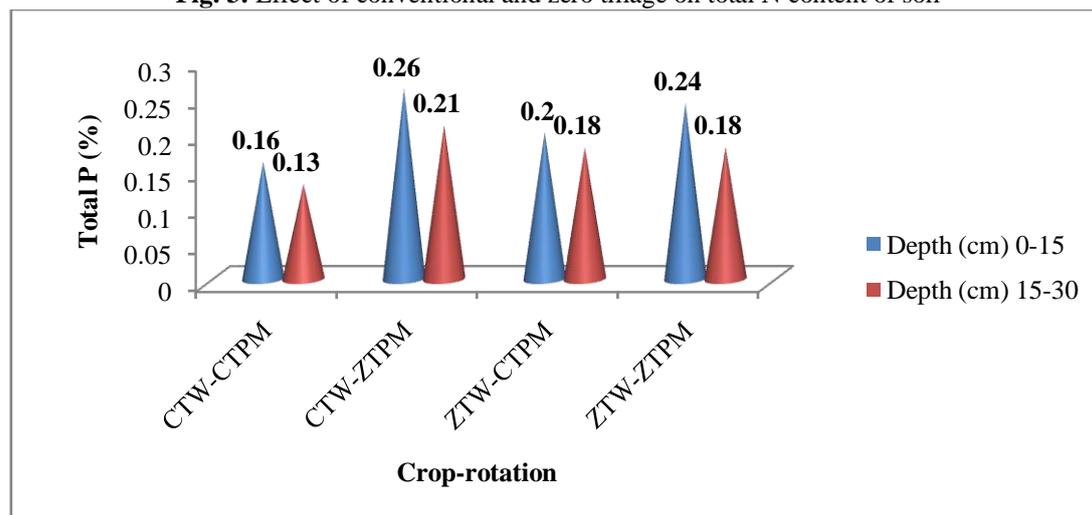


Fig. 4: Effect of conventional and zero tillage on total P content of soil

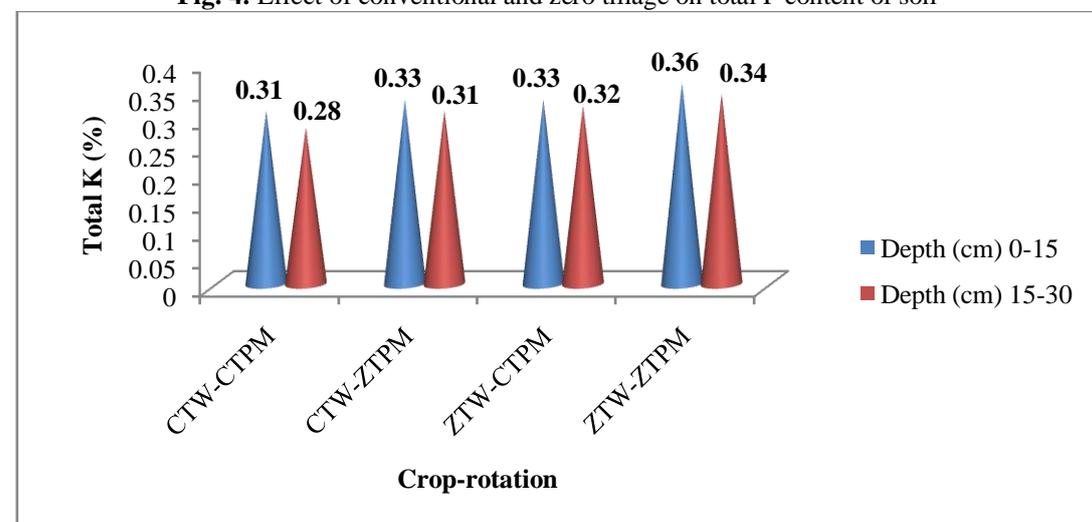


Fig. 5: Effect of conventional and zero tillage on total K content of soil

Locations	Chemical properties	A (Tillage)	B (Depth)	A X B
		C.D. at 5%		
RRS, Bawal (Rewari)	Total N	0.002	0.002	NS
	Total P	0.012	0.012	0.018
	Total K	0.007	0.007	NS

Functional microbial diversity of soil under conventional and zero-tillage practices

Community-level physiological profiling assesses the microbial community on the basis of sugar and amino acid utilization patterns and capacity to metabolize specific sole carbon sources. EcoPlate™ method can be used to study the variability of the community-level physiological profiling of microorganisms. Functional microbial diversity in different treatments was studied in terms of average well color development, richness and diversity index.

