

EFFECTS OF CONSERVATION TILLAGE AND WEED MANAGEMENT ON SOIL MICROBIAL COMMUNITY AND ENZYMATIC ACTIVITY

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Abstract

Conservation tillage and weed management practices were applied on maize-wheat cropping system to study the soil biological activities under Northern Himalayas region. The experiment included five tillage and three weed management treatments. Conservation agriculture (CA)-based management practices including residues incorporation (ZTR-ZTR), ZT-ZT, and ZT-ZTR showed higher soil microbial population (bacteria, fungi, and actinomycetes) and microbial activity during 2014-15 and 2015-16 in both maize and wheat crop as compared to conventional tillage (CT-CT). Among different weed management practices, IWM-IWM showed the highest microbial communities population and microbial activities as compared to the application of herbicides and weedy check. Results clearly exhibited that CA with all three proven principles (no-tillage, residue retention, and crop diversification) in the maize-wheat system along with intercrop resulted in higher microbial activities, and population compared to other conventional management systems.

Introduction

Intensive tillage method and misuse of herbicides contribute to soil degradation, loss of nutrients, and poor soil health (Jat *et al.* 2020) and reduction in soil microbial community along with crop productivity (Venkatramanan *et al.* 2021). Therefore, conservation agriculture (CA) with three basic principles of minimum/zero tillage, crop diversification and covering of the soil permanently with available live straw sustain crop productivity, soil biota that resulted better quality and health (Sapkota *et al.* 2014). In addition to zero-tillage along with residue incorporation and crop rotation has been widely used to increase microbial biomass and enhance enzymatic activity (Wang *et al.* 2016) which as a result affect productivity and soil organic carbon dynamics (Dong *et al.* 2014). Herbicides will affect soil microorganisms in different ways depending on their chemical composition, concentration, species, and environmental conditions (Zain *et al.* 2013).

Maize-wheat is the third most important cropping system having 1.8 m ha area and contributes nearly about 3% of the total food grain production of the North Western Himalayan region (Jat *et al.* 2011). Soil health deterioration is a continuous phenomenon under intensive cropping system in both rain-fed and irrigated ecosystems. Benign effects of conservation agriculture on soil quality index (chemical, physical and biological) help to cut down soil losses due to erosion, stabilize soil temperature and moisture, control weed population, and build up high conditions for soil flora and fauna. Conservation tillage practices contribute to nutrient cycling (Khurshheed *et al.* 2019) and decomposition of residues reported to improve the health of soil ecosystem (Dong *et al.* 2014). Conservation tillage along with its principle of crop rotations enhances soil microbial count, biomass (Guo *et al.* 2016) and enzymatic activity (Nivelle *et al.* 2016). In spite of their composition, activities and environmental phenomenon affect crop productivity and soil organic carbon footprints (Dong *et al.* 2014). However, continuous tilled soil

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illustrated higher fungal population which restricts soil arbuscular mycorrhizal fungi and hyphae (Hage-Ahmed *et al.* 2019) as compared to conservation tillage. Therefore, the present study was carried out to determine the comparison of conventional and conservation tillage along with various weed management tactics on microbial activities and to find out correlations between microbial population with maize and wheat crop yield.

Materials and Methods

The experiment was carried out from 2014-16 at Research Farm of Department of Agronomy, Himachal Pradesh Agriculture University, Palampur, India. The experiment included five tillage treatments *viz.* conventional tillage both in maize and wheat (CT-CT), conventional tillage in maize followed by zero tillage in wheat (CT-ZT), zero tillage in maize during *kharif* season and zero tillage in wheat during *rabi* season (ZT-ZT), zero tillage in maize and zero tillage incorporated with residue in wheat (ZT-ZTR) and zero tillage incorporated with residue in both maize and wheat (ZTR-ZTR); and three weed management treatments *viz.* herbicides in both maize and wheat (H-H), integrated weed management in both maize and wheat (IWM-IWM) include (Herbicide + mechanical + inter crop) and weedy check in both maize and wheat (WC-WC). Tillage and weed management treatments were arranged in horizontal and vertical strips, respectively, under strip plot design with three replications. The CT plots were plowed with a power tiller whereas, in conservation tilled plots hand plough was used for planting to just open the furrow and seed placement in it and residue incorporation was done from the preceding crop. During *kharif* "Harit Soya" a soybean (*Glycine max* L.) variety as an intercrop with maize in additive series and "HPBS-1" a mustard (*Brassica juncea*) variety as intercrop in replacement series with wheat crop were used. The experimental was carried out on silty clay loam soil having a pH of 5.6 (acidic), available 338 kg N/ha, 12.0 kg P/ha, and 225 kg K/ha. In maize, fertilizers N, P₂O₅ and K₂O at 120, 60 and 40 kg/ha, respectively, whereas, in wheat, 120 kg N, 60 kg P₂O₅ and 30 kg K₂O/ha were supplied through urea (46% N), SSP (16%) and MOP (60% K₂O). Plot-wise composite soil samples from 0-15 cm were taken with the help of tube auger. The sample soil was air-dried processed and passed through a sieve of 2 mm for lab assignments. Dehydrogenase activity, acid phosphate and alkaline phosphate and MBC were determined by using methods given by Casida *et al.* (1964), Tabatabai and Bremner (1972) and Vance *et al.* (1987), respectively. Statistical analysis of the data was performed and tested at a 5% level of significance to interpret the treatment differences by LSD comparison method. Correlation and regression analysis of crop yield and microbial activities was evaluated by three-factor analysis using the OPSTAT software package. Treatment means were tested at a 5% level of significance (SPSS 16.0).

