

Original Research Article

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Edaphic Behaviour Relation to Transition of Tillage in Wheat Rhizosphere: A Short-Term Conclusive

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ABSTRACT

Tillage one of the keystone land management practice which impinges soil ecology by altering soil physicochemical conditions. To scrutinize the modification soil physicochemical properties and microbial activity under different tillage systems, a trial was performed in an organically grown wheat crop for a time-lapse of two seasons (Rabi) 2017-18&2018-19 at student's research farm, Punjab agricultural university, Ludhiana. It encompassed three types of tillage systems alternating with paddy straw mulch (6t/ha). As it was a short-term study, the disparity in soil conditions among treatments was sparse, but treatments recorded statistically significant ($p>0.05$). Microbial counts (total viable count, *Azotobacter* count, and phosphate solubilizing microbial count) and phosphatases activity (acid and alkaline phosphatases) were pronounced in zero tillage supplemented mulch plots at 90 and 125 DAS (days after sowing). CT (conventional tillage), DT (Deep tillage) supplemented with mulch also recorded better microbial and phosphatase activity compared to control with the progression of first to the second year. Soil Electrical conductivity (E.C), available potassium and phosphorous declined with the concatenation of first to second year irrespective of tillage plots and growth stages. However, Soil texture, pH, were insignificant ($p< 0.05$). Altogether, it surmises that conservation agriculture conducive in the case of restoring soil health.

Keywords

Crop residues;
conservation tillage;
soil microbial
properties; soil
enzymes and zero
tillage

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Introduction

South and Southeast Asian countries follow a typical rice-wheat cropping system which feeds more than 20% of the world's population (Prasad and Rajendra, 2005). In India, the rice-wheat cropping system has its cultivation of around 12.5 m ha (FAO, 2019). Of the total area, rice contributes to 33% and wheat contributes to 42% of the area which is feeding nearly 75% of the population

(Mahajan and Gupta, 2009). Conventional based rice-wheat cropping systems cultivation involves wet ploughing (rice) and desi or mouldboard plow (wheat) (Hobbbs *et al.*, 2008).

These land management practices degrade soil health by erosion loss of top fertile soil; disrupting aggregates thereby decrease in microbial richness and diversity and soil organic carbon (Ghimire *et al.*, 2017; Lehman

et al., 2015). One of the major land management practices affecting soil characteristics nearly 20% is tillage (Khurshid *et al.*, 2006). Authentic use of tillage is advantageous in overcoming problematic edaphic conditions such as alkalinity/salinity, whereas, malapropos use of tillage has several detrimental impacts on soil characteristics (Rashid and Keshavarzpour, 2007). Incessant conventional tillage practices lead to modification of soil structure as the change in soil bulk density and moisture content (Powlson *et al.*, 2012; Alam 2010). Change in soil physicochemical characteristics modifies living environments of soil microorganisms thereby, decrease in soil fertility. A major solution to this problem lies in the introduction and long term application of conservative agriculture practices such as zero/minimum tillage, mulching, green manuring etc., which rejuvenate and enhance soil microbial richness and diversity. (Alam 2010).

Zero tillage is a combination of both ancient and modern agricultural practices. It has various advantages such as conservation of soil moisture as it retains 50-100% residues on the soil surface, reduction in cost of cultivation (Lefevre *et al.*, 2017; Huang *et al.*, 2012). Numerous retrospect studies on the impact of zero and conventional tillage systems without the added organic amendments on soil microbial communities have been analyzed in different cropping systems. These studies mostly concluded that zero tillage leads to increase in microbial diversity and richness under surface layers (Pastorelli *et al.*, 2013; Ceja-Navarro *et al.*, 2010; Helgason *et al.*, 2009; Feng *et al.*, 2003; Ibekwe *et al.*, 2002; Pankhurst *et al.*, 2002 and Treonis *et al.*, 2004). Zero tillage increases the organic matter retention and cycling of nutrients in soil, amount the variety of life in soil thereby promoting crop growth and yield. It was also revealed that

phylogenetic 16S rDNA sequencing analysis of bacterial community under zero-tillage was similar to those bacterial communities that fix atmospheric nitrogen and also that degrade methylbenzene.

