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TILLAGE AND WEED MANAGEMENT PRACTICES EFFECT ON YIELD, SOIL ORGANIC CARBON AND ENZYME ACTIVITIES UNDER MAIZE-WHEAT CROPPING SYSTEM

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ABSTRACT

An ongoing field experiment initiated in 2012 at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar, India was selected to evaluated the effect of three tillage practices (zero tillage, furrow irrigated raised bed system and conventional tillage) and four weed management practices (W_1: Atrazine (50% W.P.) @ 750 g/ha in maize and pinoxaden 50g/ha + premix of metsulfuron and carfentrazone (Ally Express 50% DF) 25g/ha + 0.2 % NIS as post-emergence in wheat, W_2: Tembotrione (Laudis 42% Sc @ 120 g/ha + S 1000ml/ha (10-15 DAS / 2-4 leaf stage) in maize and clodinafop 60 g/ha + metsulfuron 4 g/ha as post- emergence in wheat, W_3: Two hand weeding (HW) in maize (20 to 40 DAS) and wheat (30 to 50 DAS), W_4: Weedy check in maize and wheat) on yield, soil organic carbon (SOC) and soil micro biological properties. All the treatments were laid out in permanent plots under spilt plot design with three replication. Soil and plant samples were taken in April, 2016 after the harvesting of wheat. Significantly higher yield of wheat (pooled of four year) and maize (pooled of three year) was recorded under FIRBS followed by zero tillage and conventional tillage. Similarly under different weed management practices, hand weeding gave higher yield of wheat and maize over chemical weed control and weedy check treatments. Measurements made at the end of 4 years, showed that in the 0-15 cm soil depth, mean value of SOC (0.896%), MBC (336.02 mg kg^{-1}) reported higher under ZT followed by FIRBS and CT. However, dissolved organic carbon followed reverse trend and higher values observed under conventional tillage (415.37mg kg^{-1}). All enzymes (dehydrogenase, alkaline phosphatase and urease) activities reported higher under zero tillage followed by FIRBS and CT. MBC, dehydrogenase and urease activity reported higher at upper depth (0-5cm) while activity of alkaline phosphatase was higher at lower depth (5-15 cm). At the end of season weed management practices showed non-significant effect on MBC and all enzymatic activities indicating no adverse effect of herbicide application on soil microbiological properties.
***Keywords*:** Tillage, weed management, grain yield, soil organic carbon, MBC, enzymes.

Introduction

The furrow irrigation raised bed system (FIRBS) and zero tillage (ZT) is the tillage centric resource conserving technologies recommended for sustainable production in Indo Gangetic plains within the larger domain of conservation agriculture. Conservation technologies might appear less profitable initially but their benefits come over a period of time. Tillage is mechanical manipulation of soil as to provide a good seed bed for initial establishment of crops and also control weeds effectively. Tillage practices leads to aeration of soil which accelerates the oxidation of soil organic matter and consequentially translates in carbon loss in the form of carbon dioxide. Conservation tillage allows crop residues at surface to act as an insulator and thus improves rhizospheric, microbial biomass (Helgason *et al.,* 2010), soil carbon (Lal *et al.,* 2003), mineralizable N (Spargo *et al.,* 2011), enzyme activities (Alvear *et al.,* 2005), conserving soil moisture (Ma *et al.,* 2008) and moderating soil temperature fluctuations. Soil enzyme activities and microbial biomass responds rapidly to different management practices and thus considered as more reliable and sensitive indicators of good soil quality than other soil physico-chemical properties. The impact of tillage on the relationship between microbes and SOM is primarily through the impact of disturbance of the soil microclimate and the decomposition rate of crop residues.

