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Tillage and Nitrogen Fertilization Effect on Wheat Yield, and Soil Organic Carbon and Total Nitrogen

Muhammad Iqbal, Abdul Ghaffar Khan*, Rashid Mukhtar[1], and Sajid Hussain

Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad 38040, Pakistan

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Abstract

Carbon sequestration and increases in soil organic matter have direct positive impacts on soil quality and fertility. This two-year study was conducted to evaluate effect of tillage (zero, minimum, conventional and deep tillage) and nitrogen fertilizer (N @ 0, 130, 160 and 190 kg ha^{-1}) on wheat yield, carbon and nitrogen sequestration capacity, and soil organic carbon and nitrogen concentrations. The results show that tillage practices had a statistically significant effect on soil organic carbon and total nitrogen at different soil depths; soil organic carbon decreased with depth. Zero tillage treatments had a highly significant soil organic carbon than those of minimum, conventional and deep tillage treatments. Zero tillage treatments had higher soil organic carbon storage in the cultivated layer (0-15 cm) than the tillage treatments.

Keywords: Zero tillage; soil organic carbon; total nitrogen; storage; wheat

Introduction

Increases in atmospheric CO_2 levels during the recent decades triggered human's interests of using the soil as a potential soil organic carbon (SOC) sink. The world's soils store about 1500 Gt of organic carbon, almost twice the amount of C in the atmosphere (Schlesinger, 2000); however, world's oceans contain 38,000 Gt of C. Land use changes and increased fossil fuel combustion are the major causes of CO_2 increase in the atmosphere. Soil plowing resulted in substantial increase of soil carbon losses; tilled soils are considered carbon depleted reservoir that can be refilled (Reicosky, 2003). Intensive tillage of agricultural soils has led to considerable losses of soil C that range from 30 to 50% (Davidson and Ackerman, 1993). These CO_2 losses are related to soil management and fracturing which enhance CO_2 emission and oxygen consumption. Global warming can be alleviated through enhancing sequestration of carbon and nitrogen in the soil; in other words, diminishing greenhouse gas emission, such as CO_2 and N_2O (Lal, 2010). Soil C sequestration is a viable near-term option to mitigate increased atmospheric CO_2 because it is relatively a low cost option that can be rapidly deployed across large areas (Caldeira et al., 2004). One of the practices to enhance sequestration of carbon and nitrogen in soil is conservation tillage, defined as any tillage system that leaves sufficient crop residue in place to cover at least 30% of the soil surface after planting (Lal, 2003). Fabrizzi et al. (2005) found that conservation tillage technology plays a vital role in improving soil physical and chemical properties. Lal and Kimble, (1997) reported that no-till can sequester atmospheric CO_2 by 0.1% ha^{-1} at the top 0-5 cm soil depth every year. Sequestration of C in the soil through NT can also conserve N, because soil organic C (SOC) and total N (STN) levels are highly related and similarly impacted by conventional tillage (Franzluebbers et al., 1999; Sainju et al., 2002). Adequate N fertilization is needed to ensure optimum crop productivity and crop residue returns to soils. Sainju et al. (2002) found that N

* Corresponding author: ghaffarniazi@gmail.com

fertilization results in more SOC and STN in tilled and non-tilled soils as a result of an increase in the crop residue returned to the soil. Ishaq et al. (2002) found that N fertilizer application profoundly increases N, P, K and SOC concentrations in the surface layer than in the subsoil. Campbell et al. (2000) found that adequate N fertilizer application under semiarid climates results in a substantial increase of SOC. They also found that fertilization has a significant effect on soil organic C and total N, mineralizable N and wet aggregate stability. The influence of tillage on SOC and STN can interact with N fertilization rates (Sainju et al., 2002). Conservation tillage and nitrogen fertilization can improve C and N storage in the surface soil (Allmaras et al., 2000; Sainju et al., 2006), while conventional tillage and N fertilization decreases soil organic matter level by increasing carbon and nitrogen mineralization and limiting C and N inputs (Balesdent et al., 1990; Cambardella and Elliott, 1993). However, for soil profile below 7.5-cm depth, tilled soil may have more SOC and STN than soils under conservation tillage due incorporation of residue at greater depths (Clapp et al., 2000). The significance of increased soil organic carbon is its effect on improving soil physical properties, restoring water, and enhancing nutrients availability. These enhancements should ultimately lead to greater biomass and crop yield (Onemli 2004).

The response of wheat yield, and SOC and STN to tillage and inorganic fertilization under semiarid conduction in Pakistan were not investigated before. Thus, the objectives of this study were to: (1) examine the effects of tillage and inorganic N fertilization SOC, STN and wheat yield in semiarid climate of Pakistan; (2) and quantify their effects on soil C and N storage.