The transition of tillage to zero tillage leads to increase in total biomass (202%) and variation among soil microbial community (Hegelson *et al.*, 2009). Similar conclusive experimental were drawn by Feng *et al.*, (2003); Ibekwe *et al.*, (2002) and Pankhurst *et al.*, (2002) also indicated that soil microbial communities were more on surface layers of soil in zero tillage.

The second principle of conservation agriculture implies the application of permanent soil covering materials either crop residues or live mulches (FAO, 2014). Organic amendments are frequently supplemented with zero tillage to increase its efficiency. Crop residues as mulches, wheat straw mulch, paddy straw mulch, and cover crops are commonly used. Zero-tillage, when combined with organic amendments, has a substantial diversity of microflora and enhanced enzyme activities (Zhang *et al.*, 2010; Cao *et al.*, 2011; Mangalassery *et al.*, 2015). Fungal communities were more in zero tillage with organic amendments whereas the bacterial communities were more in conventional tillage with organic amendments.

The addition of organic amendments enhanced the growth of Burkholderiales and fluorescent *Pseudomonas* spp (Trenois *et al.*, 2010). Govaerts *et al.*, (2007) also concluded that with the addition of organic amendments higher counts of bacteria, actinomycetes and fluorescent *Pseudomonas* were observed in both conventional and zero tillage systems. Similar outcomes were drawn by Peixoto *et al.*, (2006) with the use of PCR-DGGE in rice- soybean cropping systems.

These unprecedented conservation practices such as zero-tillage, crop residue addition, and improved nutrient management are having global interest to unveil secrets of relationship between the use of conservation agriculture enactment and sustainably increase food production under rice-wheat cropping patterns (Erenstein and Laxmi, 2008; Johnston *et al.*, 2009). The short term and long term influences on soil properties is still compelling, so the objective of the current study was planned to outline the short-term impact of different tillage systems on soil physicochemical, plant root growth, biological, and activity parameters.

Materials and Methods

Experimentation site

Initially, land was under conventional practices and transition of conventional to conservation practices was initiated during the 2017 Kharif season. Trails of the current study were performed for two consecutive rabi seasons 2017-18 and 2018-2019 at the Students research farm, Department of Agronomy, Punjab Agricultural University, Ludhiana. It comes under trans-Gangetic plain region of agro-climatic zones and lies at 30°54'N, 75°98'E and 247 m above sea level. Soils were a majority of alluvial soils. Soil taxonomy was presented in table I.

Experimental design

Cropping pattern of the study was the basmati rice-wheat cropping pattern. The first crop grown was Basmati rice during the Kharif season (June-October) and winter wheat (November-April) during the rabi season. The wheat crop length period is of 155-160 days. Wheat variety sown was WHD-943a medium to late maturing, semi-dwarf, bold seed released from CCS HAU, Hissar during 2011. The experimental design was RBD –

randomized block design with six organic treatments and one control with three replications. Three tillage systems zero tillage (ZT), deep tillage (DT) and conventional tillage (CT) alternatively supplemented with paddy straw mulch which total comprises six treatments. Paddy straw mulch 6t/ha and our unit size were 7.5 X 5 m². A control treatment was also a CT without mulch but it encompassed recommended agrochemicals. Samples were drawn at a depth of 0-15 cm from each tillage treatment at 60, 90, 125 and 155 DAS. Destructive volumetric sampling under which plant was pulled out completely and rhizosphere soil was collected by continuous tapping on its roots.

Soil analysis

Rhizospheric soil collected was divided into three sections for analysis. Out of which one was for soil physicochemical analysis, pH, E.C, soil texture, available phosphorous and potassium. Soil pH was analysed by Beckman glass electrode, E.C by conductivity meter (DSM-1), texture analysed by hand and feel method, available phosphorous HNO₃-HClO₄ digestion followed by colorimetry using Baton's solution. Potassium was quantified by HNO₃-HClO₄ digestion and flame photometer (Official methods, AOAC, 2003). Second, profiling of soil microflora was performed on four different media viz Nutrient agar, Jensen's agar and National Botanical Research Institute's Agar (NBRIP), Yeast Extract Mannitol's Agar (YEMA) as per the method serial dilution pour plate method as outlined by Aneja, (2003).

