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Impact of tillage operations on wheat yield and chemical properties of soil: A review

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Abstract
Tillage by effecting soil conditions through manipulating its physical and chemical properties and influencing the availability of nutrients. Traditional practices are intensive tillage that leads to a negative impact on crop productivity and soil properties. Conservation agriculture including tillage reductions, better agronomy, and improved varieties, showed positive result on soil and plant health. Higher yield of crops reported under furrow irrigated raised bed (FIRBS) system followed by no tillage (NT) and conventional tillage (CT). Tillage practices may also influence the distribution pattern of soil organic carbon (SOC). It was observed higher SOC concentration in the surface layers in no tillage than conventional tillage. Zero tillage (ZT) treatment showed significantly higher macro and micronutrient levels in their available form than the other treatments. Mostly researchers reported higher dissolve organic carbon (DOC) under conventional tillage over the conservational tillage. Humus content was significantly affected by different tillage practices and reported higher under ZT and RT.

Keywords: Tillage, wheat yield, organic carbon and soil chemical properties

Introduction

Soil is an essential component of crop production, but soil management operations are necessary for increasing crop yield economically. Tillage has been considered as an inevitable operation for successful crop production. Tillage is mechanical manipulation of soil aimed at improving soil condition affecting crop production. It not only provides a good seed bed for initial establishment of crops but also control weeds effectively. Tillage operation involves in the manipulation of the soil upper layer and affects ecology of the soil by increase in soil organic carbon (SOC), biotic activity, soil porosity, agro-ecological diversity and reduction in soil erosion and carbon emission (due to less fuel consumption) (Derpsch *et al.,* 2010) [17]. Apart from affecting these physical and chemical parameters of the soil, it also affects the soil biological health. Incorporation of crop residue in the conservational tillage leads to tremendous increase in the microbial activities. Both fauna and flora flourished well in the conservational tillage. Due to optimization of physical, chemical and biological environment of the soil the yield of wheat crop increase under conservational tillage. Conventional tillage using a mouldboard plough, a hunk of deep soil to the surface, leads to creation of large pore in the plough layer, reduction in bulk density and escalation of soil porosity (Mousavi Bougar *et al.,* 2012) [58]. Conservational tillage is not only a concept, but a collection of series of field operation as well specifically aimed at protecting soil and water resources, securing agricultural income, reducing soil degradation and environmental degradation and conserving underlying resources (Kouchaki *et al*., 1997) [39]. Zero tillage system reduces erosion and other forms of land degradation with the corresponding benefit for national resource base. It improves environmental quality owing to less greenhouse gas emissions and air pollution made possible by reduced use of diesel fuel. It also saves 25 per cent water. Conventional tillage for wheat after rice consists of three to six ploughing operations. It involves loosening, granulating, crushing and inverting of soil to fulfil the general objective of weed control, residue incorporation and seed bed preparation. The mechanical method of weed control along with being very costly also cannot till the intra row weeds and they affect the growth and development of wheat crop. With the introduction of high yielding varieties demand for moisture and nutrient has increased immensely. Therefore, there is need to devise ways to check the losses of scarce and costly inputs. Soil and crop management practices, integrated use of minimum tillage combined with the fertilizer and herbicide can check the loss of these vital inputs to great extent and saving of energy.

