International Scholars Journals

African Journal of Agriculture ISSN 2375-1134 Vol. 3 (6), pp. 169-177, June, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Impact of short-term tillage on soil properties, weeds dynamics and crop yield of wheat

Dhirubhai F. K Ambani* and Shah Dhyan Kapoor

Agro-Ecology and Pollution Research Laboratory, Department of Zoology and Environmental Science,
Gurukula Kangri University, Haridwar-249404 (Uttarakhand), India.

Accepted 26 May, 2016

The influence of tillage on soil physical properties, weeds population and crop yield of wheat (*Triticum aestivum*) in agricultural fields was investigated in the Great Plains of Ganga River. The results revealed that summer tillage and spring tillage showed significant (P>0.05) change in moisture content, water holding capacity (WHC), hydraulic conductivity and microbial biomass of the agricultural soil in comparison to no-till soil. Soil bulk density (BD) was not significantly (P>0.05) affected by tillage. Both the summer and spring tillage decreased the moisture content, BD, WHC, hydraulic conductivity and microbial biomass. Both summer tillage and spring tillage significantly (P<0.05) decreased the number of weeds in the soil used for wheat cultivation. A total of 38 species of weeds from 22 families were recorded before the tillage, which was decreased to 5 and 12 species after summer and spring tillage respectively. Among the tillage, summer tillage more significantly (P<0.01) decreased the weeds in comparison to spring tillage. Both the summer and spring tillage significantly (P<0.05) increased crop yield of *T. aestivum*. Therefore, tillage improved the soil health and crop yield, and decreased the weed population.

Key words: Tillage, bulk density, water holding capacity, microbial biomass, weeds, wheat (*Triticum aestivum*).

INTRODUCTION

Tillage is the agricultural preparation of the soil by mechanical agitation of various types, such as digging, stirring, and overturning (Acharya and Sharma, 1994; Sharma et al., 2004; Yaduvanshi and Sharma, 2008). Tillage has been used for crop production; however, excessive tillage destroys soil structure, breaks up the soil pores, and reduces the amount of residue on the soil surface (Lampurlanes and Cantero-Martinez, 2003; Lal and Shukla, 2004; Osunbitan et al., 2005). Tillage management influences soil quality and plant growth as a result of altering physical, chemical and biological properties (Sharma et al., 2004; Osunbitan et al., 2005; Strudley et al., 2008; Yaduvanshi and Sharma, 2008). Tillage operations generally loosen the soil, decrease soil bulk density and penetration resistance by increasing soil macro porosity (Arshad et al., 1999; Logsdon et al., 1999; Engin, 2009).

Conversely, frequent tillage operations can increase soil compaction and bulk density due to the greater traffic intensity (Saxena et al., 1997; Lampurlanes and Cantero-Martinez, 2003). Mechanical disturbance of soil, caused by soil tillage changes the soil structure and pore size distribution in the tilled layer and underneath. Soil tillage has direct (through mechanical disturbance) and indirect (for example, through its effect on root growths, biological processes, soil organic matter content, etc.) effects on pore size distribution as well as soil structure and, consequently, on soil water retention and infiltration properties (Saxena et al., 1997; Osunbitan et al., 2005).

Soil microbial biomass, activity and community structure have been shown to respond to agricultural management practices. Alternation to no tillage or increased cropping intensity increases microbial biomass

---

*Corresponding author. E-mail: ambani_max@gmail.com

in response to increase nutrient reserves and improved soil structure and water retention (Lampurlanes and Cantero-Martinez, 2003; Biederbeck et al., 2005; Strudley et al., 2008). Soil microbial properties have a strong correlation with soil health. Some research has already suggested the favorable effects of conservation of tillage practices and organic fertilizers on soil enzyme activities (Sharma et al., 2004; Strudley et al., 2008; Yaduvanshi and Sharma, 2008).

The effect of tillage on soil physical properties is yet to be clearly understood (Heard et al., 1988; Strudley et al., 2008). Cassel et al. (1995) did not find any significant differences in cone-penetration resistance due to tillage treatments in sandy loam soils. Studies comparing no-tillage with conventional tillage systems have given different results for soil bulk density. In most of them, soil bulk density was greater in no-till in the 5–10 cm soil depth (Strudley et al., 2008), whereas in others, no differences in bulk density were found between tillage systems (Chang and Lindwall, 1989; Saxena et al., 1997; Taboada et al., 1998).

Mahboubi et al. (1993) reported greater soil bulk density and penetration resistance in no-tillage than conventional tillage. Hussain et al. (1998) observed higher water content and soil bulk density with a no-tillage system, than with the conventional tillage due to greater crop residues at the soil surface, and a lower proportion of soil macro pores, respectively. In the recent studies, it has been reported that continuous cropping decreased soil fertility due to change in their physico-chemical characteristics. Tillage improved the soil structure and enhanced the aeration in the soil environment (Strudley et al., 2008; Yaduvanshi and Sharma, 2008; Kabir et al., 2013).