Thirdly, analysis of enzyme activity both acid and alkaline phosphatase activity as a method outlined by Tabatabai and Bremner, (1969) using para-nitrophenyl phosphate as substrate. Dehydrogenase activity as per the method outlined by Samuel, (2010) using 2,3,5-Triphenyltetrazolium chloride (TTC).

Statistical analysis

Different parameters were analysed for the level of significance at 0.5 (C.D. 5%) through one-way ANOVA (Analysis of Variance) using software CPSC-1 in the Department of Statistics and Mathematics, College of Basic Sciences and Humanities Punjab Agricultural University, Ludhiana. Computation and preparation of graphs were calibrated using Microsoft Excel 2010 Program.

Results and Discussion

Soil physicochemical parameters

Different tillage treatments of clay loam texture recorded neutral to alkaline (7.4-8.5) pH and E.C ranged from 0.16-1.1 milli Simmons /ml. No statistically significant differences in soil pH and texture were observed, subtle differences were recorded. Rhizospheric soil samples drawn from T3 (ZT+R) reported a higher E.C (1.1 milli simmons /ml) at 125 DAS and lower E.C (0.163millisimmons /g) of T6 (CT-R) at harvest stage (155 days).

Different tillage treatments (DT, ZT, CT) with added organic residues exhibited lower pH and higher E.C. It was concluded from numerous studies that pH and E.C. are negatively correlated. Lower pH indicates more H⁺ ions and also high soluble salts resulting in increase of E.C. (Carmo *et al.*, 2016).

Soil samples irrespective of different tillage treatments measured a decline in electrical conductivity, at initial stages from a season I to season II. It assumed due to ion-humic complexes are formed at later stages, in the growth of rice. These complexes negatively influence soil E.C. Similar observations have been reported by Sarwar *et al.*, (2003) who detected the presence of ion-humic complexes in rice crops.

Available phosphorus and potassium

Rhizospheric soil samples irrespective of different tillage treatments reported higher concentrations of phosphorous in the season I & II i.e. above 40 kg/ha. Available potassium was high in T3 (ZT+R) soils pertaining 531, 240 kg/ha respectively and lower rates of 210, 129 kg/ha were found in T6 (CT-R) soils as per fig.I. Observations of the present study are in agreement with Sharma *et al.*, (2016) and Bhatt (2017) who stated that the cultivable land of Punjab has 113 kg/ha of available phosphorous and more than 44 kg/ha of available potassium. There is a decrease in phosphorous and potassium concentration from a season I to season II. Mineralization or biological immobilization is reported to cause a decline in soil phosphorous and potassium (Shelbolina *et al.*, 2014, Han and Lee 2005).

Soil microflora richness & diversity

Soil microbial richness and diversity varied with tillage. Of three types of tillage, zero tillage (ZT+R, ZT-R) recorded higher viable (9.8 log cfu/g), *Azotobacter* (5.54 log cfu/g) and phosphate solubilizers (4.72 log cfu/g) count from 90 to 125 DAS. Lower viable 9.1 log cfu/g and *Azotobacter* 4.9 log cfu/g counts were exhibited by DT-R soil samples at 60 DAS. However, no significant difference was found in case of phosphate solubilizers among conventional, deep and control treatments as shown in fig II a-d.

Nevertheless, the phosphate solubilizers were more in season II compared to season I. With the intensity of tillage decreased the *Azotobacter spp.* at surface layers (Watts *et al.*, 2010). Altogether, diazotrophic count as it is root exudates dependent, progressively increased from 60 DAS to 90 DAS and then decreased at 125DAS and 155 DAS during both seasons as per fig II. The reason ought to be that zero tillage assist in building of the

soil structure for enhancing bacterial diversity, in contrast (conventional and deep) tillage results in breaking up of micro-sites, alter microbial interactions, soil compaction, erosion, a reduced pore volume, and desiccation (Lupwayi *et al.*, 2012). Furthermore, higher levels of available nutrients in the soil (total available phosphorous and potassium) and enzyme activity separated conservation (zero) tillage from tillage (conventional and deep).