Results and Discussion

Results of soil microbial count as influenced by various tillage and weed management treatments are presented in Table 1. Generally, of the total microbial propagules density, around 10% less has been considered with plate counts estimation. Differences in the colony forming unit (CFU) among different management practices reflect an incitement of soil micro-flora. In the present experiment, conservation tillage gave out higher microbial count as compared to conventional agriculture system. Pertinent data revealed that the microbial population was upper most in the ZTR-ZTR during both maize and wheat under tillage treatments (Table 1). IWM had the highest CFU values under weed management treatments. Treatment ZT-ZTR and ZT-ZT also had higher bacteria (10⁵ CFU/g of soil), fungi (10³ CFU/g of soil), and actinomycetes (10³ CFU/g of soil) population as compared to CT-CT and CT-ZT.

Table 1. Effect of tillage and weed management practices on soil microbial population (2014-16) (Pool data of two years).

Treatment (Maize – Wheat)	Bacteria (x10 ⁵)		Fungi (x10 ²)		Actinomycetes (x10 ³)		Total PSM (x10 ⁴ /g dry soil)		Microbial biomass carbon (µg/g soil)	
	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat
Tillage										
CT-CT	8.170 ^c	9.201 ^d	2.255 ^c	2.736 ^d	1.187 ^d	1.286 ^{bc}	38.558 ^c	37.556 ^d	706.3 ^c	899.8 ^c
CT-ZT	8.542 ^d	9.572 ^{cd}	2.267 ^b	2.866 ^{bc}	1.233 ^c	1.273 ^c	41.183 ^c	43.648 ^c	723.1 ^d	939.7 ^{bc}
ZT-ZT	8.744 ^c	9.744 ^c	2.248 ^c	2.838 ^{cd}	1.273 ^b	1.290 ^b	44.796 ^b	50.167 ^b	743.2 ^c	946.8 ^b
ZT-ZTR	8.867 ^b	11.187 ^b	2.269 ^b	2.926 ^{ab}	1.277 ^b	1.317 ^a	46.986 ^b	51.412 ^b	770.8 ^b	987.0 ^{ab}
ZTR-ZTR	9.641 ^a	12.609 ^a	2.279 ^a	2.934 ^a	1.308 ^a	1.322 ^a	51.503 ^a	55.611 ^a	809.3 ^a	1003.6 ^a
SEm±	0.034	0.129	0.004	0.026	0.008	0.006	1.014	0.8	809.3	18.0
LSD (p=0.05)	0.112	0.420	0.012	0.084	0.025	0.020	3.306	2.477	8.5	58.9
Weed management										
H-H	8.731 ^b	10.351 ^b	2.257 ^b	2.836	1.236	1.286 ^b	40.831 ^c	41.481 ^b	711.6 ^c	907.0 ^b
IWM-IWM	8.895 ^a	10.566 ^a	2.272 ^a	2.893	1.281	1.315 ^a	47.351 ^a	52.721 ^a	785.2 ^a	1011.8 ^a
WC-WC	8.752 ^b	10.471 ^b	2.262 ^{ab}	2.850	1.250	1.291 ^b	45.635 ^b	48.835 ^a	754.8 ^b	947.3 ^b
SEm±	0.025	0.037	0.003	0.016	0.010	0.002	0.811	1.289	5.9	12.2
LSD (p=0.05)	0.098	0.144	0.010	NS	NS	0.009	3.183	5.060	23.0	48.0

CT, conventional tillage; ZT, zero tillage; R, residues; H, herbicide; IWM-IWM, integrated weed management; WC, Weedy check; figures with same sign as superscript in a same factor mean statistically at par with each other;

