INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
17–0838/2018/20–7–1539–1547
DOI: 10.17957/IJAB/15.0664
http://www.fspublishers.org

Full Length Article

Soil Fertility in Response to Urea and Farmyard Manure Incorporation under Different Tillage Systems in Peshawar, Pakistan

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Abstract

The farmyard manure (FYM) combined with chemical fertilizers is considered to improve soil fertility and crop production. This was tested in a field experiment using three tillage practices (i.e., rotavator (MT), conventional tillage (CT) and deep tillage (DT) and six treatments of organic and inorganic fertilizers. The fertilizer treatments were i.e., control, 100%, 75%, 50%, 25%, 0% N derived from urea, and the corresponding remaining N from FYM (i.e., 14.8 tons $ha^{-1}$for 100% FYM) to provide a pool of 120 kg N ha^{-1} as recommended for wheat crop. Averaged across fertilizer application, the soil organic matter, total nitrogen, phosphorous, potash, microbial biomass carbon and nitrogen, mineralizable carbon and nitrogen were higher in MT than CT and DT at 0–30 cm soil depths and, both soil moisture and bulk density were higher in DT than other tillage practices at 20–30 cm soil depths. Averaged across tillage practices, application of 100% N derived from FYM to fulfill the crop N requirements resulted in a lower bulk density and higher organic matter, phosphorus, potash, microbial biomass nitrogen, mineralizable carbon and nitrogen at 0–30 cm depths when compared with other fertilizer ratios, while the contents of total nitrogen and microbial biomass carbon were higher in the plots receiving 75% N from FYM and 25% from synthetic fertilizer. Most of the soil properties were better in top soil 0–10 cm as compared to 10–20 or 20–30 cm soil depth. It was concluded from the experiment that soil properties at top surface soil 0–10 cm can be improved by MT as well as by application of 100% N derived from FYM, which is an advisable practice for the local crop production in agro-climatic conditions of Peshawar, Pakistan.

Keywords: Nutrient recycling; Sustainability; Tillage; Nitrogen management; Soil fertility

Introduction

The intensification of agriculture due to increasing population had negative impacts on environment and ecosystems. The soil physical, chemical and biological functionality is related to the major agronomic practices like tillage and nutrient management (Bradford and Peterson, 2000). In areas like northern Pakistan, where the soil organic matter (SOM) content is low, the reduced tillage and integrated N management is useful. The poor soil fertility and maintaining optimum nutrients for sustainable crop production can be provided by inputs like plant residue (Khan *et al.,* 2008), animal manure (Jokela and Nair, 2016), and green manure (Prasad, 2003).

Tillage practices alter soil properties which in turn expedite crop growth and development by providing fair soil tilth for root growth and maximum uptake of nutrients. Minimum tillage is effective in saving more precipitation for crop production (Habtegebrial *et al.,* 2007), preserves soil biota and reduces N leaching (Sainju *et al.,* 2007), soil bulk density, pH and CO_2 emission (Wang and Dalal, 2006), and erosion (Lopez-Bellido and Lopez-Bellido, 2001). It also improves emergence, grain N of wheat (Wiatrak *et al.,* 2006) and crop yield. In general, no-tillage results in increased nutrient concentrations near the surface soil, but such concentrations rapidly decrease with depth, while conventional tillage results in a more homogeneous distribution of nutrients with depth (Edwards *et al.,* 1992). Bruce *et al.* (1995) found that maintenance of soil organic carbon (SOC) within the first few cm of soil is essential for improving infiltration and crop-available soil water. Similarly, the conventional and deep tillage can also improve soil aeration and porosity, conserve nutrients and moisture for plants and microbes, release nutrients from soil micro flora pool for crops (Kristensen *et al.,* 2003), and thus finally increase crop yield (Diaz-Zorita, 2000). Thus, the available literature showed the controversy for tillage effects on soil properties and crop growth, thus we hypothesized

To cite this paper: Muhammad, I., F.U. Khan, A. Khan and J. Wang, 2018. Soil fertility in response to urea and farmyard manure incorporation under different tillage systems in Peshawar, Pakistan. *Int. J. Agric. Biol*., 20: 1539–1547

that minimum tillage will improve the soil properties.