In comparison to control, microflora diversity of mulched treatments of CT and DT, ZT-R was significant, but un-mulched treatment of CT, DT recorded either similar or less. This stipulates that amalgamation of tillage and mulch improved rhizospheric microbial life. Mulch acts as a sponge/ insulator for reducing fluctuations in edaphic properties (Frith, 2017).

Soil temperatures, moisture and water holding capacity fluctuate quickly in un-mulched conditions (Ambayeba Muimba-Kankolongo, 2018). Soil temperature gets hotter in summer, sucks out moisture quickly contrarily, very cold in winter. This eventually kills top soil biodiversity and potentially affecting some roots, weakening the plant in the future. Besides, mulch also provides ample food for the microorganisms in the soil. (Frith, 2017).

Organic amendments resulted in the complex production of organic acids (gluconic acid or lactic acid and citric acid) which solubilize the unavailable phosphorous in soil and are the cues of rhizodeposition (Chen *et al.*, 2006; Lin *et al.*, 2006). Zero-tillage soils and T5-CT+R have exhibited the higher phosphate solubilisation and *Azotobacter* count which indicates richness of phosphate solubilizers and root exudates (Rosolem and Calonago, 2013). Microscopically examination of plate isolates were mostly gram-ve, cocci and in chains.

Enzyme activities

Phosphatases are group of extracellular enzymes are of prime agronomic value as they hydrolyses compounds of organic phosphorous and mineralizes them into different forms of inorganic phosphorous that are assimilated by plants (Meastre *et al.*, 2011). Acid phosphatases are both plant and microbial origin whereas alkaline phosphatases are of purely microbial origin (Rejesck *et al.*, 2012). Phosphatases and phosphate solubilizing microorganisms ameliorated during season II.

Total viable count and alkaline phosphatases were correlating with each other, as with an increase in the former, subsequently, increase in the latter. Consequently during both seasons, soil samples drawn from T3 (ZT+R), T4 (ZT-R) at 125DAS recorded the highest alkaline phosphatase activity of 0.17 μ g PNP/g/min and 0.12 μ g PNP/g/min respectively. T7 (control) exhibited lower activity 0.03 μ g PNP/g/min during both the seasons. It may be due to the formation of certain end products as a result of fertilizer applications mainly nitrogen fertilizers (Nanniperi *et al.*, 2011). Furthermore, the viable count and enzyme activity (except control) was higher in the second season compared to the first as in graph (fig III).

Acid phosphatases measure the activity of ortho-phosphates in the alkaline soil pH of 7.8-8.1 (Nanniperi *et al.*, 2011). In both the seasons, activity in soils of tillage treatments increased consistently up to 125DAS and then declined at 155 DAS. T3 (ZT+R) treatment, at 125DAS, recorded a high value of 0.53PNP/g/min and T7 (control) soil samples recorded lower acid phosphatase activity, 0.011 PNP/g/min at 60 DAS, respectively. Enzyme activity was fluctuating during both the seasons and throughout the season (Tarafdar *et al.*, 2001).

Table.1 Soil taxonomy of the experimental site

Soil Taxonomy (Thorntwaite 1948)	
Order	Entisol
Suborder	Fluvents
Parent material	Alluvial
Type	Khandar
Topography	Monotonous plain

Table.2 Variation in soil pH, E.C and texture during both seasons (2017-18& 2018-19)

Treatment	pH		E.C (milli Simmons/g)		Soil texture
	2017-18	2018-19	2017-18	2018-19	
T1 DT+R	7.77±0.11	7.8±0.07	0.4b±0.043	0.223a±0.026	clay loam
T2 DT-R	7.80±0.09	7.7±0.1	0.33c±0.04	0.218a±0.043	clay loam
T3 ZT+R	7.70±0.16	7.75±0.15	0.52a±0.1	0.233a±0.037	Clay loam
T4 ZT-R	7.80±0.13	7.82±0.1	0.34d±0.04	0.207a±0.04	Clay loam
T5 CT+R	7.85±0.09	7.85±0.08	0.39c±0.08	0.21a±0.075	Clay loam
T6 CT-R	7.90±0.09	7.9±0.07	0.28c±0.05	0.163b±0.04	Clay loam
T7 Control	7.90±0.0205	7.9±0.04	0.29d±0.015	0.209a±0.012	Clay loam