Although both the summer and spring tillage are traditionally used in the region before sowing of crops, these are practiced properly due to the short duration between two growing crops. There are few studies that have examined changes in soil physical properties in response to short-term tillage under dry land cropping systems in the adjacent areas of the Northern Great Plains of Ganga River (Bhatt et al., 2004; Sharma et al., 2004). The present investigation was conducted to evaluate the impact of short-term tillage on soil properties, weeds dynamics and crop yield of wheat in the Northern Great Plains of Ganga River in India.

MATERIALS AND METHODS

Description of experimental site

The Great Plains of Ganga River is stretched over Uttar Pradesh, Uttarakhand, Bihar and West Bengal States of India. The Northern Great Plains of Ganga River is situated in Uttar Pradesh and Uttarakhand States. Saini Agricultural Farm was selected in the Great Plains of Ganga River in the district of Shamli (29°36'15.81''N 77°14'51''E) (Uttar Pradesh) for the present investigation. The plains of Ganga River is rich of fertile loamy soil suitable for cultivation of various agricultural crops like wheat, rice, cane sugar and pulses also. The site is characterized by wide variation in mean monthly temperature from 16.4°C in December and January to 46.5°C in May and June. Average annual precipitation at the research site was from 15 to 25 mm from July to September. The ground water is used for irrigation besides rainfall in the region.

Tillage and soil description

Both the summer and rainy tillage are prevalent before sowing of crops in the region, which was not effective for the removal of weeds and crop residues due to short gap between two crops. Tillage treatments consisted of no-tillage, summer tillage and spring tillage. Both the summer and spring tillage were performed thrice a year before seeding of wheat to prepare a seedbed. The agricultural farm with an area of 9 ha (3 ha for each of no-till, summer tillage and spring tillage) was selected and it was further divided into three sub farms equally (1 ha) and used for three years. The experiment was designed as a randomized complete block with three replications. The sub farms were ploughed at selected depths (0-5, 5-10 and 10-15 cm) with a disk harrow (Sainju et al., 2007). The no-till sub farm was left undisturbed, except for seeding.

Measurement of soil properties and microbial biomass

Soil physical properties namely, moisture content, bulk density (BD), water holding capacity (WHC), hydraulic conductivity and microbial biomass were measured separately after harvest of wheat (*Triticum aestivum* L.) during 2009 to 2011. Soil was collected using a soil core sampler from each sub farms at the selected depth. Soil cores were used to measure moisture content, BD and WHC from oven dried undisturbed soil cores as a mass of oven dried soil per volume of the core. Particle size distribution for each core at each depth was determined using the hydrometer method. Soil hydraulic conductivity was measured following the methods of Reynolds and Elrick (1985). However, soil microbial biomass was estimated following the standard methods (Vance et al., 1987).

Cultivation of wheat and weed control

The seeds of wheat (var. PBW 145) were procured from Indian Agricultural Research Institute (IARI), Pusa, New Delhi and sterilized with 0.01% mercuric chloride and was soaked for 12 h. Seeds were initially sown in each sub farm at the rate of 130 Kg ha^{-1}. NPK was applied at the rate of 120 :60:60 Kg ha^{-1} and used in the region prescribed by ICAR, New Delhi. In no-till conditions, weeds were controlled by using non-selective herbicide Glyphosate before wheat sowing. Weeds in no-till sub farm were controlled by applying pre-plant and post harvest herbicides (Butachlor 50% EW), and in other treatments they were controlled by a combination of herbicides (Butachlor 50% EW and Atrazine 50%) and sweep tillage to a depth of 10 cm as needed. The species of weeds were identified by BSI (2012).

Statistical analysis

Values reported here are the means of three replicates. Means were separated using the least square means test at a significant level of $P<0.05$. Data were tested at different significant levels using one-way ANOVA to determine the difference between soil properties, weeds abundance and wheat growth and yield at no-till, summer till and spring till. Treatment was considered as the fixed effect; replication was considered as the random effect; and soil depth was considered as the repeated measured variable. A Duncan's test was used to compare the mean values when a significant variation was highlighted.

RESULTS AND DISCUSSION

Effect of tillage on soil physical properties

Tillage system (no till, summer tillage and spring tillage), the interaction of tillage with soil depth and their effect on moisture content, BD, WHC, hydraulic conductivity and microbial biomass are given in Tables 1 and 2.