Minimal soil disturbance and incorporation/retention of crop residues in conservation tillage increased soil micro-flora populations. Total bacteria population was significantly higher in ZTR-ZTR over ZT-ZTR and CT treatments, irrespective of all the weed management practices in wheat. With a numerical accession similar trend was found in maize crop. IWM proved well among all weed management practices with a significant difference during both the seasons and remained statistically same to weedy check during the *rabi* season. ZTR-ZTR listed highest fungi population followed by ZT-ZTR and CT-ZT compared to CT treatments in both wheat and maize crop. Among weed management treatments, IWM recorded the highest fungi count during both wheat and maize crop. In the case of actinomycetes population, the higher count was observed in ZTR-ZTR over CT-CT in *kharif* and *rabi* seasons, respectively. ZTR-ZTR+IWM-IWM showed the highest actinomycetes count than conventional tillage methods during both *kharif* and *rabi* seasons. Soil microbial activities are the key factors for soil health index and sustainability (Sharma *et al.* 2011) and determine the stability of soil ecosystems (Nannipieri *et al.* 2003). Majority of the results showed that the conservation agriculture ultimately increased soil microbial dynamics and activity in the maize-wheat cropping system. IWM treatments by intercropping of two different crops in the same land brought higher soil microbial population which might be far away for complex communities to catch equanimity under monoculture of the crops.

The relationships of economic yield and soil microbial population are illustrated in Table 2. The economic yield of the maize crop was correlated significantly and positively with the

population of actinomycetes ($r = 0.553^*$), whereas non-significant in case of bacterial and fungal population. However, wheat economic yield was significantly correlated with the three soil microbial populations i.e. bacterial population ($r = 0.502^*$), fungal population ($r = 0.552^*$) and actinomycetes population ($r = 0.664^{**}$).

Table 2. Correlation between the economic yield of wheat and maize with soil microbial population.

Microbial population	Maize yield (Y_m)			Wheat yield (Y_w)		
	Correlation matrix	Equation	R^2	Correlation matrix	Equation	R^2
Bacteria	NS	$Y = 0.0002381 * X + 7.764$	0.1545	0.502^*	$Y = 0.001098 * X + 5.886$	0.2517
Fungi	NS	$Y = 6.393e-006 * X + 2.236$	0.1730	0.552^*	$Y = 7.273e-005 * X + 2.557$	0.3051
Actinomycetes	0.553^*	$Y = 3.139e-005 * X + 1.120$	0.3060	0.664^{**}	$Y = 2.654e-005 * X + 1.187$	0.4410

Where Y_w = wheat yield, Y_m = maize yield; x = microbial population; *Significant at 5% level of significance; **Significant at 1% level of significance.

Tillage treatments significantly affected enzymatic activities (microbial biomass carbon [MBC], total phosphatase solubilizing microorganisms [PSM], dehydrogenase activity [DHA], basal soil respiration [BSR] and acid and alkaline phosphatase). Weed management practices were also affected by enzymatic activities except for acid phosphatase and alkaline phosphatase after maize harvest. It is observed from the Table 1 that the significant results of MBC ($\mu\text{g/g}$ soil) and PSM ($\times 10^4/\text{g}$ dry soil) were higher in the ZT-ZT and ZTR-ZTR. A higher MBC and PSM in the ZTR-ZTR system were obtained which remained statistically at par with ZT-ZTR when compared to the CT. However, IWM showed the highest MBC and PSM as compared to weedy check and herbicide applications during maize and wheat harvesting of two years. DHA ($\mu\text{g TPF/g}$ soil/hr.) is an indicator of soil microbial activity which reflects the intensity of oxidative activity of metabolism of soil microorganisms.

Topsoil layer significantly ($p < 0.05$) influenced DHA under different tillage and weed management treatments. Higher DHA is the sign of higher microbial activity and stable soil health. The significant ($p < 0.05$) maximal DHA was recorded under ZT-ZTR and under ZTR-ZTR treatments higher against conventional tillage. In case of weed management treatments, IWM showed the highest value when compared with H-H and WC-WC, after the harvesting of both maize and wheat. The DHA in the rhizospheric soil was higher in ZTR-ZTR and ZT-ZTR treatments as compared to CT respectively. As far as other enzymatic activities are concerned, tillage affected BSR ($\text{mg CO}_2/\text{h}/100 \text{ g soil}$) ($p < 0.05$), whereas weed management treatments could not affect BSR. Highest value of basal soil respiration was recorded in the conservation tillage treatments (Table 3) after the harvest of both maize and wheat. ZTR-ZTR treatment (especially the residue incorporation) stimulated the activity of the enzymes. These higher BSR rates are the consequence of greater microbial biomass. Phosphatase activity (acidic and alkaline) ($\mu\text{g p-nitrophenol/g}$ of soil/h) of the topsoil layer in the crop rhizosphere was examined after harvest of the crop. Phosphatase activity (acidic and alkaline) was significantly ($P < 0.05$) influenced by tillage and weed management treatments. The maximum phosphatase activity was recorded under ZTR-ZTR which was higher over CT during maize and wheat harvest, respectively. The observation of lower acid phosphatase activity under CT might be due to lower