Tillage can have both a negative and positive effect on weed seed banks. Tillage may temporarily incorporate some weed seeds into deeper layers while bringing others to the soil surface where they are exposed to the conditions necessary for germination (Santín-Montanyá *et al.*, 2016). Greatest challenges associated with implementation of conservation agricultural practices, eliminating tillage which mayresult into increase in weed pressure during the early period of adoption(Chauhan *et al.* 2012).However, with good weed management interventions, weed pressure should decrease over time, often within the first few years of adoption. In recent years, herbicide have been developed and found promising tool in weed management and their use made it possible to reduce mechanical approaches of weed control and increased adoption of reduced and no tillage crop production system. The direct and indirect effects of herbicide use on soil quality can range from negative to positive as understood by several researchers (Vandana *et al.*, 2012; Emurotu and Anyanwu, 2016; Arunakumari *et al.,* 2018 and Tejashree *et al.,* 2018). Use of herbicides as a sole control mechanism increases the risk of herbicide-resistant weeds population in field (Norsworthy *et al.,* 2012) and thus new herbicide molecules (pinoxaden, metsulfuron, carfentrazone, tembotrione, clodinafop etc and their combinations) are introduced to manage them. So the impact of these herbicides on soil microbial environmental must be evaluated for sustaining soil health. Keeping in view of above facts the present study was planned to observe the effect of different tillage and weed management practices on soil organic carbon stock and soil microbiological properties.

Material and Methods

Site characteristics

An ongoing field experiment since Rabi, 2012 with Maize-Wheat cropping sequence at Research Farm, Department of Agronomy CCS Haryana Agricultural University, Hisar was selected for the present study. The experiment was started in 2012 with wheat (Cv.WH 1105) in *Rabi* season and followed by maize (Cv.HQPM-1) in *Kharif* season in the same plot. The experimental site is located at 29°16'N latitude and 75°7'E longitude at the mean sea elevation of 215.2m in north-west part of India. The soil of experimental site was sandy loam, *Typic Ustocherpt*. The climate of the area is semiarid type, with very hot summers and relatively cool winters. The main characteristics of climate in Hisar are dryness, extremes of temperature, and scanty rainfall. The maximum daytime temperature during the summer varies between 40 and 47 °C and during winter; it varies from 1.5and 4 °C. Annual average maximum and minimum temperature is 32.3 °C and 15.4 °C, respectively. Relative humidity varies from 5 to 100%. Hisar is located on the outer margins of the south-west monsoon region. The average annual rainfall is around 429 mm, most of which occurs during the monsoonal month of July and August.

Treatments and lay out of experiment

The experiment of the present study was laid out with three tillage treatments in main plot and four weed management practices in sub plot under split plot design having three replications. The tillage practices i.e. conventional tillage (CT), zero tillage (ZT) and furrow irrigated raised bed system (FIRBS) were adopted in permanent plots in the same field. Different weed management practices viz: W_1: Atrazine (50% W.P.) @ 750 g/ha in maize and pinoxaden 50g/ha + premix of metsulfuron and carfentrazone (Ally Express 50% DF) 25g/ha + 0.2 % NIS as post-emergence in wheat, W_2: Tembotrione (Laudis 42% Sc @ 120 g/ha + S 1000ml/ha at 10-15 DAS / 2-4 leaf stage) in maize and clodinafop 60 g/ha + metsulfuron 4 g/ha as post-emergence in wheat, W_3: Two hand weeding (HW) in maize (20 & 40 DAS) and wheat (30 & 50 DAS), W_4: Weedy check in maize and wheat were applied in sub plot. The above tillage practices were adopted in both the crops. FIRBS system with permanent beds was maintained by only reshaping/repairing the existing beds at the time of sowing of each crop. The recommended dose of NPK fertilizer (150:60:60 kg/ha) were applied to both crops and other management practices were followed as per university recommendations.

Soil sampling and analyses

Moist soil samples were collected in triplicate from each plot (0-5 and 5-15cm depths)at the time of maturity of wheat crop in the month of April, 2016 after harvesting four wheat crop and three maize crop from each plot during the intervening period from 2012-16. Soil samples were mixed thoroughly and one part of the sample of about 100 gm was kept in refrigerator at 4 °C for analysis of microbial properties. The remaining part of soil samples was air dried, grounded and sieved through a 0.5 mm sieve before analysis of soil organic carbon. The organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Dissolved organic carbon in soil was determined by dichromate oxidation of 1:5 soil water extract (Ciavatta *et al.,* 1989). Microbial biomass carbon was determined by chloroform fumigation method as proposed by Vance *et al.* (1987). Soil dehydrogenase activity was determined by estimating the rate of production of tri-phenyl formazan (TPF) from tri-phenyl tetrazolium (Casida *et al.,* 1964). Alkaline phosphatase activity was measured by the method described by Tabatabai and Bremner (1969). Urease activity was measured by the method described by Tabatabai and Bremner (1972). Soil organic carbon stock was calculated by SOCXBDX soil depth. Soil bulk density of 0-5 and 5-15 cm depth layers was progressively determined using the core method (Blake and Hartage, 1986).