Effect of tillage on moisture content and bulk density (BD)

There were variations in percent moisture content to different thicknesses of the soil. From Table 2, it is clear that the percent moisture content decreased when the soil depths increased. The highest moisture content was observed from no-tillage and it decreased from summer tillage and spring tillage. Kabir et al. (2013) also reported the decrease in percent moisture content of the soil after conventional tillage. Additionally, tillage reduces water infiltration by breaking large pores, and the small pores are clogged by the dislocation of soil particles (Kabir et al., 2013). The season showed significant ($P<0.05$) effect on soil moisture but tillage showed insignificant ($P>0.05$) change in soil moisture content. Both the summer and spring tillage and their interaction with soil depth showed significant ($P<0.05$) effect on moisture content (Tables 1 and 2). BD was insignificantly ($P>0.05$) affected by tillage and the interaction of tillage with soil depth. Season and their interaction with tillage affected moisture content but not BD, while tillage did not affect both moisture content and BD (Tables 1 and 2). In this study, the moisture content and BD decreased due to summer and spring tillage as per soil depths when compared to no-tillage. Hussain et al. (1998) observed higher water content and soil bulk density with a no-tillage system than with the conventional tillage due to greater crop residues at the soil surface and a lower proportion of soil macropores, respectively. Osunbitan et al. (2005) reported insignificant change in soil bulk density due to different tillage systems in Nigeria. Moreover, bulk density is dependent on soil texture and the densities of soil mineral (sand, silt, and clay) and organic matter particles, as well as their packing arrangement. It is changed by crop and land management practices that affect soil cover, organic matter, soil structure, and/or porosity. Cultivation can result in compacted soil layers with increased bulk density, while consistently plowing or disking cause the decrease in bulk density (Osunbitan et al., 2005).

Effect of tillage on WHC and hydraulic conductivity

In the present study, WHC and hydraulic conductivity (HC) were significantly ($P<0.05$) affected by tillage and the interaction of tillage with each soil depth (Tables 1 and 2). Hydraulic conductivity was also significantly ($P<0.01$) affected by tillage at each depth. Both the WHC and hydraulic conductivity decreased in comparison to no-tillage. Season affected the WHC but not hydraulic conductivity, while tillage and their interaction with season affected both the WHC and hydraulic conductivity (Tables 1 and 2). The WHC and hydraulic conductivity (HC) decreased when the depths increased. The most WHC and HC were noted from no-tillage and it decreased from summer tillage and spring tillage. Water holding capacity is the amount of water soil can hold for plant use. The decrease in WHC and HC after different tillage systems due to redistribution of topsoil from the upper landscape positions by the various tillage operations reduces significantly the effective soil depth and the water holding capacity was reported by Osunbitan et al. (2005). Furthermore, no-tillage systems are very effective in reducing evaporation from soil, and increasing the water holding capacity and soil moisture as well as the water infiltration reported by Hussain et al. (1998).

Effect of tillage on soil microbial biomass

In the present study, tillage showed significant ($P<0.01$) effect on microbial biomass. The interaction of tillage with soil depth also showed significant ($P<0.01$) effect on microbial biomass at different soil depth. Microbial biomass was decreased with an increase in soil depth. Conventional tillage (summer tillage) decreased soil organic matter and soil structure which may be due to the reduction in soil microbial communities. When microbial biomass changes, one might also expect shifts in microbial community structure to occur due to the temporal increase in microbial niche, water retention or

Table 1. ANOVA for effect of tillage in summer and winter season on soil characteristics during the year 2009 to 2011.

Source		Moisture content	BD	WHC	Hydraulic conductivity	Microbial biomass	Weeds species
Season (S)		*	ns	*	ns	**	*
Tillage (T)		ns	ns	*	**	**	*
Depth (D)	0-5	*	ns	*	**	**	*
	5-10	*	ns	*	**	**	*
	10-15	*	ns	*	**	**	*
Interaction S × T × D		*	ns	*	**	**	*

ns, *, ** non-significant or significant at P≤0.05 or P≤0.01 probability level of ANOVA.

Table 2. Effect of tillage and depth on moisture content, bulk density (BD), water holding capacity (WHC), hydraulic conductivity (HC) and microbial biomass during the year 2009 to 2011.

Tillage	Depth (cm)	Moisture content (%)	BD (g cm^{-3})	WHC (%)	Hydraulic conductivity (µm s^{-1})	Microbial biomass (µg g^{-1})
No- tillage		55.04a*	1.48ns	56.02ab*	8.56ab**	253.46ab**
Summer tillage		53.32a*	1.47ns	50.97ab*	6.47a**	234.35ab**
Spring tillage		45.14ab*	1.46ns	43.05ab*	4.41a**	216.15ab**
	0-5	56.40ab*	1.48ns	58.84ab*	11.18ab**	257.02ab**
	5-10	54.64b*	1.47ns	53.21ab*	8.82ab**	240.53ab**
	10-15	42.61ab*	1.45ns	41.40b*	4.24b**	211.09ab**
Analysis of variance P>F						
Tillage (T)		5.867524	1.388587	5.321036	13.28734	47.15401
Soil depth (D)		5.8862	1.371212	4.814472	25.97242	17.9541
T × D		4.704095	2.893467	4.015929	18.60187	18.99593

Values are the mean of nine replicates; ns, *, ** non-significant or significantly different at P≤0.05 or P≤0.01 level of probability level of ANOVA.