Materials and Methods

A Field study was conducted on the Research Farm of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan (31˚26'N; 73˚06'E, and altitude of 184.4 m), to evaluate the effects of tillage and nitrogen levels on soil organic carbon, soil total nitrogen, soil C and N storage and the yield of wheat for two years. The existing farming system in this region is predominantly based on rotations which includes irrigated maize, wheat, cotton, sugarcane, rice, fodder, and pulses.

The soil of the study area is a well-drained Hafizabad sandy clay loam (mixed, semi-active, isohyperthermic Typic Calciargids, based on USDA soil classification) and contains 530, 210, 260 g kg^{-1} sand, silt, and clay, respectively. This soil type under this semiarid condition has low organic matter, N, and P contents that can't support a productive agriculture. Soil physical and chemical characteristics of the study area presented in Table 1. The climate of the region is subtropical to semi-arid with an annual average rainfall of 292 mm out of which more than 70 % occurs as heavy showers during June to September. Mean monthly minimum temperature is 13˚ C in January and maximum temperature is 39˚ C in July. Average temperature, total rainfall, and average relative humidity of research area are presented in Table 2.

Four tillage systems (zero, minimum, conventional, and deep tillage) and four nitrogen levels (0, 130, 160, 190 kg ha^{-1}) were applied depending on treatments. Tillage systems were kept on the main plots, while nitrogen levels were applied to the sub-plots. Recommended rates of P and K were applied as Triple Super Phosphate (TSP) and Sulphate of Potash (SOP) at planting. Nitrogen was applied in three splits. One third of each nitrogen level was applied at planting, the second third at first irrigation and the last third with the second irrigation. Hoeing along with herbicides was used to control weeds. The seeding rate was 110 kg ha^{-1} and planting was done using a drill machine with an inter-row spacing of 22.5 cm. the weight variety is called Sahar. The first crop was planted in November 2009 and the second crop in November 2010. The experimental layout was a split plot design with the tillage system as the main plots and the inorganic nitrogen levels as the sub-plots. Each treatment was replicated thrice. The dimension of each treatment plot, sub-plot, was 10 X 10 m. Soil samples were randomly collected from 0.0-0.05, 0.05-0.15 and 0.15-0.30 m depths before planting and at harvest at six different locations on each plot. Samples from each plot were mixed to form a composite. These samples were analyzed for soil C and total N contents. Soil samples were air dried and ground to pass a 2mm sieve; then, they were analyzed for total organic carbon and other soil properties. Total organic carbon was determined by potassium

Table 1. Physical and Chemical Properties of the Hafizabad Sandy Clay Loam Soil (mixed, semi-active, isohyperthermic Typic Calciargids) at the research site.

Soil Properties (0-0.04 m)	Values
Sand (%)	53
Silt (%)	21
Clay (%)	26
Textural Class	Sandy Clay Loam
pH	7.5
Electrical Conductivity (d Sm^{-1})	1.35
Bulk Density (Mg m^{-3})	1.45
Organic carbon contents (g kg^{-1})	3.5
Soil total N (g kg^{-1})	0.40

Table 2. Average temperature, total rainfall and average relative humidity of research area at meteorological cell of University of Agriculture, Faisalabad, Pakistan.

Month	Temperature °C			Total Rainfall (mm)	RH (%)
	Maximum	Minimum	Mean		
2009-2010					
November	25.7	10.8	18.2	0.70	64.7
December	22.1	7	14.5	0	64.4
January	16.2	6	11.1	0.8	82.3
February	22	9.5	15.7	11.9	62.7
March	30.4	16.5	23.5	8.8	57.5
April	38.4	21.4	29.9	1.3	36.8
2010-2011					
November	27.1	10.5	18.8	0	62.3
December	20.8	5.9	13.3	1.0	70.5
January	15.9	4.3	10.1	0	73.4
February	20.1	8.6	14.4	20.6	72.9
March	26.3	13.1	19.7	6.8	59.8
April	32.0	17.1	24.8	20.9	46.9

Data were collected from meteorological cell of UAF.

Table 3. Effect of tillage and nitrogen rates on soil organic carbon and soil total nitrogen (g kg-1) under Sahar wheat Crop.