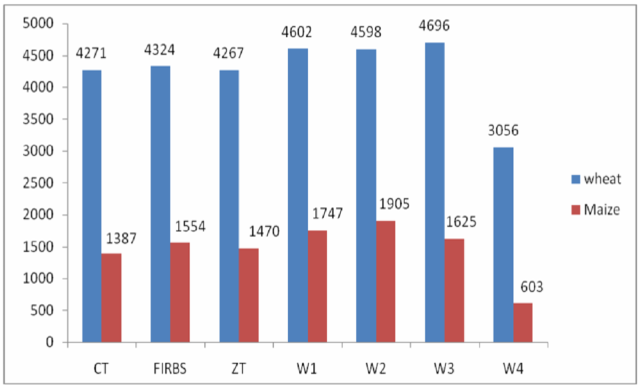
Statistical analysis

The data obtained under study were statistically analyzed using spilt plot design. Comparisons among treatment means were made using the least significant difference (LSD) calculated at $P < 0.05$ subjected to statistical analysis for significance using OPSTAT software.

Results and Discussion

Grain yield of wheat and maize

Pooled grain yield of wheat and maize was significantly affected by different tillage practices and highest (4324, 1554 kg/ha) and lowest (4217, 1387 kg/ha) grain yield of wheat and maize, were recorded under FIRBS and CT, respectively (Fig 1). The higher grain yield under FIRBS was mainly due to higher number of effective tillers and number of grains per spike. The grain yield of wheat under ZT was statistically at par with CT. Similar type of results was also reported in other studies under Indian conditions (Singh *et al.*, 2017 and Kumar *et al.,* 2018). The data also revealed that significantly lower grain yield of wheat and maize (3056, 603 kg/ha, respectively) was observed under weedy check as compared to other weed management practices. This lower yield was due to competition between weeds and crops for water, nutrients and sunlight. About 2% percent higher grain yield of wheat was observed with manual weeding over herbicide application of W_1 and W_2 treatments, respectively. This may be due to better soil aeration and loosening of soil by hoeing. While highest grains yield of maize (about 14%) was observed in herbicide treatment of W_2 as compared to manual weeding (W_3). Singh *et al.* (2002b) also observed highest grain yield of wheat under ZT weed-free situation as compared to CT weed-free situation. The lower grain yield of maize than the average yield was observed in the present study was due to lack of assured irrigation as canal water is the source of irrigation and underground water is brackish at research farm. The annual rainfall of the region is about 443 mm and during past four years we have receive deficit rainfall. Thus maize a high water requiring crop cannot be the substitute for pearl millet in semiarid western part of Haryana.



C.D. (p=0.05): Wheat (Tillage (T) = 62 Weed (W) = 64 TXW = NS); Maize (Tillage (T) = 42 Weed (W) = 46 TXW = NS)

Fig. 1: Pooled yield (kg/ha) of wheat and maize under different tillage and weed management practices

Soil Organic Carbon

Soil Organic Carbon (SOC) content of soil after taking four wheat and three maize crops significantly affected by different tillage practices (Table 1). The highest mean value of SOC was observed under ZT (0.896 %) followed by FIRBS (0.84 %) and CT (0.78 %). It was due to more retention of crop residue at soil surface under ZT and FIRBS as compared to CT. Another possible reason was minimum disturbances of soil under ZT and FIRBS, which reduces the oxidation of organic matter. Data also revealed that SOC content in soil significantly decreased at lower depth as compared to upper depth in FIRBS and zero tillage conditions. However, such type of results was not observed under CT. Interaction between tillage and depth showed significant effect on SOC contentand highest mean value of 0.99% was observed at 0-5 cm depth of weedy check treatment under zero tillage system. Mean value of SOC content varied from 0.78 (CT) to 0.97 % (ZT) at 0-5 cm depth and 0.77 (CT) to 0.82 % (ZT) at 5-15 cm depth under different tillage and weed management practices. ZT system showed an average increase of 9% and 19% of SOC at upper depth and 3% and 7% at lower depth over FIRBS and CT, respectively. The SOC content decreased more at 5-15 cm depth in ZT due to less amount of crop residue incorporation as compared to upper depth (Zuber *et al.,* 2018, Aseno *et al.,* 2019). Khorami *et al.*(2018) reported the highest SOC under reduce tillage (RT) followed by NT and CT. While Issaka *et al.* (2019) observed that conventional tillage recorded 10.37% higher TOC than conservation tillage. Effect of different weed management practices on SOC was non-significant however, numerically higher values were observed under weedy check treatment under all tillage practices.