reduced physical disturbance with no-tillage. Similar observations were recorded by Leita et al. (1999). Microbial biomass was affected by season, tillage and with the interaction of the season and tillage (Tables 1 and 2). Roger-Estrade et al. (2004) observed the differences in soil microbial biomass between different soil depths and it may be due to their distinct physical properties. In a compacted environment, where microporosity dominates, oxygen circulation and substrates originate from raw materials. Thus, oxygen diffusion could limit the development of aerobic bacteria and poor nutrients diffusion, via the soil solution, could limit microbial growth (Ranjard et al., 2001; Andrade et al., 2003). Roger-Estrade et al. (2004) reported the decrease in soil microbial biomass after summer tillage due to disturbance of soil structure. Soil microbial biomass plays significant role in soil fertility. In this study, more soil microbial was recorded with no-tillage. More soil microbial biomass was also observed due to more organic matter in the no-tilled soil, and it was reported that conventional tillage decreased soil organic matter and soil structure due to the reduction in soil microbial communities (Mohammadi, 2011). Elcio et al. (2003) also reported that tillage affected the soil physical and chemical properties of the soil and microbial biomass due to decomposition of organic matter. Furthermore, fewer disturbances due to no-tillage favoured the formation and stabilization of macroaggregates to improve and protect habitat for microbiota.

Effect of tillage on weed species

Number of weeds species and their abundance was significantly (P<0.05) affected by tillage. A total of 38 species of weeds from 22 families were recorded before the tillage, which was decreased to 5 species and 12 species after summer and spring tillage respectively. Season, tillage and their interaction affected the number of weed species (Table 2). Summer tillage showed significant (P<0.01) decrease in weed species in comparison to spring tillage (Tables 1 and 3). In this study, it was observed that the number of weed species

Table 3. Effect of tillage on weeds species in wheat (*Triticum aestivum*) during the year 2009 to 2011.

Name of weed plant	Family	No-tillage	After summer tillage	After spring tillage
Alhagi pseudalhagi (M. Bieb.)	Fabaceae	+	-	-
Argemone maxicana (L.)	Papaveraceae	+	-	+
Amaranthus viridis (L.)	Amaranthaceae	+	-	+
Anagallis arrensis (L.)	Primulaceae	+	-	
Asphodelus tenuifolius (Cav.)	Liliaceae	+	-	+
Avena fatua (L.)	Poaceae	+	-	-
Avena ludoviciana (L.)	Poaceae	+	-	-
Cannabis sativa (Linn.)	Cannabinaceae	+	-	-
Carthamus oxyacantha (M. Bieb.)	Asteraceae	+	-	
Chenopodium album (L.)	Amaranthaceae	+	+	+
Chenopodium murale (L.)	Chenopodiaceae	+	-	-
Cichorium intybus (L.)	Asteraceae	+	-	-
Cirsium arvense (L.) Scop.	Asteraceae	+	-	+
Convolvulus arvensis (L.)	Convolvulaceae	+	-	-
Conyza bonariensis (L.)	Asteraceae	+	-	-
Cronopus didymus (L.) Sm.	Brassicaceae	+	-	-
Cynodon dactylon (L.) Pers.	Poaceae	+	-	+
Cyperus rotundus (L.)	Cyperaceae	+	-	+
Desmostachya bipinnata (L.) Stapf.	Poaceae	+	+	+
Euphorbia jelioscopia (L.)	Euphorbiaceae	+	+	+
Fumaria indica (L.)	Fumariaceae	+	-	-
Fumaria parviflora (Lam.)	Fumariaceae	+	-	-
Heliotropium europaeum (L.)	Boraginaceae	+	-	-
Lathyrus aphaca (L.)	Fabaceae	+	-	-
Malva parviflora (L.) William	Malvaceae	+	-	-
Medicago denticulate (Willd.)	Fabaceae	+	-	-
Melilotus alba (L.)	Fabaceae	+	-	-
Phalaris minor (Retz.)	Poaceae	+	+	+
Poa annua (L.)	Poaceae	+	-	-
Polygonum plebejum (R. Br.)	Polygonaceae	+	-	-
Portulaca oleracea (L.)	Portulacaceae	+	-	-
Rumex dentatus (L.)	Polygonaceae	+	-	-
Rumex retroflex (L.)	Polygonaceae	+	+	+
Scandix pecten-veneris (L.)	Apiaceae	+	-	-
Solanum nigrum (L.)	Solanaceae	+	-	-
Sonchus oleraceus (L.)	Asteraceae	+	-	-
Spergularia rubra (L.) C. Presl.	Caryophyllaceae	+	-	-
Vicia sativa (L.)	Papilionaceae	+	-	+

LSD, 0.002231 at P<0.01 probability level; +, present; -, absent.