The commercially available N has positive effects on crop productivity with little or no effects on soil properties (MartÍNez-Eixarch *et al.*, 2013). Additionally, chemical fertilizers are required in high amount, which is expensive (Romero *et al.*, 2013) and also non-sustainable. While the application of farm yard manure alone is labor intensive, having low N ratio, required in large amount and also release nutrients slowly as compared to synthetic fertilizer (Jokela and Nair, 2016).Whereas, integrated use of N in the form of synthetic and natural sources are considered to increase both crop productivity as well as soil properties. Integrated nutrient management (INM) increased N efficiency and thereby increased the crop yields on sustainable basis (Ahmadi *et al.*, 2014), increased water conservation and plant growth (Khan *et al.*, 2015) and recovered soil health through minimizing the soil erosion, reduced nitrate leaching (Yagioka *et al.*, 2015) and other form of N losses (Zhao *et al.*, 2016). This integration also increased the microbial respiration and microbial biomass C (Ouédraogo *et al.,* 2006). However, the sole use of synthetic or organic N sources is considered inferior in term of crop productivity (Nakamoto *et al.*, 2006). Application of INM helped in proper nutrition and maintenance of soil fertility (Salim *et al.*, 1988).

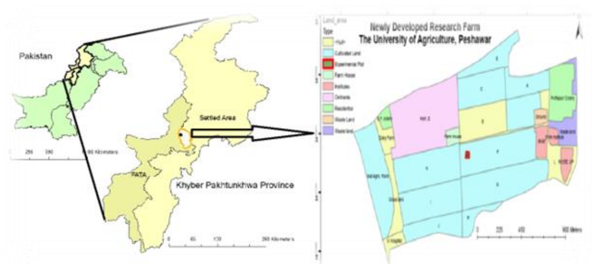
The integrated use of nutrients is considered a primary substrate for replenishment of soil organic matter (Rasool *et al.,* 2007) and can be regarded as an alternative way of adding fertilizer to increase soil fertility and crop productivity in organic farming. Microorganisms in soil have positive effects on plant growth and development (Montesinos, 2003). The higher populations of microorganisms are the indication of qualitative soil which also plays a significant role in activation of nutrients for plants. The available literature had documented positive effects on the integrated use of N from synthetic and organic sources. However, knowledge gap still exist to quantify, the appropriate ratio of these two sources on the soil physical, chemical and biological properties. From the available literature, no clear conclusions are available that how much manure will be integrated with commercial N. Thus it was hypothesized that the 50% N derived from both commercial sources (urea) and 50% from organic sources (farmyard manure) will be more helpful in increasing the soil properties.

The reduced tillage practices when received organic source of N could have improved soil health by reducing N losses (Lopez-Bellido and Lopez-Bellido, 2001). The rapid losses of soil organic carbon in response to tillage led to decrease the soil biological activity, and thus have negative effects on soil microbial biomass and soil enzyme (David *et al.,* 2007). The physical disturbance of the soil due to tillage implement affects the soil properties in addition to the manure decomposition (Espana *et al.,* 2002). However, no clear conclusion is drawn from the available literature, which can show the interactive response of tillage and integrated nutrient management. Thus, we hypothesize that minimum ploughed plots receiving sole manure would have positive effects on the soil properties. Therefore, the present experiment was conducted to quantify the effects of three tillage practices (minimum, congenital and deep) and integrated use of urea and farmyard manure in different ratios applied to wheat crop on the soil physical, chemical and biological properties.

Materials and Methods

Experimental Location

A field experiment was conducted at Agronomy Research Farm, the University of Agriculture, Peshawar (34° N, 71° E, Fig. 1) from Nov 2014 to May 2015. Soil physical-chemical properties studied during the experiment before sowing (Table 1) indicated that the pH of the site was alkaline (8.09) and varied with soil depth. However, the texture was silt loam. The soil had low organic matter, EC, total nitrogen, mineral nitrogen, soil phosphorus and optimum soil potash (0.83%, 0.18 dS m^{-1}, 0.41 g kg^{-1}, 8.45 mg kg^{-1}, 3.06 mg kg^{-1} and 90.39 mg kg^{-1}), respectively. Soil total nitrogen and phosphorus were higher in the surface soil as compared to sub surface soil, while other nutrients had no variation across the soil depth.