± Implies to SE (standard error); where n (sampling plots) = 7; r(replication)= 3; N(Total number of plots) = 21

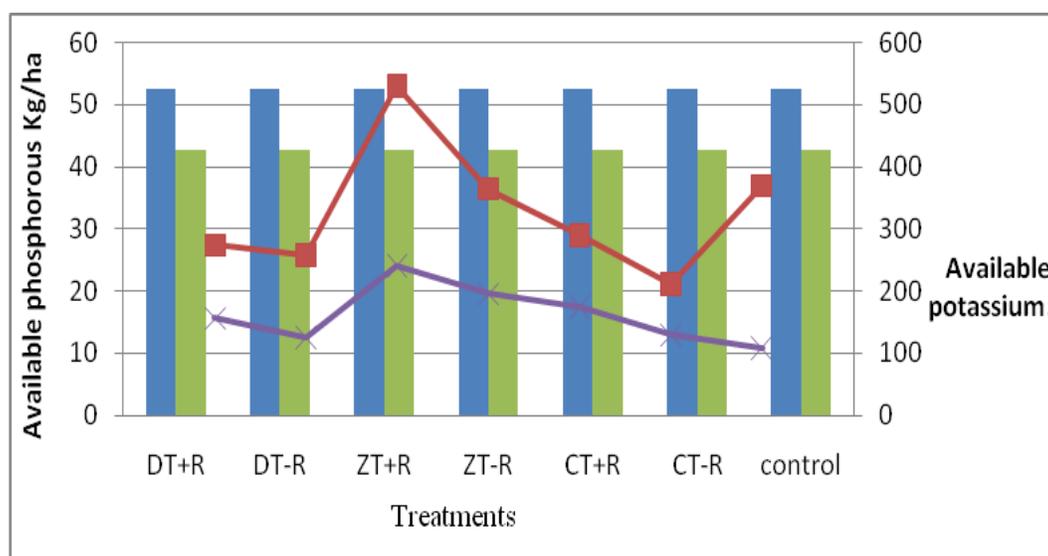


Fig.1 Illustrates available phosphorus and available potassium in different treatments during both seasons

Available phosphorous 2017- 18
 Available phosphorous 2018-19
 Available potassium 2017-18
 Available potassium 2018-19