gradually decreased during the study period after summer and spring tillage. The most frequently recorded weeds were *Chenopodium album, Desmostachya bipinnata, Euphorbia jelioscopia, Phalaris minor* and *Rumex retroflex* after both the summer and spring tillage, whereas *Argemone maxicana, Amaranthus viridis, Asphodelus tenuifolius, Cirsium arvense, Cynodon dactylon, Cyperus rotundus and Vicia sativa* were also observed after spring tillage, and it is likely due to the fact that such weeds pose problems in their eradication as they regrew from underground parts (Peltzer et al., 2009). Sharma et al. (2004) reported the decrease in weeds diversity due to conventional tillage. In this study, the most weeds diversity was recorded from no-tillage and was decreased from summer and spring tillage. Although herbicides decreased the weeds diversity, it was observed that the underground root of the weeds regenerate them. In the case of summer and spring

Table 4. ANOVA for effect of tillage in summer and winter season on agronomical characteristics of wheat (*Triticum aestivum*) during the year 2009 to 2011.

Source	Seed germination	Number of tillers	Plant height (cm)	Chlorophyll content	LAI	No. of grains/ spike	Yield (Kg ha^{-1})
Season (S)	ns	ns	*	*	*	*	*
Tillage (T)	*	*	*	*	*	*	*
Interaction S × T	*	*	*	*	*	*	*

*, ** significant at P≤0.05 or P≤0.01 probability level of ANOVA.

Table 5. Effect of tillage on plant height, number of grains and yield of wheat (*Triticum aestivum*) during the year 2009 to 2011.

Tillage	Plant height (cm)	No. of grains/ spike	Yield (Kg ha^{-1})
No- tillage	125.18*	14.67*	2287*
Summer tillage	137.33*	24.67*	3889*
Spring tillage	135.29*	21.33*	3572*
Analysis of variance P>F			
Tillage (T)	5.592232	5.30303	6.524294

Values are the mean of nine replicates; *, significantly different at P≤0.05 probability level of ANOVA.

tillage, the tillage reduced the compaction of the soil and decreased the weeds diversity due to loosening of the soil from the roots of the weeds. Additionally, although the experimental fields were sprayed before seeding, weed control was not sufficient. Spraying application did not result in weed elimination; therefore weed growth began before crop growth. Moreover, tillage has been considered a major agricultural weed control technique. Tillage affects weeds by uprooting, dismembering and burying them deep enough to prevent emergence, by changing the soil environment and inhibiting the weeds germination and establishment, by moving their seeds vertically and horizontally (Peltzer et al., 2009).

Effect of tillage on wheat growth and yield

Tillage showed significant (P<0.05) effect on seed germination, number of tillers, plant height, chlorophyll content, LAI, number of grains/spike and crop yield of wheat (Tables 4 and 5). Most seed germination, number of tillers, chlorophyll content and LAI were after summer tillage in comparison to spring tillage and no tillage (Figures 1 to 4). In this study, the highest grain yield of wheat was produced after summer tillage and was statistically greater than that produced after spring tillage and no-tillage. Kabir et al. (2013) reported the increase in crop yield of garlic (*Allium Sativum* L.) after conventional tillage in Bangladesh. The findings are also supported by Shams Abad and Rafiee (2007). The soil with good structure or physically loose structure is to be considered suitable for crops cultivation than the compacted soil. To penetrate the soil, seedlings require a loose soil structure. Roots develop stronger and more extensive systems in porous soil; they meet less resistance and can follow the spaces between aggregates where water and nutrients in solution can be found and used. Additionally in compacted soils, water fills the few pore spaces left at the expense of air. The lack of air (oxygen) may produce changes in soil chemistry that are unfavorable for nutrient availability or uptake and as a result decreased the crop yield (Kabir et al., 2013). Moreover, tillage triggers the decomposition of organic matter and the release of nutrients, and mixes nutrients throughout topsoil. Excessive tillage reduces organic matter and the nutrient-holding capacity of the soil. Thus, soil compaction is the main reason of yield reduction. Soil compaction leads to restriction of root growth. Consequently water and nutrient uptake by roots will be confused and diminished. Schillinger (2005) demonstrated that using no-tillage system caused lower production of wheat, barley and oat in comparison with conventional tillage system. The main reasons cited for lower yields under no-till system are reductions in plant density (Hemmat and Eskandari, 2006) increased weed infestation (Peltzer et al., 2009) and soil physical properties that limit crop growth (Haj Abbas and Hemmat, 2000). Furthermore, crop productivity is influenced by soil characteristics, and the spatial pattern of productivity results from corresponding variation in certain soil properties (Gaston et al., 2001). Changes in soil compactness influence the hydraulic and thermal properties and aeration of soils that determine mass and energy flow and, consequently, root growth