SOC content. However, IWM-IWM showed the highest acid and alkaline phosphatase activity followed by weedy check compared to H-H during both the seasons. Zero tillage along with preceding crop residue in rhizospheric root zone below the soil surface enhances soil water holding capacity (Jin *et al.* 2009), which as result significantly increases microbial enzymatic activities (Jin *et al.* 2009) as compared to CT. Zero tillage with surface residue retention increases phosphatases activity (Wang *et al.* 2011) and DHA (Heidari *et al.* 2016). Liu *et al.* (2016) revealed that MBC concentration was significantly higher under zero tillage treatments. Acid phosphatase activity was greater under zero tillage than under conventionally plowed plots with a disk harrow and disk plow (Chaudhary *et al.* 2018).

Table 3. Effect of different tillage and weed management practices on soil enzymatic activity (2014-16).

Treatment (Maize – Wheat)	Dehydrogenase activity ($\mu\text{g TPF/g soil/hr.}$)		Basal soil respiration ($\mu\text{g/g/min}$)		Acid phosphatase ($\mu\text{g/g/h of soil}$)		Alkaline phosphatase ($\mu\text{g/g/h of soil}$)	
	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat
Tillage								
CT-CT	1.705 ^d	1.803 ^b	0.510 ^d	0.658 ^e	20.408 ^c	17.314 ^e	6.717 ^d	6.863 ^{bc}
CT-ZT	1.767 ^{cd}	1.748 ^c	0.523 ^{cd}	0.682 ^d	20.850 ^{bc}	18.124 ^{de}	6.843 ^c	6.997 ^b
ZT-ZT	1.815 ^{bc}	1.729 ^{cd}	0.535 ^{bc}	0.760 ^c	21.648 ^b	18.643 ^{cd}	6.917 ^{bc}	7.009 ^{ab}
ZT-ZTR	1.832 ^b	1.698 ^d	0.562 ^{ab}	0.778 ^b	22.004 ^{ab}	19.228 ^{bc}	7.077 ^a	6.686 ^c
ZTR-ZTR	1.908 ^a	1.830 ^a	0.583 ^a	0.796 ^a	23.769 ^a	20.608 ^a	7.120 ^a	7.137 ^a
SEm \pm	0.022	0.016	0.009	0.002	0.441	0.320	0.026	0.084
LSD (p=0.05)	0.073	0.053	0.029	0.008	1.437	1.042	0.085	0.275
Weed management								
H-H	1.776 ^b	1.742 ^b	0.530	0.727	20.855 ^c	18.423	6.929 ^b	6.800 ^b
IWM-IWM	1.846 ^a	1.790 ^a	0.551	0.744	22.847 ^a	19.457	6.972 ^a	7.156 ^a
WC-WC	1.794 ^b	1.754 ^b	0.546	0.734	21.506 ^b	18.471	6.904 ^b	6.860 ^b
SEm \pm	0.010	0.007	0.005	0.004	0.349	0.395	0.011	0.049
LSD (p=0.05)	0.038	0.027	NS	NS	1.370	NS	0.045	0.192

CT, conventional tillage; ZT, zero tillage; R, residues; H, herbicide; IWM-IWM, integrated weed management; WC, Weedy check; figures with same sign as superscript in a same factor mean statistically at par with each other;

Results from the present study showed that on a short-term basis, soil microbial dynamics and activities are highly influenced by the method and degree of tillage practices along with either incorporation of residue is done or not and different tactics of weed management used in maize wheat cropping system. Zero tillage with residue retention under during both cropping seasons increase was found to the soil microbial population. MBC, DHA, BSR, acid phosphatase, and alkaline phosphatase were maximum under the CA-based system, as compared to the conventional system. The ZT production systems are the utmost adequate procedure for increasing soil microbial biomass, carbon and enzyme activities in a relatively short term and for sustaining higher crop productivity. However, IWM resulted in higher microbial population, and soil

enzymatic activities as compared to the application of recommended herbicides during both seasons. ZTR-ZTR+IWM-IWM could be the better option for a higher economic yield of maize and wheat and soil microbial population and activities.

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