Treatments		Soil Organic Carbon (g kg^{-1})						Soil Total Nitrogen (g kg^{-1})			
		0-5 cm		5-15 cm		15-30 cm		0-15 cm		15-30 cm	
Years	-	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Tillage	ZT	4.9 a	5.17 a	4.9 a	5.24 a	4.7 a	3.68 a	0.53	0.54	0.48	0.49
	MT	4.8 a	5.00 ab	4.8 a	5.07 a	4.5 a	3.53 ab	0.54	0.54	0.49	0.49
	CT	4.5 b	4.66 ab	4.5 b	4.69 ab	4.3 b	3.20 bc	0.55	0.56	0.50	0.51
	DT	3.9 c	4.07 b	3.9 c	4.08 b	3.8 c	2.79 c	0.56	0.57	0.51	0.52
Nitrogen (N)	N_0	4.1 d	4.29 c	4.0 d	4.35 c	3.2 b	3.01 c	0.44 c	0.49 c	0.40 d	0.45
	N_{130}	4.4 c	4.61 bc	4.3 c	4.67 bc	3.3 a	3.23 bc	0.52 b	0.54 b	0.48 c	0.49
	N_{160}	4.6 b	4.79 ab	4.5 b	4.84 ab	3.3 a	3.35 b	0.59 a	0.58 ab	0.53 b	0.53
	N_{190}	5.0 a	5.18 a	4.6 a	5.23 a	3.4 a	3.62 a	0.63 a	0.60 a	0.58 a	0.55
Tillage * Nitrogen	ZT x N_0	4.6 e	4.82 e	4.5 de	4.90 bc	2.8 g	3.44 bc	0.449 de	0.476 e	0.39 h	0.43
	ZT x N_{130}	4.7 de	4.93 de	4.6 cd	5.00 b	3.5 abcd	3.51 b	0.504 cde	0.543 b	0.46 fgh	0.49
	ZT x N_{160}	4.9 cd	5.11 cd	4.8 ab	5.18 ab	3.4 cde	3.63 ab	0.585 abcd	0.576 abc	0.51 bcdef	0.52
	ZT x N_{190}	5.6 a	5.81 a	5.0 a	5.88 a	2.9 g	4.13 a	0.612 abc	0.586 abc	0.56 abc	0.53
	MT x N_0	4.2 fg	4.39 fg	4.0 gh	4.46 gh	3.6 a	3.10 gh	0.438 e	0.486 de	0.41 gh	0.44
	MT x N_{130}	4.9 cd	5.07 cd	4.6 d	5.13 ab	3.1 f	3.58 ab	0.0.513bcde	0.540 b	0.47 efg	0.49
	MT x N_{160}	4.9 c	5.10 c	4.8 ab	5.16 ab	3.3 ef	3.60 ab	0.590 abc	0.566 abcd	0.53 bcde	0.51
	MT x N_{190}	5.3 b	5.46 b	4.8 ab	5.55 ab	3.5 abc	3.86 ab	0.634 abc	0.580 abc	0.56 abc	0.52
	CT x N_0	4.3 f	4.47 f	4.1 fg	4.55 fg	3.4 bcde	3.10 fg	0.429 e	0.510 c	0.39 h	0.46
	CT x N_{130}	4.4 f	4.54 f	4.3 ef	4.64 ef	3.5 abcd	3.15 ef	0.532 abcde	0.540 b	0.49 def	0.49
	CT x N_{160}	4.7 e	4.80 e	4.5 de	4.84 de	3.1 f	3.31 de	0.597 abc	0.603 abc	0.55 abcd	0.54
	CT x N_{190}	4.6 e	4.73 e	4.4 e	4.74 e	3.5 abc	3.26 e	0.643 ab	0.623 ab	0.58 ab	0.56
	DT x N_0	3.4 i	3.50 i	3.3 j	3.52 j	2.9 g	2.40 j	0.443 e	0.510 c	0.41 h	0.46
	DT x N_{130}	3.8 h	3.90 h	3.8 i	3.92 i	3.3 de	2.68 i	0.550 abcde	0.563 abcd	0.50 cdef	0.51
	DT x N_{160}	4.0 g	4.15 g	3.9 hi	4.17 hi	3.5 abcd	2.85 hi	0.607 abc	0.610 abc	0.55 abcd	0.55
	DT x N_{190}	4.6 e	4.71 e	4.4 e	4.72 e	3.6 a	3.23 e	0.664 a	0.630 a	0.61 a	0.57

Means for treatments within columns for each experiment followed by the same letter are not significantly different at α=0.05.
ZT = Zero tillage, MT = Minimum tillage, CT = Conventional tillage, DT= Deep tillage
N0 = Nitrogen @ 0 kg ha-1, N130= Nitrogen @ 130 kg ha-1, N160 = Nitrogen @ 160 kg ha-1, N190 @ 190 kg ha-1

dichromate ($K_2Cr_2O_7$) method (Ryan et al., 2001); pH was determined in water (McLean 1982); electrical conductivity of soil extract was measured by the method developed by Rhoades (1982); and soil texture was determined using Bouyoucos hydrometer method (Moodie et al., 2001); Total N by Bremner and Mulvancy (1982).