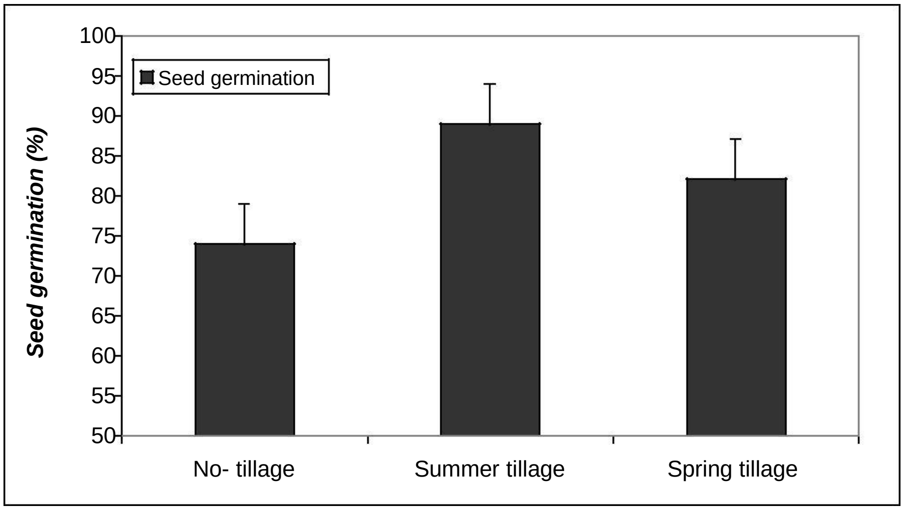

Figure 1. Effect of tillage on seed germination of wheat (*Triticum aestivum*) during the year 2009 to 2011. Error bars are standard error of the mean of nine replicates.

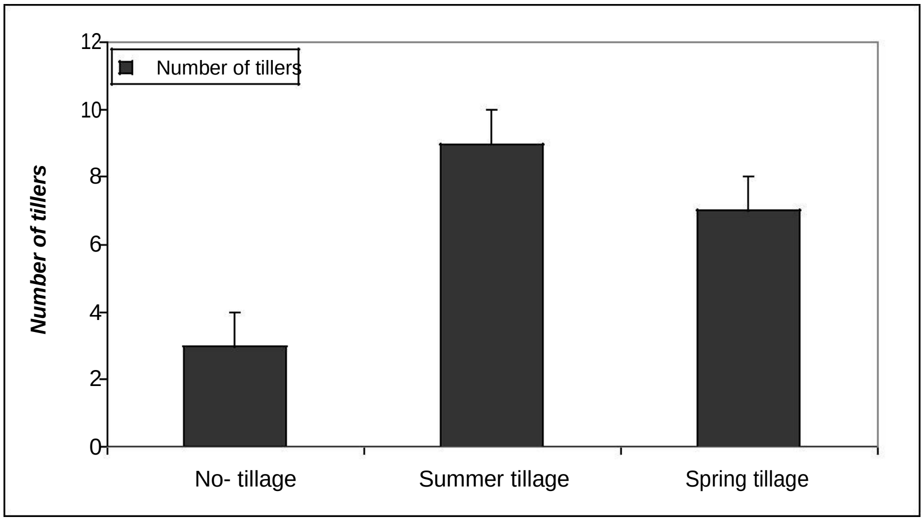

Figure 2. Effect of tillage on number of tillers of wheat (*Triticum aestivum*) during the year 2009 to 2011. Error bars are standard error of the mean of nine replicates.

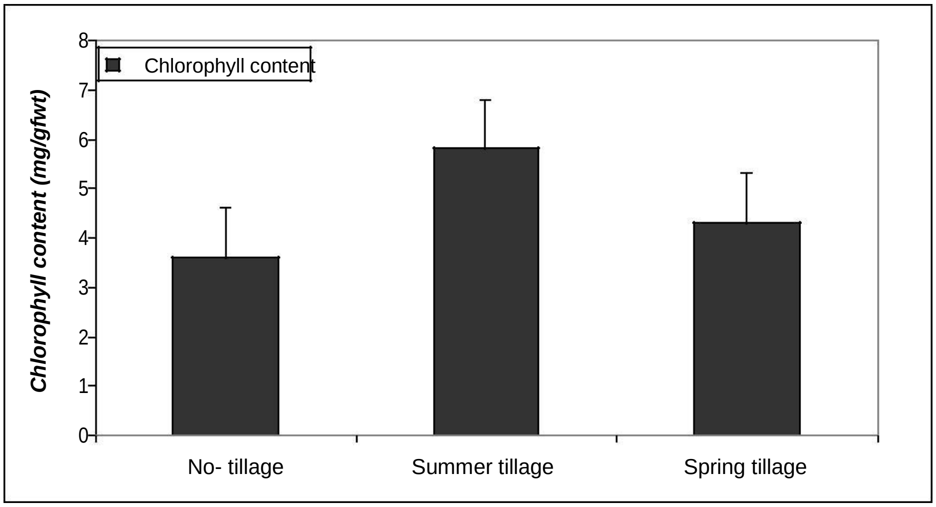

Figure 3. Effect of tillage on chlorophyll content of wheat (*Triticum aestivum*) during the year 2009 to 2011. Error bars are standard error of the mean of nine replicates.