Impact of tillage operations on grain and straw yield of wheat

Contradictory results were obtained by different tillage on yield of different crop in India and abroad. Changes in the same property can have different effects on crop growth and yield depending on dominant soil and climatic conditions (Małecka *et al*., 2004; Angas *et al*., 2006; Machado *et al*., 2007; Martin-Rueda *et al*., 2007; Lepiarczyk and Stępnik 2009 and Jug *et al*., 2011) [50, 65, 44, 33]. Bilalis *et al*., 2011 [9]; Naresh *et al*., 2012 [61], Singh *et al*., 2017 [68] and Kumar *et al*., 2018 reported significantly higher grain under FIRBS (Furrow Irrigated Raised Bed System) highest grain yield in the deep tillage followed by conventional tillage (CT) and lowest under zero tillage (ZT) during initiation but after 4 years, ZT having maximum grain yield but minimum straw yield. While Bhattacharyya *et al*. (2008) [8] reported that direct seeded CT plots had statistically similar grain yield as the direct seeded ZT plots, of rice and wheat, after 4 years of cropping although about 6% wheat yield decline was there under ZT. Tarkalson *et al.* (2006) [73] reported that NT increased the average grain yield of winter wheat and sorghum over CT by 300 and 1060 kg ha-1, respectively. Researchers from both Pakistan and India are reporting higher wheat yields under ZT in rice–wheat rotations in rice growing belt (Gupta and Seth, 2007) [28]. Sharma *et al*. (2009) [67] reported significant effects of tillage as well as conjunctive nutrient–use treatments on grain yield of sorghum and mung bean and found that CT up to the eighth year of the study maintained 12.8 and 11.2 % higher sorghum and mung bean grain yields, respectively, over reduced tillage. After eight years, reduced tillage tended to be equal or better than CT in improving crop yields. Malecka *et al*. (2012) [52] reported that the no-tillage system had a negative effect on yield of spring barley and reduced the yield of barley by 6.8% over CT. Martinez *et al*. (2016) [54] after long term experiment reported that the overall average crop yield was higher in NT than in mouldboard plough tillage but difference was insignificant.

Tillage operation vis a vis soil chemical property

pH and EC

pH is a factor that affecting soil fertility, which strongly influenced by cultivation and crop residue management. Tarkason *et al*. (2006) [73] under their long-term study found that the at 0-7.5 cm depth greatest acidification rate with NT, whereas in CT it occurred at 7.5- 15 cm depth. Govarts *et al*. (2007) in their study on permanent and conventional raised bed reported significantly higher pH in the topsoil (0–5 cm) of the permanent raised beds but no such effect was found in the 5–20 cm layer. Rahman *et al*., 2008 [64], Kaushik *et al*. (2018) [36] reported lower pH in NT as compared to CT. Contradictory result found by Cookson *et al*. (2008) [15] and lal (1997) [42] and reported a significantly higher in NT plots compared to those in tilled plots. Lopez-Fando and Pardo (2009) [49] reported lower pH (0.3 units) in uppermost layer (0-10 cm) for NT than for mouldboard plough tillage after 5 years but for 20-30 cm depth they reported higher pH for NT as compared to mouldboard plough tillage. Martinez *et al.* (2016) [54] after a long-term study reported soil slightly acidic pH (5.3) in 0-5 cm layer and approximately moderately acidic (5.0) in the 5-10 cm layer, while in case mouldboard plough pH was about 5.4 in both the layers. Issaka *et al*. (2019) [31] found that conservational tillage lowered value of pH by 2.87% over the conventional tillage at the depth of 0-20 cm.
Govaerts *et al*. (2007) [26] reported that management practices showed non-significant effect on electrical conductivity (EC) at 0–5 cm layer, but at 5-20 cm it was significantly higher under conventional raised beds as compared to permanent raised beds. Rahman *et al*. (2008) [64], Kahlon and Gurpreet (2014) [34] and Kaushik *et al*. (2018) [36] also reported the highest value of EC under NT as compared to CT. This may be due to higher pore size and porosity under zero tillage leads to leaching of the basic cations and reduces EC.

Available macronutrients

Nitrogen

Arshad *et al*. (1990) [4] found that available N content of surface soil was 25% higher under NT than CT plots. Ali *et al*. (2006) [2] also reported lowest value of soil N under conventional tilled plots. Lopez-Fando and Pardo (2009) [49] at the end of 5 year found that NT and ZT had increased N as compared to MT (minimum tillage) and CT at 0-30 cm depth and ZT had 0.5 Mg ha-1 and 0.3 Mg ha-1 more N over MT and CT. Jin *et al*. (2009) [32] observed that NT and sub soiling with mulch increased 8% higher N content over reduced tillage (RT) and CT. Moussa-Machraoui *et al*. (2010) [60] also reported more available N under NT due to more organic matter accumulation. Reduced tillage and NT favoured the surface accumulation of N in the soil as compared to CT (Malecka *et al*., 2012) [52]. Kahlon and Gurpreet (2014) [34] also reported that highest available nitrogen found under reduce tillage and lowest under the CT. Alam *et al*. (2014) [1] after 4year found that total N content was 73.68, 32.0, 13.79 % higher in ZT than the deep tillage, CT and minimum tillage respectively, and also found that with progressive time total N content gradually increased in ZT and minimum tillage. Similarly, Martinez *et al*. (2016) [54] studied from their long-term field experiment that NT showed a strong stratification regarding N content, with higher concentration of N in uppermost soil while mouldboard plough tillage showed uniform distribution of nitrogen throughout the depth. Kaushik *et al*. (2018) [36] reported higher value of available N at surface as well as sub surface under ZT as compared to CT.