Soil bulk density was determined following the method described by Blake and Hartge (1986). However, nitrogen fertilizer use efficiency (FUE) was calculated using the following equation:

FUE (kg grains kg^{-1} nutrient) = Yield with fertilizer–Yield in control (kg)/Nutrient (Equation1)

Water use efficiency (WUE) was calculated using the following equation:

WUE (kg ha^{-1} mm^{-1}) = Grain yield (kg ha^{-1})/ Water applied (mm) (Equation 2)

The calculation of the soil carbon ratio, which is a sensitive indicator of soil quality, is calculated as follows:

$$SOCs / TNs = \sum^{n}_{(i=1)} (Ci/Ni \times \rho i \times Ti)/10 \quad \text{(Equation 3)}$$

In this equation, SOCs and TNs are organic carbon storages, and total nitrogen storages (t•ha^{-1}) of soil at depth i, respectively; Ci/Ni is the organic carbon concentrations and total nitrogen concentrations (g kg^{-1}) in layer-i soil; ρi is the soil bulk density of lay-i soil (g cm^{-3}); Ti is the soil thickness of lay-i soil; n is the soil layer quantity (Jiang et al., 2005).

Economic and Marginal Analysis

The data collected from this study were used for economic and marginal analysis. Expenditures on different nutrient sources were as follows: N, US \$0.199 kg^{-1}; P_2O_5, US \$ 0.59 kg^{-1}; K_2O, US \$ 0.48 kg^{-1}. Seed, US \$ 43.07; herbicide, US \$ 14.15; harvesting and threshing US \$ 95.36 Mg^{-1}. Irrigation US \$ 176.0. The N was applied @ 0, 130, 160 and 190 kg N ha^{-1}. P and K were applied @ 85:62 kg P_2O_5:K_2O ha^{-1} in all treatments, respectively. DT, US \$ 148.0, CT, US \$ 109.4, MT, US \$ 69.1 and ZT, US \$ 17.2.

Price of the wheat produce is as follows: wheat grain, US\$ 265.5 Mg^{-1}; Wheat straw = US \$ 115.1 Mg^{-1}.

Statistical Analysis

An analysis of variance was performed on data collected from this trial for the split-plot design. Duncan's multiple range test was performed for the mean separation analysis.

Results

Soil organic C was significantly affected by tillage in the 0-5, 5-15 and 15-30 cm depths during 2009-10 and 2010-11 (Table 3). Zero tillage had greater amounts of SOC than MT, CT and DT at 0-5, 5-15 and 15-30 cm during both years. Nitrogen application significantly affected SOC values for 0-5, 5-15 and 15-30 cm during both years. The higher N rate treatments, 190-N and 160-N, have higher SOC (5.0 and 4.6 g kg^{-1}, respectively) than the 0-N and 130-N treatments (4.1 and 4.4 g kg^{-1}, respectively) for 0-5 cm depth during 2009-10. For the 5-15 cm depth, N application significantly affected SOC; the 190-N rate treatment (4.6 g kg^{-1}) had a greater SOC than the control (4.0 g kg^{-1}) treatment during 2009-10.

The effect of tillage and nitrogen rates on total nitrogen is shown in Table 3. The soil total nitrogen concentrations at 0-15 and 15-30 cm depths was not significantly affected by tillage practices during the two growing seasons. Overall, the soil total nitrogen concentrations are higher at 0 –15 cm depth than at15 –30 cm depth. There was a significant positive correlation between nitrogen fertilizer rates and the soil total nitrogen concentrations for the 0-15 and 15-30 soil depths. . In other words, STN for the four N fertilization treatments and for the two soil layers ranked as follows: 190-N > 160-N > 130-N > 0-N.

Soil bulk density was measured separately for different layers. Soil bulk density under DT, CT, MT and ZT was 1.38, 1.42, 1.45 and 1.46 g cm-3, respectively, for the top two depths (0-5 and 5-15 cm). For the 15-20 cm depth, soil bulk density was 1.52 under ZT, MT and CT, and 1.48 for the DT treatment.

At 0-5 depth, SOC storage for DT was statistically different from that of ZT, MT and CT treatments. The SOC storage for these latter treatments was statistically the same. However, at 0-15 cm depth, SOC storage was similar for ZT and MT treatment, which were significantly greater than that of CT and DT treatments during the two growing seasons. There were no significant differences between tillage systems at the 0-30 cm depth, although MT (15.5 t C ha^{-1}) had 1.1 t ha^{-1} more C storage than ZT (14.4 t C ha^{-1}) (Table 4) during the first growing season. There was a significant effect of N application at 0-5 cm where the 190-N rate (3.60 t C ha^{-1}) had 0.62 t C ha^{-1} more C than the 0-N rate (2.98 C t ha^{-1}) during the first growing season. Also, differences in SOC storage between N rates were observed at 0-15 cm and 0-30 cm, 1.42 and 0.9 t ha^{-1} or carbon, respectively.