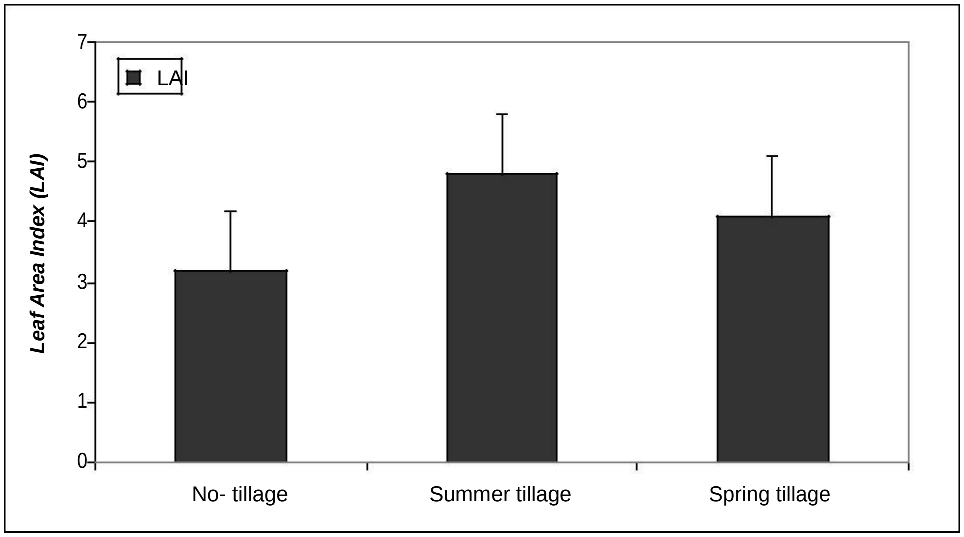

Figure 4. Effect of tillage on LAI of wheat (*Triticum aestivum*) during the year 2009 to 2011. Error bars are standard error of the mean of nine replicates.

and crop yield, especially at high intensity of agricultural mechanization (Engin, 2009).

Conclusion

The present investigation concluded that tillage influenced the soil characteristics. The soil moisture content, BD, WHC, hydraulic conductivity and soil microbial biomass decreased after summer and spring tillage as compared to no-tillage in wheat production conditions. Both the summer and spring tillage affected the wheat attributes throughout the period of investigation. Tillage increased the seed germination, number of tillers, plant height, chlorophyll content, LAI, number of grains and crop yield of wheat and decreased the weeds diversity when compared to no-tillage. Thus, tillage increased yield by altering soil physical properties, increasing soil fertility and increasing beneficial microbial populations. Further research should be carried out for the effect of long term tillage on soil, weed diversity and agronomical characteristics of wheat in the Northern Great Plains of Ganga River.

ACKNOWLEDGMENT

The University Grants Commission, New Delhi, India, is acknowledged for providing the financial support in the form of a research fellowship (F.7–70/2007–09 BSR) to the corresponding author.

REFERENCES

Acharya CL, Sharma PD (1994). Tillage and mulch effects on soil physical environment, root growth, nutrient uptake and yield of maize and wheat on an Alfisol in North West India. Soil Till. Res., 32: 291-302.

Andrade DS, Colozzi-Filho A, Giller KE (2003). The soil microbial community and soil tillage. In A. El Titi (ed.): Soil tillage in agroecosystems, CRC Press LLC, pp. 51-81.

Arshad MA, Franzlubbers AJ, Azooz RH (1999). Components of surface soil structure under conventional and no-tillage in northwestern Canada. Soil Till. Res., 53:41–47.

Bhatt R, Khera KL, Arora S (2004). Effect of tillage and mulching on yield of corn in the submontaneous rainfed region of Punjab, India. Int. J. Agr. Biol., 6: 126-128.

Biederbeck VO, Zentner MRP, Campbell CA (2005). Soil microbial populations and activities as influenced by legume green fallow in a semiarid climate. Soil Biol. Biochem., 37: 1775-1784.

Botanical Survey of India (BSI) (2012). Botanical Survey of India, Northern Regional Centre, 192, Kaulagarh Road, Dehradun (Uttarakhand) India.

Cassel DK, Raczkowski CW, Denton HP (1995). Tillage effects on corn production and soil physical conditions. Soil Sci. Soc. Am J., 59: 1436-1443.

Chang C, Lindwall CW (1989). Effect of long term minimum tillage practices on some physical properties of Chernozemic clay loam. Can. J. Soil Sci., 69: 433-449.

Elcio LB, Arnaldo CF, Diva SA, Richard PD (2003). Microbial biomass in soils under different tillage and crop rotation systems. Biol. Fertil. Soils, 38: 15-20.

Engin Ö (2009). Long term conventional tillage effect on spatial variability of some soil physical properties. J. Sust. Agr., 33(2): 142-160.