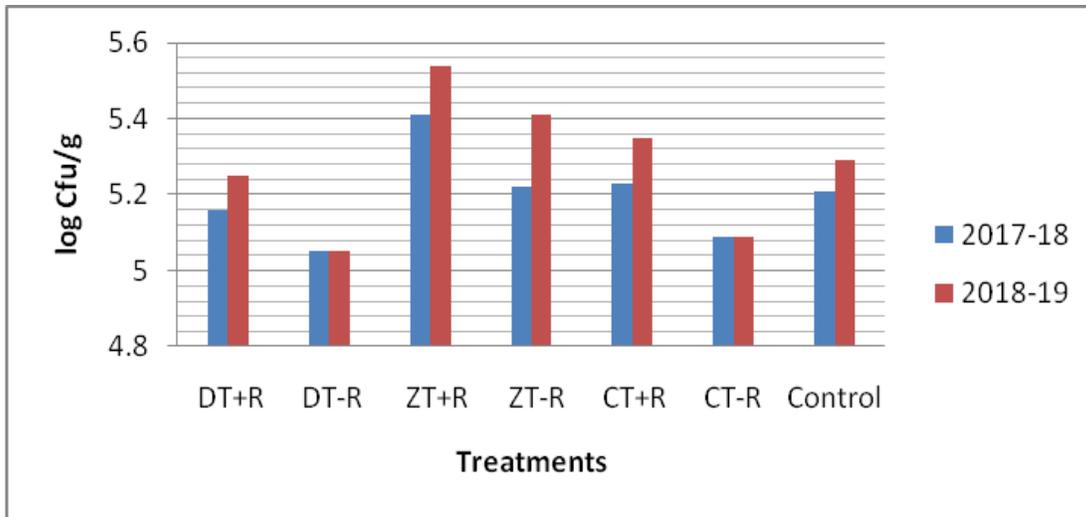


Fig.2 Mean Azotobacter counts (log cfu/g) of two seasons

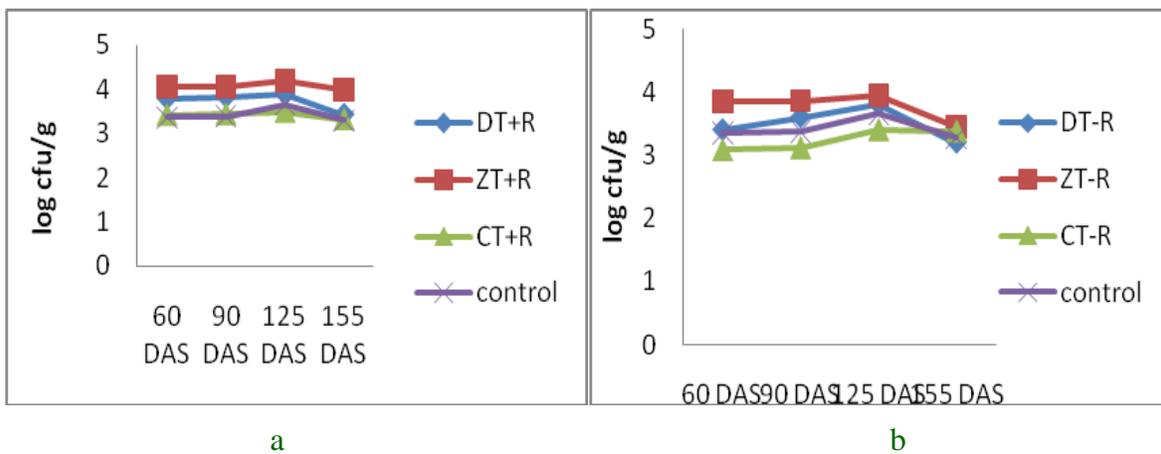


Fig.3 a,b Log cfu/g phosphate solubilizing microorganisms during 2017-18

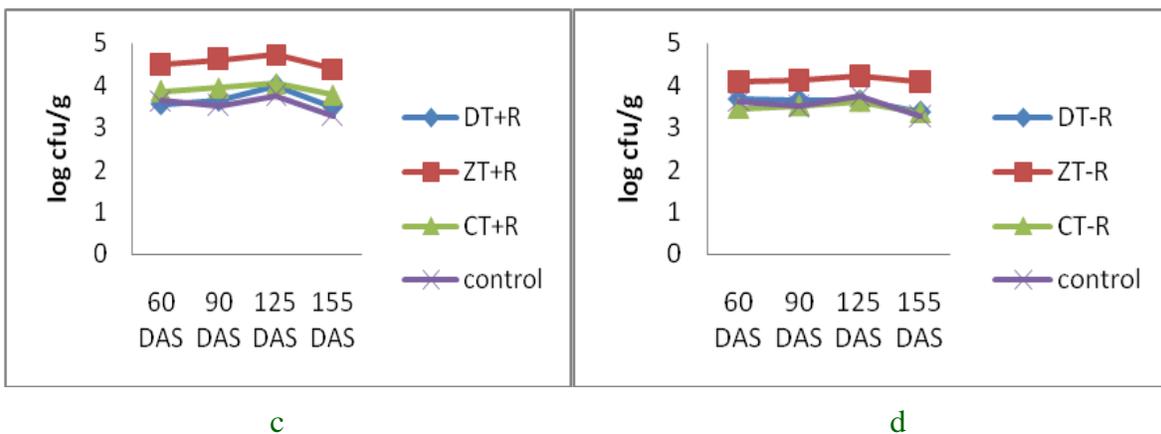


Fig.3 c,d implies Log cfu/g phosphate solubilizing microorganisms during 2018-19

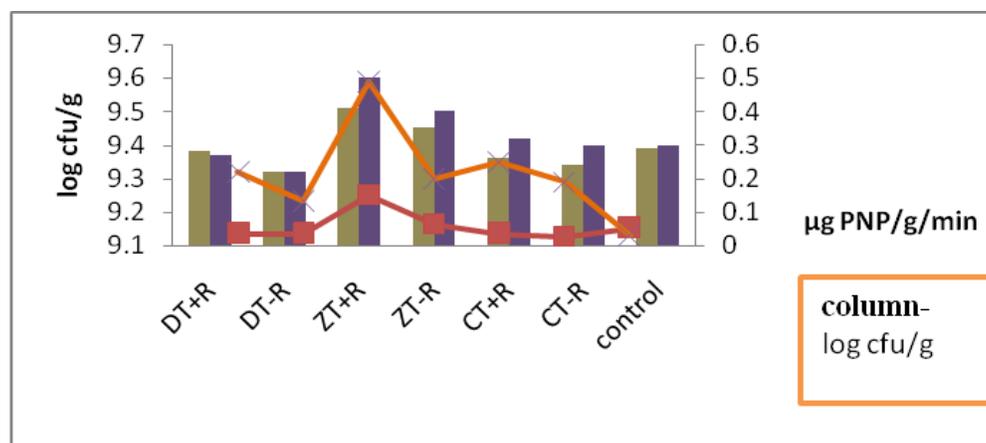
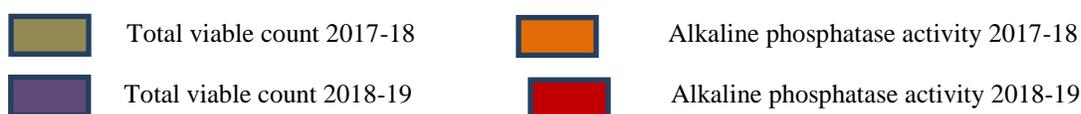


Fig.4 Illustrates the total viable count and alkaline phosphatase activity during both seasons



Reportedly, at surface layers, higher activity phosphatases enunciated in zero tilled soils when compared to conventional and deep tilled soils. The addition of organic amendments enhanced the activity of phosphatases irrespective of different tillage treatments at various crop growth stages (Zhang *et al.*, 2010). Soil physicochemical, biological and enzyme activities are in favour of ZT (both with and without residual) treatments whereas conventional with mulch treatment also has a remarkable effect compared to other treatments (DT (Deep tillage, control)). Disturbance of soil structure by tillage operations leads to a decline in microbial diversity due to desiccation, mechanical destruction, soil compaction, and reduced porosity, access to food sources which affects nutrient cycling and further overall soil quality.

Overall, numerous studies reported that organic agriculture will be a long term investment for a continuous profit. Even though a short term research, haven't found a distinguishing aftermath among treatments, nevertheless, there was increase of microbial diversity was recorded 1% both for T3 and T4, 0.7% T5 and 0.4% T7 for viable count,