Soil nitrogen storage was not significantly influenced by soil tillage treatments at 0-15 cm and 0-30 cm soil depth (Table 4) during 2009-10 and 2010-11. However, soil nitrogen storage was greater in MT at 0-15 cm soil depth than in ZT, CT and DT. Soil nitrogen storage was significantly influenced by soil N treatments in the soil layers evaluated (Table 4), emphasising significantly greater value of soil nitrogen storage with 190 -N than 160-N, 130-N and 0-N at 0-15 and 15-30 cm soil layers during both the years.

Plant height was significant affected by tillage practices; however, effect of N application was non-significant (Table 5). Higher average plant height (97.7 cm) was recorded with minimum tillage. Average plant height increased from 92.4 to 96.8 cm with increase in N rates from N0 to N190, respectively. Grain yield was significant affected by N application; however, effect of tillage was non-significant (Table 5). Grain yield significantly increased from 3.68 to 5.80 Mg ha^{-1} with increase in N rates from N0 to N160, respectively. There were significant differ-

Table 4. Effect of tillage and nitrogen rates on soil organic carbon and soil total nitrogen storage (t ha-1) under Sahar wheat.

Treatments		Soil organic carbon storage (t ha^{-1})						Soil total nitrogen storage (t ha^{-1})			
		0-5 cm		5-15 cm		15-30 cm		0-15 cm		15-30 cm	
Years	-	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Tillage	ZT	3.64 a	3.77 a	10.4 a	11.4 a	14.4	16.7 a	1.17	1.19	2.30	2.26
	MT	3.52 a	3.63 a	9.99 a	11.0 a	15.5	16.1 a	1.18	1.18	2.33	2.25
	CT	3.20 ab	3.29 ab	9.26 b	10.0 ab	15.2	14.6 ab	1.17	1.21	2.36	2.36
	DT	2.74 b	2.80 b	8.00 c	8.46 b	14.9	12.3 b	1.17	1.19	2.42	2.34
Nitrogen (N)	N_0	2.98 c	3.07 c	8.58 c	9.34 c	14.5	13.6 c	0.94 c	1.06 b	1.80 c	2.04 b
	N_{130}	3.20 b	3.30 bc	9.31 b	10.0 bc	15.2	14.6 bc	11.3 b	1.16 ab	2.25 b	2.25 ab
	N_{160}	3.33 b	3.42 ab	9.70 ab	10.3 ab	15.0	15.1 ab	1.27 a	1.25 a	2.55 a	2.42 a
	N_{190}	3.60 a	3.70 a	10.0 a	11.2 a	15.4	16.4 a	1.36 a	1.29 a	2.73 a	2.49 a
Tillage * Nitrogen	ZT x N_0	3.40 e	3.52 abcd	9.58 abcd	10.7 abcd	13.0	15.6 abcd	0.984 bc	1.04	1.92 d	1.98
	ZT x N_{130}	3.47 de	3.60 abcd	10.1 abcd	10.9 abcd	15.9	16.0 abcd	1.10 abc	1.19	2.16 cd	2.25
	ZT x N_{160}	3.60 cd	3.73 abc	10.6 abc	11.3 abc	15.5	16.5 abc	1.28 a	1.25	2.51 abc	2.39
	ZT x N_{190}	4.08 a	4.24 a	10.9 a	12.8 a	13.3	18.8 a	1.34 a	1.28	2.62 abc	2.40
	MT x N_0	3.06 fg	3.18 abcd	8.70 def	9.66 abcd	16.6	14.1 abcd	0.95 c	1.05	1.87 d	2.01
	MT x N_{130}	3.57 cd	3.68 abc	10.0 abcd	11.1 abc	14.3	16.3 abc	1.11 abc	1.17	2.20 bcd	2.25
	MT x N_{160}	3.60 c	3.70 abc	10.4 abc	11.2 abc	15.0	16.4 abc	1.28 a	1.23	2.53 abc	2.35
	MT x N_{190}	3.84 b	3.96 ab	10.5 abc	12.0 ab	16.2	17.6 ab	1.38 a	1.26	2.72 abc	2.40
	CT x N_0	3.07 f	3.17 abcd	8.87 def	9.69 abcd	15.3	14.1 abcd	0.91 c	1.09	1.84 d	2.13
	CT x N_{130}	3.12 f	3.22 abcd	9.23 bcdef	9.69 abcd	15.6	14.3 abcd	1.13 abc	1.15	2.28 abcd	2.25
	CT x N_{160}	3.33 e	3.41 abcd	9.58 abcde	9.84 abcd	13.9	15.0 abcd	1.27 ab	1.28	2.56 abc	2.50
	CT x N_{190}	3.28 e	3.63 abcd	9.37 bcde	10.1 abcd	15.8	17.6 ab	1.37 a	1.32	2.57 ab	2.58
	DT x N_0	2.36 i	2.42 d	6.90 g	7.30 d	13.0	10.6 d	0.918 c	1.05	1.90 d	2.07
	DT x N_{130}	2.64 h	2.69 cd	7.86 fg	8.12 cd	14.9	11.8 cd	1.13 abc	1.16	2.36 abcd	2.27
	DT x N_{160}	2.80 g	2.86 bcd	8.14 efg	8.64 bcd	15.6	12.6 bcd	1.25 ab	1.26	2.60 abc	2.47
	DT x N_{190}	3.19 e	3.25 abcd	9.10 cdef	9.78 abcd	16.1	14.3 abcd	1.37 a	1.30	2.84 a	2.55