Experimental Design

The tillage practices were rotavator (minimum tillage, MT), filed cultivator (Conventional tillage, CT), and chisel plough (Deep tillage, DT). Whereas, the N sources were urea and FYM ratios (i.e., 0:0, 100:0, 75:25, 50:50, 25:75, 0:100%, respectively) to supply 120 kg N ha^{-1}. The experiment was carried out in randomized complete block design in split plot arrangement with three replications. Tillage practices were allotted to the main plot and integrated nutrient to the sub plots. The sub plot size was kept 5 × 3 m^2 containing 10 rows, each row was 5 m long with row-row distance of 30 cm. Tillage practices was carried out in the designated plots, and the farmyard manure (having 0.81% total N, 0.10% mineral N, and 14.5% carbon) obtained from the Dairy Farm of the University of Agriculture, Peshawar was soil incorporated 30 days before sowing. Recommended doses of P_2O_5 and K_2O at the rate of 90 and 60 kg ha^{-1}, respectively were used. Half of N (urea) and full doses of P (single supper phosphate) and K (Sulphate of potash) were

Table 1: Soil physical and chemical properties

Soil physical and chemical	Units	Soil depths (cm)		
		0-10	10-20	20-30
Sand	%	18.47	20.55	23.62
Silt	%	71.32	68.18	64.22
Clay	%	10.21	11.27	12.16
Textural Class		Silt loam	Silt loam	Silt loam
Organic matter	%	0.89	0.85	0.75
pH	-	8.10	8.05	8.13
EC	d Sm^{-1}	0.17	0.18	0.18
Total N	g kg^{-1}	0.45	0.41	0.38
Mineral N	mg kg^{-1}	8.24	9.12	7.98
Potassium	mg kg^{-1}	89.43	96.29	85.44
Phosphorous	mg kg^{-1}	3.25	2.98	2.95

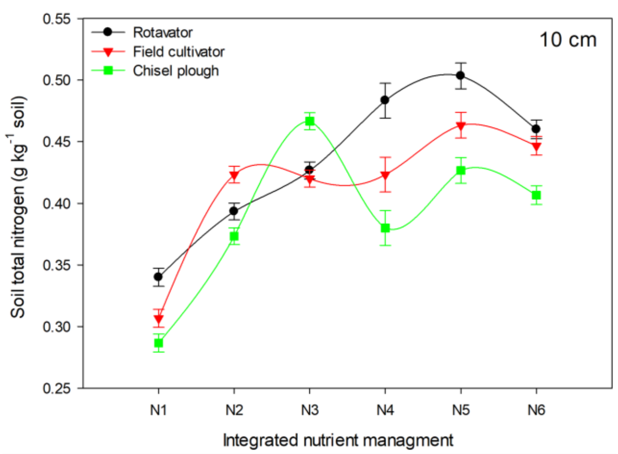


Fig. 1: Tillage and integrated nutrient management interaction for nitrogen content (%) it 10 cm soil depth. Vertical bars are standard error

N1=Control, N2=100% N from urea, N3=75% N from urea + 25% N from FYM, N4=50% N from urea + 50% N from FYM, N5=25% N from urea + 75% N from FYM and N6=100% N from FYM

applied at seed bed preparation, whereas other half of N was applied with first irrigation. Wheat variety Siran 2010 was sown at the seed rate of 120 kg ha^{-1} in the second week of November and harvested it first week of May. All other cultural techniques such as irrigation, hoeing, and weeding etc. was uniformly performed in all the subplots. Field was irrigated 5 times at seedling, tillering, booting, flowering and ripening stages.