Phosphorous

NT having higher available P in upper layer (0-10cm) as compared to CT (Standley *et al*., 1990; Unger *et al*., 1991) [69, 76]. Balota *et al*. (2003) [6] reported that extractable P in the soil increased by 398% and 96% for 0-5, 5-10 cm depth under ZT but decreased by 39% at 10-20 cm depth over CT. Gangwar *et al*. (2004) [24] reported higher value of phosphorous in CT as compared to ZT. Lopez-Fando and Pardo (2009) [49] reported that greater available P concentration under no and ZT as compared to minimum and CT at 0-5, 5-10, 10-20 cm depth, but no significant difference between all tillage practices at 20-30 cm interval. In contrast, Malecka *et al*. (2012) [52] found there were no significant effect of tillage on available P in the 0-5 cm and 10-20 cm layers. Alam *et al*. (2014) [1] noticed that the available P content was 41.90, 36.74, 9.66% higher in ZT than the deep tillage, CT and minimum tillage, respectively. Neugschwandtner *et al*. (2014) [62] revealed from their long term study that NT, deep conservational tillage and shallow conservational tillage increased P concentration in the uppermost soil layer (0-10 cm) as compared to mouldboard plough whereas at deeper depth (30-40 cm), NT and shallow conservation tillage decreased P concentration as compared to mouldboard plough and deep conservational tillage. According to Kahlon and Gurpreet (2014) [34], highest P was found under NT (58.1 kg/ha) as compared to CT (52.6 kg/ha). Martinez *et al*. (2016) [54] reported non-significant effect of

NT and mouldboard plough tillage on the total amount of P up to 0-50 cm depth. Kaushik *et al*. (2018) [36] found higher value of P under ZT as compared to CT under pearlmillet wheat cropping system. Issaka *et al*. (2019) [31] found 35.82% higher available P content under conservational tillage as compared to conventional tillage at the depth of 0-20 cm. Meng *et al*. (2019) [56] reported significantly higher contents of available phosphorus at 0-10 cm for NT then ploughing and rotary tillage.

Potassium

Malecka *et al*. (2012) [52] reported higher concentration of K under reduced tillage by 36.9 % and under NT by 51.0 % than that of under CT at 0-5 cm depth. However, Gangwar *et al*. (2004) [24] reported higher value of potassium in CT as compared to ZT. Govaerts *et al*. (2007) [26] reported that permanent raised beds had 1.65 and 1.45 higher concentration of K in the 0-5 cm and 5-20 cm layer, respectively, over conventional tilled raised beds. They found that K accumulated under both the tillage at 0-5 cm layer, but more accentuated in permanent than in conventionally tilled raised beds. Neugschwandtner *et al*. (2014) [62] reported accumulation of K occur with reduced tillage (NT and shallow conservation tillage) in the top soil layer and depletion in deepest soil layer over time. NT resulted in 2.90-fold increase in K at 0-10 cm and 1.38-fold at 10-20 cm depth over mouldboard plough. Contrary to that, NT reduced K level by 31% than mouldboard plough at 30-40 cm depth. Alam *et al*. (2014) [1] reported 42.11, 35.0, and 17.39% higher available K under ZT than the deep, conventional and minimum tillage, respectively. Kahlon and Gurpreet (2014) [34] found that higher K under NT as compared to CT. Similarly, Martinez *et al*. (2016) [54] reported the strong stratification showed by K in uppermost soil layer (0-2 cm) and concentration of K was 75 % higher in uppermost soil layer than at 10 cm depth. Kaushik *et al*. (2018) [36] reported higher value of available K under CT at both 0-5 and 5-15 cm depth over ZT. Issaka *et al*. (2019) [31] also reported 25.96% higher available K content under conservational tillage as compared to conventional tillage at the depth of 0-20 cm. Meng *et al*. (2019) [56] also observed higher value of available K at 0-10 cm depth under NT as compared to ploughed and rotary tillage.