Table 1: Effect of tillage and weed management practices on SOC (%) at different soil depth

	Conventional tillage			FIRBS			Zero tillage		
	Depth		Mean	Depth		Mean	Depth		Mean
	0-5cm	5-15cm		0-5cm	5-15cm		0-5cm	5-15cm	
W_1	0.77	0.76	0.76	0.87	0.80	0.83	0.96	0.82	0.89
W_2	0.78	0.77	0.77	0.88	0.79	0.83	0.97	0.81	0.89
W_3	0.77	0.77	0.77	0.87	0.80	0.83	0.97	0.82	0.89
W_4	0.80	0.79	0.79	0.89	0.81	0.85	0.99	0.83	0.91
Mean	0.78	0.77	0.77	0.88	0.80	0.84	0.97	0.825	0.90
C.D. (p=0.05) : Tillage (T) = 0.07, Weed (W) = NS, Depth (D) = 0.08, TXW = NS, TXD = 0.12, WXD = NS, TXWXD = NS									

Soil organic carbon stock

Soil organic carbon stock at both the depth was significantly affected by different tillage practices. The higher mean value of SOC stock was observed under ZT (14.06t/ha) followed by FIRBS (13.19 t/ha) and CT (12.41 t/ha) (fig. 2). Data also revealed that SOC stock in soil decreased at lower depth compared to upper depth in FIRBS and zero tillage conditions. However, such type of results were not observed under CT. Interaction between tillage and depth showed significant effect on SOC and higher value was observed at 0-5 cm depth under zero tillage. Value of SOC stock varied from 12.17 (CT) to 15.44 t/ha (ZT) at 0-5 cm depth and 12.16 (CT) to 13.28 t/ha (ZT) at 5-15 cm depth under different tillage and weed management practices. ZT system showed increase of 9% and 16% of SOC stock at upper depth and 3% and 5% at lower depth over FIRBS and CT, respectively. Effect of different weed management practices on SOC stock was non-significant, however; slightly higher value was observed under weedy check treatment of all tillage practices. Bama *et al.* (2017) also reported higher value of SOC stock under zero/ no tillage as compared to CT.

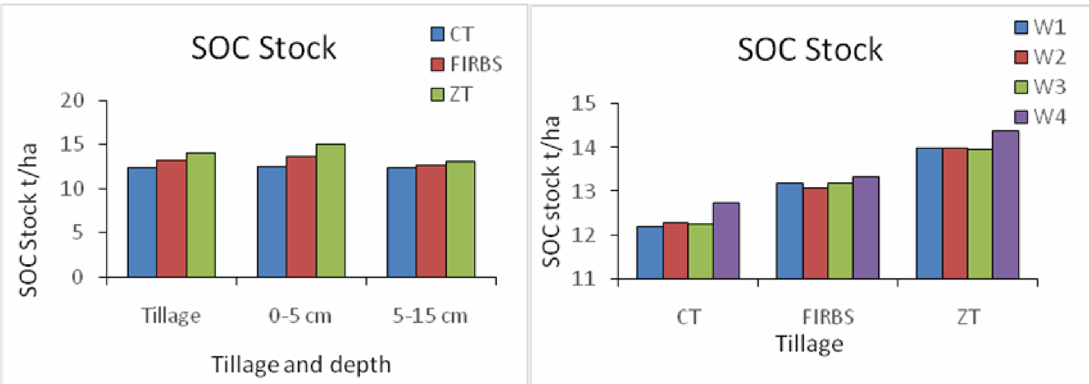


Fig. 2: Effect of tillage and weed management practices on SOC stock (t/ha) at different soil depth