Haj Abbasi MA, Hemmat A (2000). Tillage impacts on aggregate stability and crop productivity in clay-loam soil in central Iran. Soil Till. Res., 56: 205-212.

Heard JR, Kladivko EJ, Manning JV (1988). Soil macroporosity, hydraulic conductivity and air permeability of silt soils under long-term conservation tillage in Indiana. Soil Till. Res., 11: 1-18.

Hemmat H, Eskandari I (2006). Dryland winter wheat response to conservation tillage in a continuous cropping system in northwestern Iran. Soil Till. Res., 86: 99-109.

Hussain I, Olson KR, Siemens LC (1998). Long-term tillage effects on physical properties of eroded soil. Soil Sci., 163: 970-981.

Kabir MA, Rahim MA, Majumder DAN, Iqbal TMT (2013). Effect of mulching and tillage on yield and keeping quality of Garlic (*Allium Sativum* L.) Bangladesh J. Agric. Res., 38(1): 115-125.

Lal R, Shukla MK (2004). Principles of soil physics. New York: Marcel Dekker, Inc.

Lampurlanes J, Cantero-Martinez C (2003). Soil bulk density and penetration resistance under different tillage and crop management systems and their relationship with barley root growth. Agron. J., 95: 526-536.

Leita L, De Nobilli M, Mondini C, Muhlbacova G, Marchiol L, Bragato G, Contin M (1999). Influence of inorganic and organic fertilization on soil microbial biomass, metabolic quotient and heavy metal bioavailability. Biol. Fertil. Soils, 4: 371-376.

Logsdon SD, Kasper TC, Camberdella CA (1999). Depth incremental soil properties under no till or chisel management. Soil Sci. Soc. Am. J., 63: 197-200.

Mahboubi AA, Lal R, Fausey NR (1993). Twenty-eight years of tillage effects on two soils in Ohio. Soil Sci. Soc. Am. J., 57: 506-512.

Mohammadi K (2011). Soil microbial activity and biomass as influenced by tillage and fertilization in wheat production. American-Eurasian J. Agric. Environ. Sci., 10(3): 330-337.

Osunbitan JA, Oyedele DJ, Adekalu KO (2005). Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil in southwestern Nigeria. Soil Till. Res., 82: 57-64.

Peltzer SC, Hashem AIA, Osten BVA, Gupta CML, Diggle DAJ, Riethmuller EGP, Douglas FA, Moore GLM, Koetz H (2009). Weed management in wide-row cropping systems: a review of current practices and risks for Australian farming systems. Crop Pasture Sci., 60: 395-406.

Ranjard L, Richaume A (2001). Quantitative and qualitative microscale distribution of bacteria in soil. Res Microbiol., 152: 707-716.

Reynolds WD, Elrick DE (1985). *In-situ* measurement of field-saturated hydraulic conductivity, sorptivity and a parameter using the Guelph permeameter. Soil Sci., 140: 292-302.

Roger-Estrade J, Richard G, Caneill J, Boizard H, Coquet Y, Defossez P, Manichon H (2004). Morphological characterization of soil structure in tilled fields: from a diagnosis method to the modelling of structural changes over time. Soil Till Res., 79: 33-49.

Sainju UM, Caesar-Ton That T, Lenssen AW, Evans RG, Kolberg R (2007). Long-tillage and cropping sequence effects on dryland residue and soil carbon fractions. Soil Sci. Soc. Am. J., 71: 1730-1739.

Saxena A, Singh DV, Joshi NL (1997). Effects of Tillage and Cropping Systems on Soil Moisture Balance and Pearl Millet Yield. J. Agron. Crop Sci., 178: 251-257.

Schillinger WF (2005). Tillage method and sowing rate relations for dryland spring wheat, barley and oat. Crop Sci., 45: 2636-2643.

Shams Abadi HA, Rafiee S (2007). Study on the effect of tillage practices and different seed densities on yield of rainfed wheat. Iran. J. Agr. Sci. Nat. Res., 13: 95-102.

Sharma RK, Babu KS, Chhokar RS, Sharma AK (2004). Effect of tillage on termites, weed incidence and productivity of spring wheat in rice-wheat system of North Western Indian plains. Crop Prot., 23: 1049-1054.

Strudley MW, Green TR, Ascough JC. (2008). Tillage effects on soil hydraulic properties in space and time: state of the science. Soil Till. Res., 99: 4-48.

Taboada MA, Micucci FG, Cosentino DJ, Lavado RS (1998). Comparison of compaction induced by conventional and zero tillage in two soils of rolling Pampa of Argentina. Soil Till Res., 49: 57-63.

Vance ED, Brookes PC, Jenkinson DS (1987). An extraction method for measuring soil microbial biomass-C. Soil Biol. Biochem., 19: 703-707.

Yaduvanshi NPS, Sharma DR (2008). Tillage and residual organic manures/chemical amendment effects on soil organic matter and yield of wheat under sodic water irrigation. Soil Till. Res., 98: 11-16.