Average well color development and Richness

The AWCD denotes the expression of different microbial activities in the soil samples, which integrates the microbial diversity and cell densities with the substrate utilization patterns.

The results for AWCD of soil samples with pearl millet-wheat crop-rotation shown in Fig. 6 revealed that the AWCD values significantly increased on adopting zero-tillage practices. Maximum values of AWCD *i.e.* 0.706 and 0.523 was observed under pearl millet-wheat crop-rotation at 0-15 and 15-30 cm depth, respectively, under ZTW-ZTPM while under CTW-CTPM corresponding values were 0.395 and 0.233.

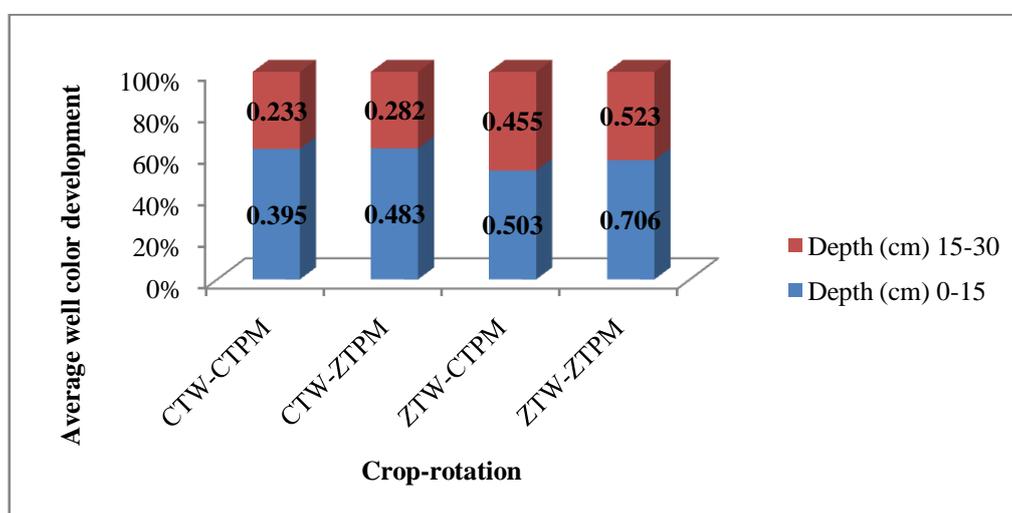


Fig. 6: Effect of conventional and zero tillage on average well color development

R values represented the functional diversity measured as the number of total C substrate utilized and the maximum values was observed 19 and 14 at

surface and subsurface layer, respectively, under ZTW-ZTPM while under CTW-CTPM, corresponding values were 12 and 6 (Fig. 7).