Sulphur

There is a general correlation between organic matter and sulphur content (Eaton, 1922) soils of high organic matter having high sulphur content that why ZT having high sulphur content as compared to CT. Tracy *et al*. (1990) [75] found that ZT with wheat crop after 16 years accumulated greater SO4-S in the 0-2.5 cm soil depth then plough plots. Alam *et al*. (2014) [1] after four years of crop rotation and tillage noticed that available sulphur content was 34.45, 30.73, and 18.88 % higher in ZT as compared to deep, conventional and minimum tillage respectively. Kaushik *et al*. (2018) [36] also reported higher value of sulphur under NT.

Available micronutrients

Level of copper, zinc and manganese were higher in the soils with the highest level of organic carbon (Czekała and Jakubus; 2000, Straczynska and Straczynski; 2000). Rueda *et al*. (2007) [16, 65] reported that NT had higher amount of Zn, Cu, Mn and Fe in the upper layer as compared to CT. While Govaerts *et al*. (2007) [26] found that tillage practice had no significant effect on the extractable concentration of Fe, Mn, Cu in the 0-5 cm soil layer, but the amount of Zn was significantly lower in conventionally tilled raised beds with residue incorporation compared to permanent raised beds. Santiago *et al*. (2008) [66] reported from their long-term experiment that NT had higher amounts of DTPA extractable Mn, Cu, and Zn than under CT and minimum tillage, while effect of tillage was non-significant on the amounts of Fe released by this extractant. Lopez-Fando and Pardo (2009) [49] found that under NT, available Zn, in the 0-5 cm depth was higher as compared to other tillage regimes. Available Cu exhibited similar behaviour, showing no difference due to tillage practices. Available Fe in the top soil (0-5 cm) was similar between tillage regimes, under NT, ZT and minimum tillage available Fe decreased with depth whereas in plots under CT, was evenly distributed in the profile (0-30 cm) and consequently, total Fe stock under conventional tillage showed the maximum value. Available Mn in NT and ZT was greater by 14 % as compared to minimum and CT. Nta *et al*., (2017) recorded higher percentage of Zn and Mn on the tilled site, while Fe recorded the higher percentage on the ZT site. Kaushik *et al*. (2018) [36] reported higher value of all micronutrient under ZT as compared to CT.