Measurements

Composite soil samples were taken from each sub plot at 0–30 cm soil depth before sowing and after harvest and analyzed for soil characteristics. Soil pH of the sample was determined by pH meter in 1:5 (soil:water) solution. Electrical conductivity (ECe) of soil extract was determined by EC meter (McLean, 1982). Soil texture was calculated by using dispersing agent and electrical shaker (Kochler *et al.*, 1984). Bulk density was calculated by using core sampler-42 in field via taking three cores from each subplot and averaged (Black and Hertge, 1984). The soil moisture was determined as the weight difference of moist soil (at the sampling time) and oven dried at 105ºC sample. Soil organic matter contents were determined using the procedure of Nelson and Sommers (1982).

Macro nutrients Analysis

Soil total N content was determinate by using Kjeldahl procedure (Bremner and Mulvaney, 1982). P and K content of soil were determined by the procedure described by Sultanpur and Schawab (1977).

Microbial Biomass

Microbial biomass C and N was found by using chloroform fumigation methods using constants (Horwath and Paul, 1994).

Mineralizable C and N

The total amount of CO_2 produced in incubated soil samples during 10 days was used to calculate the potential carbon mineralization (PCM). Similarly, the potential nitrogen mineralization (PNM) was determined by difference of mineral N after 10 days of incubation and zero day incubation.

Statistical Analysis

The collected data were analyzed statistically using Linear Model, upon the significant F-test, means were separated using least significance difference test (LSD).

Linear Model: $Y_{ij} = \mu + \alpha + \beta_i + \mathcal{E}1 + \gamma_j + \beta_i{*}\gamma_j + \mathcal{E}2$

Where,

μ= Mean effect	α= Replication effect
βi = ith block effect	Ɛ1= Error first
ɣj= jth treatment effect	βi*ɣj= treatment × block interaction
Ɛ2 =	Error 2nd

Results

Soil pH and Electrical Conductivity

Tillage had no significant effects for soil pH and electrical conductivity (Table 2). The integrated nutrient management (INM) effects were also non-significant for soil electrical conductivity, while INM significantly affected the soil pH. Addition of fertilizer N increased soil pH while the plots having organic source of N decreased soil pH as compared to CK at each soil depth.

Soil Bulk Density (g cm^{-3})

Averaged across fertilizer application, DT had significantly higher bulk density at 0–10 cm soil depth than CT and MT. Similarly, in 10–20 cm and 20–30 cm soil depths, the DT plots had significantly higher soil bulk density than MT plots (Table 2). Similarly soil bulk density was significantly higher in CK than into the plots with sole application FYM or in combination with fertilizer nitrogen to provide a pool N of 120 kg ha^{-1}at all soil depths.

Soil Moisture Contents (%)

More moisture content was observed in plots with DT as compared to MT at 0–10 and 20–30 cm soil depths averaged crossed fertilizers (Table 2). Whereas, the moisture contents of DT was statistically similar to CT but higher than MT. Soil moisture contents was significantly affected by INM. The moisture content was high for 100% FYM over CK at 0–10 cm soil depth. Similarly, 10–20 cm and 20–30 cm soil depth the moisture content was higher for FYM treated plots than CK.

Soil Organic Matter Contents (%)

Highest organic matter was recorded at 0–10 cm soil depth for MT, as compared to CT and DT, while the organic matter content of CT was not statistically different from DT. Similarly, in case of 10–20 and 20–30 cm soil depth, the higher soil organic matter content was recorded for MT plots and CT than DT plots. Addition of FYM alone or in combination with fertilizer N (less contribution i.e., 25%) had higher soil organic matter content compared to CK (Table 3) across all sampling depth. However, the content was high in the top soil layers as compared to bottom soil layer. Higher organic matter content was observed for plot receiving 100% FYM, followed by the plot receiving 75% FYM and 25% fertilizer N, and whereas the minimum soil organic matter was observed for CK at 0–10 cm depth. Similarly for 10–20 and 20–30 cm soil depth higher organic matter content were observed for plots receiving 100% N from FYM or in combination with fertilizer N than CK or plot receiving 100% fertilizer N.