Dissolved organic carbon

Dissolved organic carbon (DOC) content in soil was significantly affected by different tillage practices; however effect of weed management practices and soil depth was not significant (Table 2). Highest value (415.37 mg kg^{-1}) of DOC was observed under CT which was 9% and 11% higher than that of FIRBS and ZT, respectively. The lower DOC content under ZT system may be due to increase in pore size and continuity of pores that's leads to more leaching of DOC from upper plough layer. Tillage cause mixing of crop residue, which by enhancing the oxidative microbial activity increases the DOC content (Leinweber *et al.,* 2001). Data also revealed that DOC slightly increased at lower depth under CT, however reverse trend was observed under FIRBS and ZT, but difference was non-significant. Interaction between tillage and depth was significant and highest value (424 mg kg^{-1}) was observed at 5-15 cm under weedy check of CT practice. Values of DOC varied from 368 to 416 mg kg^{-1} at upper depth (0-5 cm) and 362 to 424 mg kg^{-1} at 5-15 cm soil depth under different tillage and weed management practices. CT system showed increase of 7% and 9% of DOC at upper depth and 11% and 13% at lower depth over FIRBS and ZT, respectively. However, the other interactions were non-significant. Bama *et al.* (2017) also reported the higher value of DOC under CT as compared to minimum and ZT that was due to disturbance caused by tillage which would have releases easily dissolvable organic carbon. While Dou *et al.* (2008) reported higher DOC under NT as compared to CT.

Table 2: Effect of tillage and weed management practices on DOC (mg kg^{-1}) of soil at different depth

	Conventional tillage			FIRBS			Zero tillage		
	Depth		Mean	Depth		Mean	Depth		Mean
	0-5cm	5-15cm		0-5cm	5-15cm		0-5cm	5-15cm	
W_1	412	420	416	378	375	376.5	368	370	369
W_2	416	422	419	380	372	376	370	368	369
W_3	410	419	414.5	382	376	379	371	362	366.5
W_4	400	424	412	375	377	376	372	370	371
Mean	409.5	421.25	415.37	378.75	375	376.87	370.42	367.5	368.87
C.D. (p=0.05): Tillage (T) = 5.47 Weed (W) = NS, Depth (D) = NS TXW= NS TXD = 7.9 WXD = NS, TXWXD = NS									

Microbial Biomass Carbon

The results pertaining to microbial biomass carbon (MBC) content in soil revealed that tillage practices significantly affected the MBC content and highest mean value (335.1mg kg^{-1}) recorded with in CT followed by FIRBS (295.39 mg kg^{-1}) and ZT (273.33 mg kg^{-1}) (Table 3). Depth wise distribution of MBC revealed that highest amount (372 mgkg^{-1}) was recorded at 0-5 cm depth under ZT which was 5% and 2% higher than FIRBS and CT respectively. However, at lower depth (5-15 cm) CT showed increase of MBC values by 22% and 42% over that of FIRBS and ZT respectively. Higher MBC recorded under ZT at upper depth might be due to several factors, such as lack of soil disturbance provides a steady source of organic carbon to support the microbial community, less disturbance also favors the formation and stabilization of macro aggregates to improve and protect habitat for microorganism. Higher MBC at lower depth under CT practice might be due to homogenous mixing of crop residue up to 15 cm depth provides more carbon substrate for their growth and proliferation (Kumar *et al.,* 2017 and Zuber *et al.,* 2018). Interaction between tillage and depth showed significant effect and highest value (369.75mg kg^{-1}) under ZT. However, other interaction was non-significant. Weed management did not show significant effect on MBC, however numerically higher value was observed in weedy check than other treatment. This may be due to loosening of soil under manual weeding and removal of weed enhances the accessibility of microbes to incorporated organic matter. The data also indicated that the magnitude of difference in the MBC value at upper and lower depth was more in ZT followed by FIRBS. This may be due to decrease in organic matter in lower depth due to less homogenization and disturbance of soil by tillage practices.