Means for treatments within columns for each experiment followed by the same letter are not significantly different at α=0.05.
ZT = Zero tillage, MT = Minimum tillage, CT = Conventional tillage, DT= Deep tillage
N0 = Nitrogen @ 0 kg ha-1, N130= Nitrogen @ 130 kg ha-1, N160 = Nitrogen @ 160 kg ha-1, N190 @ 190 kg ha-1

Table 5. Effect of tillage and nitrogen rates on grain yield, harvest index, water use efficiency and fertilizer use efficiency in wheat (Average of two years).

Treatments		Plant Height (cm)	Grain Yield (Mg ha^{-1})	Water Use Efficiency (kg $ha^{-1}mm^{-1}$)	Fertilizer Use Efficiency
Tillage	ZT	94.9 ab	5.05	12.6	4.12
	MT	97.7 a	5.08	12.7	4.13
	CT	93.4 b	5.08	12.7	4.19
	DT	95.7 ab	5.25	13.4	4.27
Nitrogen (N)	N_0	92.4	3.68 c	9.20 c	-
	N_{130}	96.1	5.32 b	13.3 b	5.29 b
	N_{160}	96.5	5.80 a	14.5 a	5.78 a
	N_{190}	96.8	5.66 a	14.1 a	5.64 a
Tillage * Nitrogen	ZT x N_0	93.03	3.63 f	9.08 b	-
	ZT x N_{130}	95.17	5.46 bcde	13.6 a	5.43
	ZT x N_{160}	96.5	5.60 abcde	14.0 a	5.58
	ZT x N_{190}	95.23	5.50 bcde	13.7 a	5.48
	MT x N_0	98.6	3.74 f	9.35 b	-
	MT x N_{130}	98.3	5.30 de	13.2 a	5.27
	MT x N_{160}	97.97	5.68 abcd	14.2 a	5.66
	MT x N_{190}	96.03	5.61 abcde	14.0 a	5.59
	CT x N_0	85.3	3.50 f	8.75 b	-
	CT x N_{130}	98.13	5.16 e	12.9 a	5.13
	CT x N_{160}	93.33	5.93 ab	14.8 a	5.91
	CT x N_{190}	97.03	5.74 abcd	14.3 a	5.72
	DT x N_0	92.73	3.85 f	9.63 b	-
	DT x N_{130}	92.8	5.36 cde	13.4 a	5.33
	DT x N_{160}	98.27	5.99 a	14.9 a	5.97
	DT x N_{190}	99.2	5.81 abc	14.5 a	5.79

Means for treatments within columns for each experiment followed by the same letter are not significantly different at α=0.05. ZT = Zero tillage, MT = Minimum tillage, CT = Conventional tillage, DT= Deep tillage. N0 = Nitrogen @ 0 kg ha-1, N130= Nitrogen @ 130 kg ha-1, N160 = Nitrogen @ 160 kg ha-1, N190 @ 190 kg ha-1

ences among treatments in case of water use efficiency (Table 5). Water use efficiency was improved with increasing N rate and tillage intensity; and their combined use was also significant. The maximum WUE (14.9 kg ha^{-1} mm^{-1}) was observed in case of treatment receiving 160 kg N ha^{-1} along with deep tillage. The results of our study revealed that the application of nitrogen fertilizer increased the fertilizer use efficiency (Table 5). The maximum FUE (5.78) was observed in case of treatment receiving 160 kg N ha^{-1} than the control.

Data regarding economic analysis of wheat yield indicate that the maximum net field benefit of US $ 2356.9 ha^{-1} was achieved from treatment combination DT × N190 followed by CT × N160 having US $ 2353.9 ha^{-1} and the lowest (US $ 1361.9 ha^{-1}) in the case of CT × N0 treatment (Table 6). Dominance and marginal analysis indicate that marginal rate of return was maximum from the treatment combination CT × N160 followed by DT × N160 and ZT × N130, while all control N treatment combinations were un-economical due to higher input cost and low returns (Table 7).