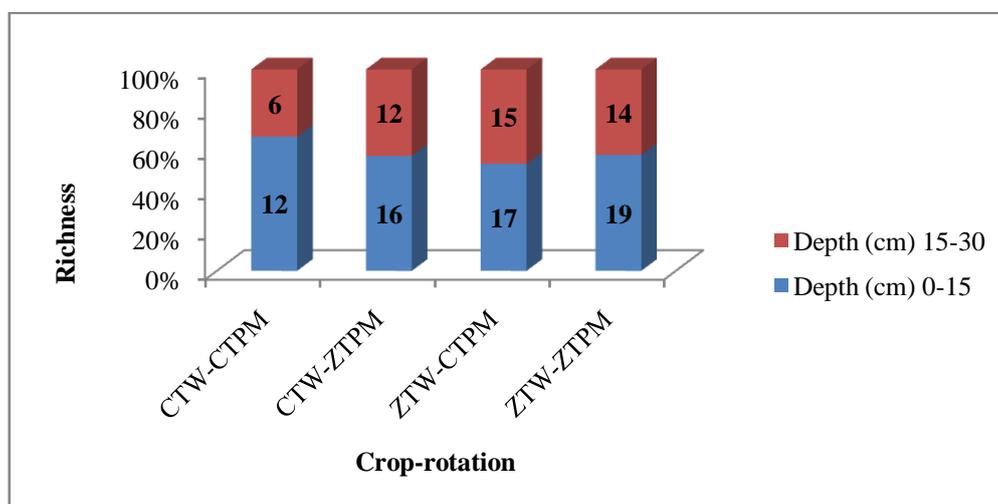


Fig. 7: Effect of conventional and zero tillage on richness

Diversity Index

The diversity index of the microbial communities of each sample was calculated as Shannon-Weaver (H) and Simpson's index (D) on the basis of sole carbon and sole nitrogen source utilization (Fig. 8). The microbial diversity of the samples analyzed, as Shannon-Weaver (H) was maximum at surface layer (2.87) under ZTW-ZTPM and at subsurface layers

(2.8), while comparatively lower, respective values were 2.657 and 2.524 under conventional tillage system. The Simpson's index (D) was observed higher under ZTW-ZTPM at surface layer with the value of 0.937 and 0.931 at subsurface layer while under conventional tillage respective values were 0.907 and 0.897.

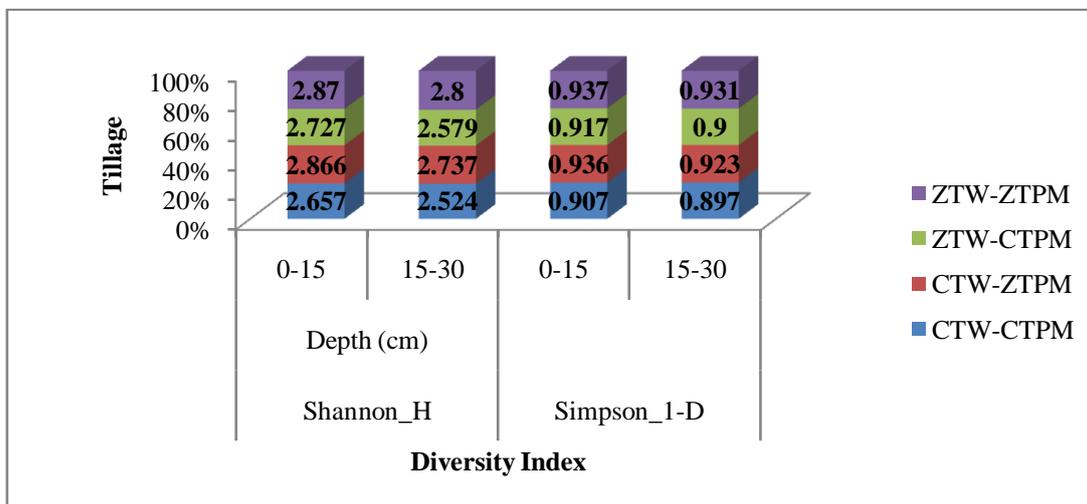


Fig. 8: Effect of conventional and zero tillage on diversity Index

Principal Component Analysis

To determine how the different soil samples were related with each on the basis of carbon source utilization pattern, the absorbance values were subjected to Principal component analysis (PCA).

The scatter plot displayed the principal component 1st and 2nd (PC1 and PC2) explaining % of variation in the CLPP (Fig. 9). Pearl millet-wheat crop-rotation was found different on correlating carbon source utilization pattern with PC1 and PC2 (R > 0.70).