Organic carbon

Soils under long term NT or reduced tillage system generally contain higher amount of soil organic carbon (SOC) in the soil surface than under CT (Dick *et al*., 1991, Bajracharya *et al*., 1998; Freibauer *et al*., 2004; Conant *et al*., 2007 and Thomas *et al*., 2007) [18, 5, 23, 14, 74]. Bhattacharyya *et al*. (2008) [8] reported that SOC after rice and wheat harvest in the 0-15 cm soil depth were higher under ZT than under CT, however, SOC content in the 15-30 cm soil layer after 4 years of cropping remained almost unchanged in both conventional and ZT. Mina *et al*. (2008) [57] noticed that zero-zero tillage practices increased the SOC content in the upper layer from 6.8 to 7.5 Mg g-1 soil. Lopez-Fando and Pardo (2009) [49] reported that in the 0-10 cm depth, SOC and nitrogen had increased under NT and ZT compared to conventional and minimum tillage and most drastic changes occurred within 0-5 cm depth where plots under NT and ZT had respectively 7.0 Mg ha-1 and 6.2 Mg ha-1 more SOC than under conventional and minimum tillage. Malecka *et al*. (2012) [52] reported that the concentration of OC in reduced tillage particularly in NT, had significantly higher in the top layer (0-5 cm) by 18.3 % and 26.1 %, respectively, in comparison with CT. Neugschwandtner *et al*. (2014) [62] noticed that SOC increased in the uppermost layer with reduced tillage intensity and in case of mouldboard plough tillage SOC were more evenly distributed whereas a generally higher decline downwards the soil profile in case of lower tillage intensity. Stocks of OC in the 10-20 cm depth, in contrast, were significantly lower in NT with comparison with CT. Similarly, Martinez *et al*. (2016) [54] reported that SOC increased under NT in the upper soil layer (0-10 cm depth), but at around 15-25 cm depth mouldboard plough having tendency of higher concentration of SOC as compared to NT. Many studies showed that conservational tillage favoured higher SOC, especially near the surface soil (Kern and Johnson, 1993 and Tan and Lal, 2005) [37, 72]. Kumar *et al*. (2017) reported that the use of ZT with residue retention and RT with residue retention for two crop cycle increased soil organic carbon by 54.68 % and 54.22 % more than that of CT, respectively. Kaushik *et al*. (2018) [36] reported the higher SOC in case of ZT. Khorami *et al*. (2018) [38] observed highest SOC under RT followed by NT, which were 34% and 13% greater than CT. Zuber *et al*.

(2018) [78] reported 7% higher SOC content under NT under corn-soyabean-wheat rotation. While Issaka *et al*. (2019) [31] observed that conventional tillage recorded 10.37% higher TOC than conservation tillage.

Dissolve organic carbon

Water extractable carbon represents only a small fraction and most active component of SOC but determines soil microbial activity (Janzen *et al*., 1992, McGill *et al*., 1986) [55]. Water extractable carbon, being a highly labile pool of soil C, may be sensitive to perturbation and stress in the soil-plant ecosystems (Doran and Parkins, 1994) [20] and therefore, could be used as a sensitive indicator of soil quality. Water extractable carbon is usually smaller than other labile pool and it constituted between 1-7 % of the microbial biomass carbon pool. Like SOC, there was a direct relationship between straw incorporation and water extractable carbon. Although DOC represents only small parts of C pools, it appears to be involved in many processes, such as translocation of nutrient and their biogeochemistry of N and P (Kalbitz *et al*., 2000) [35] microbial decomposer activities. Linn and Doran (1984) [47] reported that compared to no till plots, water soluble carbon was lower in conventional tilled plots. Gregorich *et al*., (2000) [27] found more DOC under CT, when corn residues were incorporated and loosening of soil is done by tillage practices that would stimulate microbial degradation of residue, there by CT increasing the DOC content. Similarly, Leinweber *et al*., (2001) [43] also reported that an increase in tillage intensity effect DOC content as increasing tillage intensity enhanced oxidative microbial activity. Dou *et al*. (2008) [21] reported after 20 years of experiment that dissolved organic carbon (DOC) was 36% higher under NT than CT at 0-5 cm depth. Ghimire *et al*. (2014) [25] studied that DOC content was higher under organic management than under reduced tillage and CT. Bama *et al*. (2017) [7] reported higher DOC values under CT than ZT and minimum tillage.

Humic acid and fulvic acid carbon

The organic matter that does not degrade completely to carbon dioxide forms humic substances through secondary synthesis reactions (Lichtfouse *et al*., 1998) [46]. They are higher molecular weight substances that are stabilized by humification process and are considered to be highly resistant to further biodegradation, thus belonging provide a long-term sink for carbon in soils (Hayes and Clapp 2001; West and Post 2002;) [29, 77]. Humic substances account for 65% to 75% of the soil organic matter (Brady and Weil 2010). Investigations reported that NT systems affect not only humic substances are also important aspects of soil fertility as they are involved in stabilization of soil aggregates and binding of metals and anthropogenic organic chemicals (Donisa *et al*., 2003) [19]. Liaudansikene *et al*. (2011) [45] reported that sustainable soil tillage significantly increased the humus content in the whole plough layer compared with CT, the highest humus content (25.0 g kg-1 in 0-15 cm and 24.3 g kg-1 in 15-25 cm soil layer) was established in the sustainable tillage system in the rotation with 100% of winter crops. Sustainable soil tillage as compared to CT shows more favorable values of the HA to FA ratio in the whole plough layer, thereby soil organic matter in general became richer in humic acid, which means that the quality of humus improved. Szajdak *et al*. (2003) [71] found that bound amino acid in HA was higher for NT soils compared to CT, whereas FA bound amino acid higher in CT system soils. Ohno *et al*. (2009) [63] reported that HA and FA fractions were not significantly affected by tillage practices. Horacek *et al*. (2014) reported that in 0-15 and 30-55 cm layers, humic acid and fulvic acid concentration were higher under minimum tillage as compared to CT. Moussadek *et al*. (2014) [59] observed significantly higher humic acids and humin under NT compared to CT, but fulvic acid concentrations were significantly lower.