Discussion

There were significant differences in response of wheat yield, SOC, and STN to tillage and N rates. The impact of tillage was significant at three soil layers (0-5, 5-15 and 15-30 cm) where SOC was greater under ZT than under DT. Several authors have found that the tillage impact is confined to the soil surface (Deen and Kataki, 2003; Fabrizzi et al., 2003; Mikha and Rice, 2004; Wright and Hons, 2004). Results from our research show the positive impact that minimum and zero-tillage systems have on SOC accumulation. The limited soil disturbance and better aggregation (McVay et al., 2006) under these systems could explain the greater C storage than CT and DT systems. Nitrogen fertilization significantly affected soil organic where the highest rate of N application had the greatest soil organic carbon, which can be attributed to greater amount of residues produced with increased N. Russell et al. (2005) also reported significant effects of N fertilization rate on SOC pool in the 0-15 cm depth. This indicated that long-term applications of inorganic fertilizers are unable to maintain levels of SOC and nutrients under conventional management with no aboveground crop residues re-

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Table 6. Economic analysis for the Sahar wheat crop (Average of two years: 2009-2010/2010-2011).

Irrigation levels	Nitrogen Rates (kg ha^{-1})	Grain Yield (Mg ha^{-1})	Straw Yield (Mg ha^{-1})	Variable Cost (US $ ha^{-1})	Permanent Cost (US. $ ha^{-1})	Total Cost (US $ ha^{-1})	Gross Income (US $ ha^{-1})	Net return (US $ ha^{-1})	Net field Benefits (US $ ha^{-1})	Benefit Cost Ratio
ZT	N_0	3.63	5.03	17.27	408.2	425.47	1542.718	1117.248	1525.448	1.38
	N_{130}	5.46	7.38	43.14	408.2	451.34	2299.068	1847.728	2255.928	1.24
	N_{160}	5.60	7.53	49.11	408.2	457.31	2353.503	1896.193	2304.393	1.24
	N_{190}	5.50	8.06	55.08	408.2	463.28	2387.956	1924.676	2332.876	1.24
MT	N_0	3.74	5.21	69.1	408.2	477.3	1592.641	1115.341	1523.541	1.42
	N_{130}	5.30	7.78	94.97	408.2	503.17	2302.628	1799.458	2207.658	1.27
	N_{160}	5.68	7.92	100.94	408.2	509.14	2419.632	1910.492	2318.692	1.26
	N_{190}	5.61	8.14	106.91	408.2	515.11	2426.369	1911.259	2319.459	1.26
CT	N_0	3.50	4.71	109.42	408.2	517.62	1471.371	953.751	1361.951	1.54
	N_{130}	5.16	7.26	135.29	408.2	543.49	2205.606	1662.116	2070.316	1.32
	N_{160}	5.93	8.00	141.26	408.2	549.46	2495.215	1945.755	2353.955	1.28
	N_{190}	5.74	8.36	147.23	408.2	555.43	2486.206	1930.776	2338.976	1.28
DT	N_0	3.85	5.36	148.0	408.2	556.2	1639.111	1082.911	1491.111	1.51
	N_{130}	5.36	7.57	173.87	408.2	582.07	2294.387	1712.317	2120.517	1.33
	N_{160}	5.99	8.12	179.84	408.2	588.04	2524.957	1936.917	2345.117	1.30
	N_{190}	5.81	8.69	185.81	408.2	594.01	2542.774	1948.764	2356.964	1.30

ZT = Zero tillage, MT = Minimum tillage, CT = Conventional tillage, DT= Deep tillage
N0 = Nitrogen @ 0 kg ha-1, N130= Nitrogen @ 130 kg ha-1, N160 = Nitrogen @ 160 kg ha-1, N190 @ 190 kg ha-1

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Table 7. Dominance and Marginal analysis for the Sahar wheat crop (Average of two years: 2009-2010/2010-2011).

Irrigation Levels	Nitrogen Rates (kg ha^{-1})	Variable Cost (US .$ ha^{-1})	Net Field Benefits (US $ ha^{-1})	Marginal Cost that vary	Marginal Net Field Benefits	Marginal Rate of Return	Dominated Treatments
ZT	N_0	17.27	1525.448	-	-	-	-
ZT	N_{130}	43.14	2255.928	25.87	730.48	28.23	
ZT	N_{160}	49.11	2304.393	5.97	48.465	8.11	
ZT	N_{190}	55.08	2332.876	5.97	28.483	4.77	
MT	N_0	69.1	1523.541	-	-	-	D
MT	N_{130}	94.97	2207.658	25.87	684.117	26.44	
MT	N_{160}	100.94	2318.692	5.97	111.034	18.59	
MT	N_{190}	106.91	2319.459	5.97	0.767	0.128	
CT	N_0	109.42	1361.951	-	-	-	D
CT	N_{130}	135.29	2070.316	25.87	708.365	27.38	
CT	N_{160}	141.26	2353.955	5.97	283.639	47.51	
CT	N_{190}	147.23	2338.976	-	-	-	D
DT	N_0	148.0	1491.111	-	-	-	D
DT	N_{130}	173.87	2120.517	25.87	629.406	24.32	
DT	N_{160}	179.84	2345.117	5.97	224.6	37.62	
DT	N_{190}	185.81	2356.964	5.97	11.847	1.984	