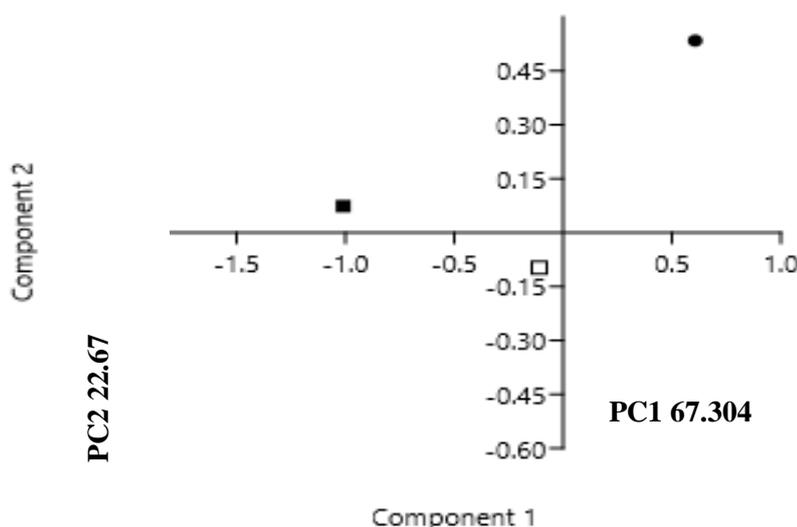


Fig. 9(a): Principal component analysis of conventional tillage wheat for pearl millet- wheat crop rotation
 Dot means CTW-CTPM 0-15 Plus CTW-CTPM 15-30
 Square CTW-ZTPM 0-15 Fill square CTW-ZTPM 15-30

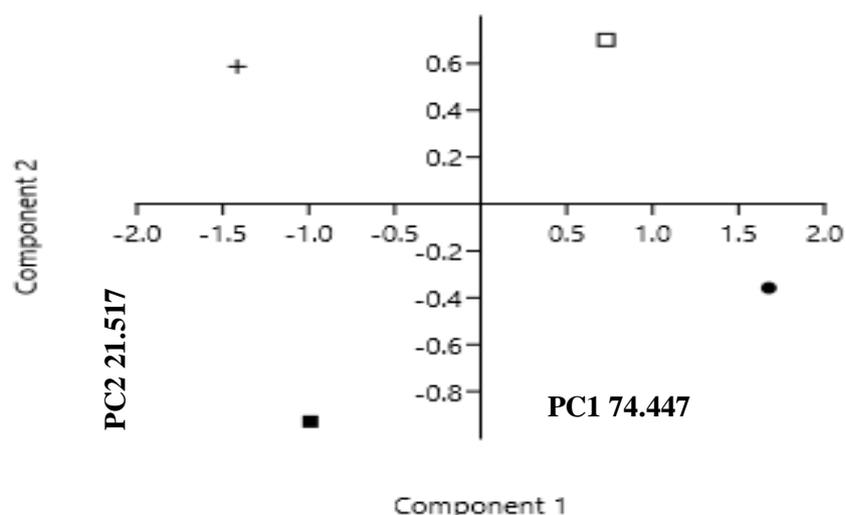


Fig. 9(b): Principal component analysis of zero tillage wheat for pearl millet-wheat crop rotation

Dot means	ZTW-CTPM 0-15	Plus	ZTW-CTPM 15-30
Square	ZTW-ZTPM 0-15	Fill square	ZTW-ZTPM 15-30

During the present investigation, the results of Biolog® Ecoplate™ from different tillage practices with pearl millet-wheat crop-rotation revealed that the microbial community was relatively higher at surface layer under ZT showing an expression of different microbial activities in terms of AWCD, total C substrate utilized (richness) and the number of positively utilized substrates (Shannon-Weaver (H) and Simpson's index (D)). Similar findings were reported by Habig and Swanepoel, (2015) that microbial diversity and activity were higher at surface layer under no-till than conventional tillage because the stimulation of soil microbial populations in no-tillage, promoted the availability of carbon sources for microbial utilization. Nivelles *et al.* (2016) found lowest AWCD and Shannon index under bare fallow and highest under cover crop-NT plots might be due to higher total nitrogen content and total organic carbon content that led to increased the diversity of substrate-richness and induced more microbial enzymes because of greater metabolism of phenolic compounds and carbohydrates (under no-till) and polymers (under conventional till) as carbon sources in plots under standard cover crop. In contrary to our results, Janušauskaite *et al.* (2013) found higher AWCD values under conventional tillage than no-tillage because higher availability of hydrocarbon sources in conventional tillage could promote microbial community's diversity and increased use of carbon sources. During present investigation, different soil samples under pearl millet-wheat crop-rotation were found related to each other, based on C source utilization pattern on principal component analysis. Gałazka *et al.* (2017) observed that principal component analysis showed strong correlation between soil quality parameters and biodiversity indicators that explained 71.51 % biological variability in no-tilled soils.

CONCLUSION

Zero-tillage practice resulted in relatively higher soil organic carbon at the surface layer, as well as changes in the soil microbial community and the tillage effect on microbial community varied by soil depths. The use of community level physiological profiling allows us to have better understanding regarding the changes of the microbial community under different management systems and might provide insights into how conservation tillage practice improves soil quality and sustainability.

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