Table 3: Effect of tillage and weed management practices on Microbial Biomass Carbon (MBC) (mg kg^{-1}) at different depth

	Conventional tillage			FIRBS			Zero tillage		
	Depth		Mean	Depth		Mean	Depth		Mean
	0-5cm	5-15cm		0-5cm	5-15cm		0-5cm	5-15cm	
W_1	362.00	305.33	333.66	348.67	243.50	296.08	368.00	177.50	272.75
W_2	360.33	307.83	334.06	354.33	237.67	296.00	372.00	174.67	273.33
W_3	366.00	309.33	337.66	346.67	239.33	293.00	371.00	176.00	273.5
W_4	363.33	306.67	335	357.00	236.00	296.50	368.00	179.50	273.75
Mean	362.91	307.29	335.1	351.67	239.12	295.39	369.75	176.92	273.33
C.D. (p=0.05): Tillage (T) =43.7 Weed (W) = NS Depth (D) = 21.7 TXW = NS TXD = 37.66 WXD = NS TXWXD = NS									

Dehydrogenase Activity

The results related to dehydrogenase activity (DHA) are expressed as rate of formation of tri-phenyl formazan (TPF) from tri-phenyl tatrazolium chloride (TTC). Adoption of ZT significantly increase the DHA activity as compared to other tillage practices and follows the trend ZT>FIRBS>CT (Table 4). The highestmean value of DHA (44.51µg $TPFg^{-1}$ $24hr^{-1}$) recorded under ZT followed by FIRBS (35.64 µg $TPFg^{-1}$ $24hr^{-1}$) and CT (27.53 µg $TPFg^{-1}$ $24hr^{-1}$). On an average, ZT cause 19% and 38% higher activity of dehydrogenase over FIRBS and CT, respectively. Activity of dehydrogenase in ZT was higher about 21%, 34% at upper depth and 17%, 44% at lower depth over same conditions of FIRBS and CT, respectively. The highest mean value of DHA under ZT was due to more left-over crop residue, undisturbed natural ecosystem of ZT stimulated the enzyme activity. CT leads to the impairment of soil microbiological activity and aggregate stability, therefore, decreased enzyme activities (Acosta-Martinez *et al.,* 2003). Bama *et al.* (2017) and Aseno *et al.* (2018) also reported higher activity of DHA under ZT as compared to other tillage practices. Data also revealed that DHA activity significantly decreased at lower depth (5-15 cm) as compared to upper depth under all tillage and weed management practices. DHA activity varied from 35.38 to59.6 µg $TPFg^{-1}$ $24hr^{-1}$ and 16.16 to 33.17 µg $TPFg^{-1}$ $24hr^{-1}$ at upper and lower depth, respectively. This might be due to lower organic carbon content in soil at lower depth. Aseno *et al.,* 2018 also reported decrease in activity of DHA at lower depth as compared to upper depth. Weed management practices showed non-significant effect on dehydrogenase activity which indicates that there was no residual effect of herbicides on soil microbial processes. Rao *et al.* (2017) also observed non significant effect of herbicide application on dehydrogenase activity. However, Tomkiel *et al.* (2015) reported that optimum dose of carfentrazone stimulate the dehydrogenase activity. Among all interactions, interaction between tillage and depth showed significant difference and highest value(59.6 µg $TPFg^{-1}$ $24hr^{-1}$) recorded under 0-5 cm depth under ZT having mechanical weed management practices, however lowest value(16.16 µg $TPFg^{-1}$ $24hr^{-1}$) of DHA observed at 5-15cm soil depth under CT with W_2 treatment.

Table 4: Effect of tillage and weed management practices on dehydrogenase (µg $TPFg^{-1}$ $24hr^{-1}$) activity at different depth

	Conventional tillage			FIRBS			Zero tillage		
	Depth		Mean	Depth		Mean	Depth		Mean
	0-5cm	5-15cm		0-5cm	5-15cm		0-5cm	5-15cm	
W_1	36.13	17.02	26.58	44.33	26.88	35.60	55.14	31.54	43.34
W_2	37.66	16.16	26.91	45.11	28.03	36.57	56.74	33.17	44.95
W_3	35.38	19.37	27.37	43.45	25.68	34.56	59.6	31.64	45.62
W_4	38.91	19.65	29.28	45.23	26.44	35.83	55.57	32.75	44.16
Mean	37.02	18.05	27.53	44.53	26.76	35.64	56.76	32.26	44.51
C.D. (p=0.05) : Tillage (T) = 8.91 Weed (W) = NS Depth (D) = 4.5 TXW= NS TXD =7.9 WXD = NS TXWXD = NS									