1.7% T1, 3.3% T3, 2.3% T5, 0.1% T7 for *Azotobacter* and 11.8% T3, 8% T4, 2% T5 in case of phosphate solubilizing microorganisms. Alkaline phosphatases by 34% - ZT+R, 23.9%-CT+R, 17.8%-DT+R, 15.3%-ZT-R, 15.1%-CT-R, and 10.8%-DT-R; acid phosphatase activity was increased in different tillage treatments by 12%-ZT+R, 5.5%-CT+R, 2.2%-DT+R, 0.8%-ZT-R, 0.9%-CT-R were recorded at the end of season-II. CT-R, DT-R, and control treatments were almost similar in their effect except regarding enzyme activities. Conventionally tilled soils exhibited higher alkaline activities compared to deep tilled soils at various crop growth stages during both seasons (2017-18 and 2018-19).

To conclude, soil health is best conserved with zero tillage practices. This is further enhanced by the incorporation of organic residues. Un-mulched treatments indicate either lower or similar soil physicochemical, which in turn biological and enzyme activities compared to control therefore, indicating that mulch can improve soil properties. Deep tillage treatments also recorded lower soil physicochemical, biological, biochemical parameters compared to conventional and

zero tillage as they were presumed to be higher in deeper layers. Although, short-term conclusions were unable to provide a clear difference, speculations under long-term presumed to create a clear scenario.

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