Conclusion

Tillage operations affects the soil conditions through manipulating its physical and chemical properties and influencing the availability of nutrients. Tillage operations under long term also impact the carbon dynamics and affecting largely over active fractions of carbon viz., dissolved organic carbon fraction. Conservational tillage through incorporating the organic matter in the soil made optimum tilth of soil which proved conducive for the optimum growth of the crops. In this way, conservational tillage enhances the wheat yield and maintain the soil health and quality in long run.

Table 1: Yields of ploughing tillage (PT) and conservation tillage (CT) with standard deviation (SD) data of plots.

	2004		2005		2006		2007		2008		2009		2010		2011		2012		2013	
	Mg hi’	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**	**Mg hi’**	**SD**
DI PT	4.73	0.28	8.67	0.25	4.93	0.31	5.12	0.82	5.24	0.11	3.12	0.17	4.01	0.32	3.76	0.86	5.26	0.34	3.38	0.14
CT	4.51	0.49	8.71	0.35	4.58	0.40	5.92	0.46	5.62	0.39	3.53	0.19	4.30	0.51	4.95	0.45	5.73	0.20	3.83	0.11
D2 PT	10.63	0.54	5.91	0.65	8.53	0.23	5.10	0.15	3.94	0.06	5.92	0.71	3.20	0.19	4.19	0.92	4.86	0.64	4.71	0.37
CT	10.24	0.54	4.82	0.38	6.92	0.74	5.20	0.17	4.35	0.18	6.76	0.41	3.63	0.10	4.24	0.67	5.09	0.92	5.66	0.27

Note: Dio'skal 1 (D1), Dio'slcal 2 (172) study site.
Source: pilga Uggelor, m (2016)

Table 2: Grain and straw yield as influenced by tillage operations and planting techniques

Planting technique	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Conventional tillage (transplanting)	51.8	93.7
Broadcast sprouted seed after puddling	51.8	96.2
Broadcast sprouted seed without puddling	44.9	89.3
Drum sowing after puddling	44.8	84.0
Drum sowing without puddling	42.6	86.4
Zero tillage (line sowing)	41.4	72.0
CD (p=0.05)	2.3	7.5

Source: Kumar, (2008)

Table 3: Effect of tillage on soil chemical properties after maize harvest.

Year	2008					2009				
Tillage	pH (H_2O)	OC (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg kg^{-1})	ECEC (cmol kg^{-1})	pH (H_2O)	OC (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg kg^{-1})	ECEC (cmol kg^{-1})
CT	6.0	16.50	1.38	26.64	6.31	6.69	2.79	0.32	65.59	8.05
MT	6.2	19.80	1.52	24.33	6.24	6.79	4.59	0.55	40.47	8.51
ZT	6.1	21.20	1.58	33.28	7.36	6.64	5.00	0.53	61.13	9.39
LSD (*P* >0.05)	0.05	2.20	ns	7.13	0.49	0.04	0.44	0.08	13.25	0.79

Source: Busari and Salako (2013)

OC¼ organic carbon; TN¼ total nitrogen; Avail. *P* ¼ available phosphorus, ECEC¼ effective cation exchange capacity; ZT¼ zero tillage; MT¼ minimum tillage; CT¼ conventional tillage; LSD=least significant difference; ns¼ not significant.

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