ZT = Zero tillage, MT = Minimum tillage, CT = Conventional tillage, DT= Deep tillage
N0 = Nitrogen @ 0 kg ha^{-1}, N130= Nitrogen @ 130 kg ha^{-1}, N160 = Nitrogen @ 160 kg ha^{-1}, N190 @ 190 kg ha^{-1}.

turning to the soil (Su et al. 2006). Results of this study revealed that increasing the nitrogen rates also increased soil total N. The increase in soil N might be due to residual buildup of soil nitrogen by continuous application of inorganic fertilizer. Hati et al. (2008) also reported increase in total N content with increasing N rates in the uppermost soil layer. These results are in accordance with those of Agbede et al. (2008) who found that higher nitrogen fertilizer levels resulted in higher concentrations of available P, K, N and organic C than the control treatments in soil. Tillage and nitrogen fertilizer also improved soil organic carbon storage. More soil organic carbon storage under zero tillage might be due to high amounts of biomass added to the soil, causes minimal soil disturbance, conserves soil and water, improves soil structure, and enhances soil fauna activity (Six et al., 2000). Lal et al. (1998) summarized the rate of accumulation of soil organic carbon (SOC) stock under NT at 300-800 kg SOC ha^{-1} year^{-1}. The introduction of conservation tillage increases the organic carbon storage in the cultivated layer (0 -20 cm) from 0.19 to 0.81 Mg ha^{-1} year^{-1} (Baker et al., 2007; Bayer et al., 2006; Zhang et al., 2009). Zero and minimum tillage and nitrogen fertilization can improve C and N storage in the surface soil (Allmaras et al., 2000; Sainju et al., 2006), while conventional and N fertilization decreases soil organic matter level by increasing carbon and nitrogen mineralization and limiting C and N inputs (Balesdent et al., 1990; Cambardella and Elliott, 1993). Results of this study revealed that increasing the nitrogen rates also increased plant height, grain yield, WUE and FUE in wheat crop, over control. Increase in plant height at high fertilizer level might be due to proper nutrition availability which resulted in increase in vegetative growth of the plants. This might be due to the cell division and enlargement which might be stimulated by nitrogen nutrition. Similar result were recorded by Maqsood et al. (2000) who concluded that application of nitrogen at the rate of 125 kg ha^{-1} produced significantly taller plants (97.6 cm) than 100 and 75 kg N ha^{-1}, yet it did not significantly differ from treatment 150 kg N ha^{-1} (97.1 cm). These results are in conformity with those noted by Shivay and Singh. (2000), who reported that plant height of maize decreased under minimum tillage. Similarly, Singh and Sharma (2001) also observed that grain yield and yield-attributing parameters significantly increased with increasing nitrogen levels up to 150 kg ha^{-1}. Results of this study are also in line with those of Kumbhar et al. (2007) who found that increase in levels of fertilizer at 150-50 NP kg ha^{-1} gradually increased grain yield (3198.2 kg ha^{-1}). This could have been due to both the higher nutrient availability from fertilizer and the improvement in the soil physical conditions due to tillage. FUE also increased by recommended dose of NPK compared to less or more application of nitrogen (Raza et al., 2005). Daniels and Scott (1991) also found an average WUE of 9.66 kg ha^{-1} mm^{-1} of water.

Conclusion

A study was conducted to assess the effect of tillage and nitrogen application rates on the soil organic carbon, soil total nitrogen in the surface soil, and yield of wheat in a sandy clay loam soil. Results obtained from this study show that tillage practices and fertilizer application rates affected the concentrations of soil organic carbon and total nitrogen in the surface soil, with higher application rates leading to greater accumulations of residual nitrogen and organic carbon.

Grain yield was significantly increased in response to nitrogen rates and tillage intensity with higher grain yields occurring when deep tillage was combined with nitrogen fertilizer. Zero tillage enhances the SOC and STN at 0-30 cm depth, compared with conventional and deep tillage measure sequestrates more carbon and nitrogen, this is helpful to the buildup and storage of SOC and nitrogen, consequently it is a valuable tillage measure and its further popularization is worth.

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