Alkaline Phosphatase Activity

Alkaline phosphatase (ALP) activity was significantly affected by tillage at both soil depth (Table 5). Highest activity (512.52µg PNP g^{-1} $24hr^{-1}$) of alkaline phosphatase was recorded under ZT followed by FIRBS (420.82 µg PNP g^{-1} $24hr^{-1}$) and CT (377.36 µg PNP g^{-1} $24hr^{-1}$). The activity of ALP under ZT was about 33% and 46% (0-5 cm) and 4% and 9% (5-15 cm) higher than that of CT and FIRBS respectively. Higher activity of ALP under ZT may be due to higher accumulation of organic P and lack of soil disturbance as compared with other tillage practice. Mina *et al.* (2008) found that ALP activity was 9.3- 48.1 % higher in ZT system over CT practices. Mathew *et al.* (2012) and Aseno *et al.* (2018) observed that soil under the long-term no-till treatment had higher phosphatase activities at the 0–5 cm depth than that under the CT treatment. Contrary to this, Kheyrodin *et al.* (2012) observed higher ALP activity in tillage treatments as compared to no-till plots. Data also showed that ALP activity significantly increased at lower depth (5-15 cm) as compared to upper depth (0-5 cm) under all the tillage practices and their value varied from 246.92 to 500.51 µg PNP g^{-1} $24hr^{-1}$ and 313.05 to 560.05 µg PNP g^{-1} $24hr^{-1}$ at upper and lower depth respectively under different tillage and weed management practices. Results of present study are contradictory to that of Kheyrodin*et al.*(2012)who reported lower ALP at lower depth. Effect of weed management practices on alkaline phosphatase activity was non-significant which shows that there is no adverse effect of herbicides on ALP activity at the end of cropping season. Recommended dose of herbicide (metasulfuron & atrazine) application typically have limited effect on soil enzyme activities (Rose *et al.,* 2018), however, optimum dose of carfentrazone stimulate the ALP activity (Tomkiel *et al.,* 2015).Among all interaction, interaction between tillage and depth showed significant difference on ALP activity and higher mean value of 550.57 µg PNP g^{-1} $24hr^{-1}$ recorded under ZT at 5-15 cm soil depth and lowest mean value of 254.49µg PNP g^{-1} $24hr^{-1}$ was observed at 0-5 cm soil depth

Table 5: Effect of tillage and weed management practices on alkaline phosphatase (µg PNP $g^{-1}hr^{-1}$) activity at different depth

Conventional tillage				FIRBS			Zero tillage		
	Depth		Mean	Depth		Mean	Depth		Mean
	0-5cm	5-15cm		0-5cm	5-15cm		0-5cm	5-15cm	
W_1	255.89	478.10	366.99	313.05	533.91	423.48	461.28	545.78	503.53
W_2	256.59	481.77	369.18	317.09	523.04	420.06	474.38	551.06	512.72
W_3	258.56	557.8	408.18	324.33	525.15	424.74	500.51	560.05	530.28
W_4	246.92	483.29	365.10	316.59	513.37	414.98	461.69	545.38	503.53
Mean	254.49	500.24	377.36	317.77	523.87	420.82	474.47	550.57	512.52
C.D. (p=0.05) : Tillage (T) = 22.53 Weed (W) = NS Depth (D) = 35.13 TXW = NS TXD = 43.87 WXD = NS TXWXD = NS									

Urease Activity

Urease activity significantly influenced by tillage practice at both 0-5 cm and 5-15 cm depth (Table 6). Higher activity (160.46µg NH^+_4-$Ng^{-1}hr^{-1}$) of urease was observed under ZT and lowest under CT (149.05µg NH^+_4-$Ng^{-1}hr^{-1}$). ZT system showed increase of 5% and 10% of urease activity at upper depth and 3% and 4% at lower depth over FIRBS and CT respectively. Mullen *et al*. (1989) found that no tillage treatment with post-harvest residue increased urease activities. Similarly, Mikanova *et al.* (2006) found higher activity of urease under protective tillage with residue biomass-mulch as compared to other tillage practices. Data showed that activity of urease significantly decreased at lower depth (5-15 cm) as compared to upper depth (0-5 cm) and their values varied from148.29 to 171.33µgNH^+_4-$Ng^{-1}hr^{-1}$ at upper depth and 146.23 to 155.23 µgNH^+_4-$Ng^{-1}hr^{-1}$at lower depth. Higher urease activity at upper surface also due to higher urea substrate applied by broadcasting of fertilizers during crop growth season. Kheyrodin *et al.* (2012), and Aseno *et al.* (2018) also reported a decrease in urease activity at lower depth. The magnitude of decrease in urease activity was less under CT due to mixing of soil by tillage practices. In the present study, weed management practices did not show significant effect on urease activity. As concentration of atrazine increased correspondingly urease activity also increased in a 70 days incubation study conducted by Emurotu and Anyanwu (2016), however, atrazine application along with tembotrione showed mixed response as reported by Aruna Kumari *et al.* (2018). Among all the interactions, effect of tillage and depth interaction was significant

Table 6: Effect of tillage and weed management practices on urease (µgNH^+_4-$Ng^{-1}hr^{-1)}$ activity at different depth

Conventional tillage				FIRBS			Zero tillage		
	Depth		Mean	Depth		Mean	Depth		Mean
	0-5cm	5-15cm		0-5cm	5-15cm		0-5cm	5-15cm	
W_1	153.63	148.37	151.00	160.40	150.37	155.38	162.73	156.53	159.63
W_2	149.00	146.73	147.865	159.73	148.40	154.06	167.60	154.63	161.11
W_3	148.29	149.93	149.11	158.23	150.67	154.45	171.33	155.23	163.28
W_4	150.20	146.23	148.215	155.87	149.80	152.83	164.60	151.00	157.80
Mean	150.28	147.82	149.05	158.56	149.81	154.18	166.57	154.35	160.46
C.D. (p=0.05) : Tillage (T) =7.7 Weed (W) = NS Depth (D) = 3.9 TXW= NS TXD = NS WXD = NS TXWXD = NS									

Bulk density

Bulk density of soil was not significantly influenced by different tillage and weed management practices at different soil depth (Fig. 3). Higher mean value (1.59 g cm^{-3}) of bulk density was found under ZT followed by FIRBS (1.58 g cm^{-3}) and CT (1.57 g cm^{-3}). The higher value of soil bulk density under zero tillage plots in the surface soil layer may be due to non-disturbance of the soil matrix, which resulted in less total porosity compared to tilled plots (Bhattacharyya *et al*., 2008). Many workers reported greater bulk density in zero tilled soil than conventionally tilled soil (Gajda *et al.,* 2017 and S*tanek-Tarkowska et al.,* 2018). Data also revealed that bulk density increased at lower depth as compared to upper depth and it varied from 1.54 to 1.60 g cm^{-3} at upper depth and from 1.56 to 1.60 g cm^{-3}at lower depth under different tillage and weed management practices. Bhattacharyya *et al.,* 2006 also reported similar trend of bulk density at different depth in Indian conditions.

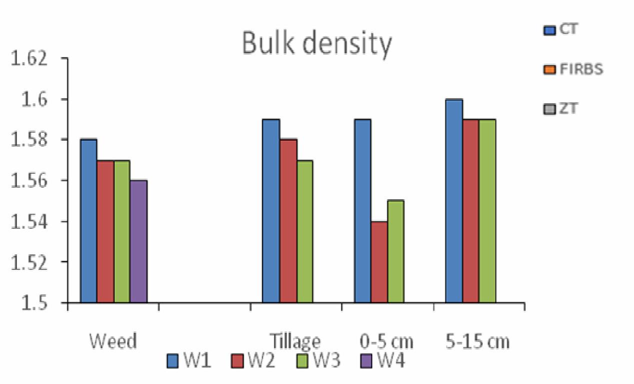


Fig. 3 : Effect of tillage and weed management practices on soil bulk density

Conclusion

Grain yield of wheat and maize was significantly higher under FIRBS followed by zero and conventional tillage. Result showed that in the 0-15 cm depth, SOC, MBC reported higher under ZT followed by FIRBS and CT, while dissolved organic carbon followed reverse trend. All enzymes (Dehydrogenase, alkaline phosphatase and urease) activities reported higher under ZT followed by FIRBS and CT. Dehydrogenase and urease activity reported higher at upper depth (0-5cm) while activity of alkaline phosphatase was higher at lower depth (5-15 cm). At the end of season weed management practices showed non-significant effect on MBC and all enzymes activities indicating no adverse effect of recommended herbicides on soil microbiological properties.

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