Soil Macronutrients

The interaction response of tillage x INM in 0–10 cm depth, indicated that increasing the FYM proportion as N source, the soil total N increased linearly in MT plots, and remained unchanged in CT or DT plots. However, in all cases, the soil total N contents were higher than CK plots (Fig. 1). At 10–20 cm depth, the soil total N content increased with increasing the FYM proportion as N sources across all the tillage practices; however, the content was higher for MT plots over CT or DT plots (Fig. 2). In case of 20–30 cm sampling depth, the soil total N content increased linearly with DT (Fig. 3). Whereas in MT or CT, the N content increased with increasing FYM proportion from 0 to 25% as

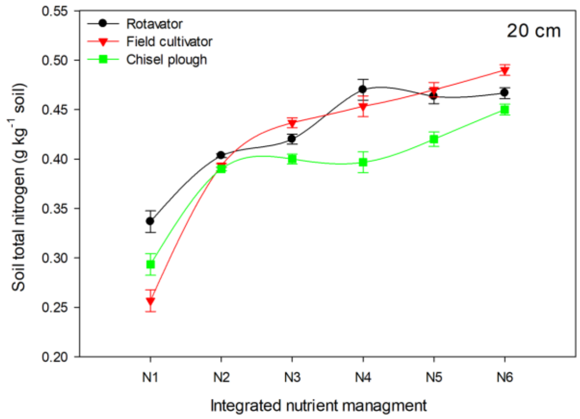


Fig. 2: Tillage and integrated nutrient management interaction for nitrogen content (%) it 20 cm soil depth. Vertical bars are standard error
N1=Control, N2=100% N from urea, N3=75% N from urea + 25% N from FYM, N4=50% N from urea + 50% N from FYM, N5=25% N from urea + 75% N from FYM and N6=100% N from FYM

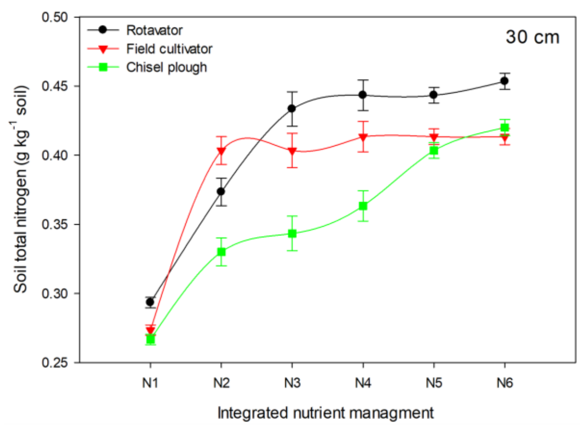


Fig. 3: Tillage and integrated nutrient management interaction for nitrogen content (%) it 30 cm soil depth. Vertical bars are standard error
N1=Control, N2=100% N from urea, N3=75% N from urea + 25% N from FYM, N4=50% N from urea + 50% N from FYM, N5=25% N from urea + 75% N from FYM and N6=100% N from FYM

N source, and thereafter with further increasing the FYM proportion increases in soil total N contents were non-significant. However, the N contents were higher with MT plots over the CT plots.

Higher soil phosphorus was observed for MT at 0–10 cm sampling depth, compared to DT. Likewise, 10–20 cm soil depth higher soil phosphorus was observed for MT followed by CT, while lower phosphorus was observed for DT plots. A similar trend was observed for 20–30 cm soil depth as presented in Table 3. Sole application of FYM to provide a pool N of 120 kg ha^{-1} had significantly higher soil phosphorus, followed by the plots receiving 25% N from urea and 75% N from FYM, whereas the lower soil phosphorus was observed for CK on each soil depth (Table 4). The higher amount of FYM incorporation advocated

Table 2: Soil pH, EC (dSm^{-1}), bulk density ($g\ cm^{-3}$), and soil moisture (%) in response to integrated nutrient management and soil depths under various tillage practices

Tillage practices	% of FYM	Soil pH			EC ($dS\ m^{-1}$)			Bulk density ($g\ cm^{-3}$)			Soil moisture (%)		
		at various soil depth (cm)											
		0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Rotavator		8.09	8.09	8.07	0.17	0.17	0.18	1.27c	1.32c	1.33c	17.89b	18.18b	19.00c
Field cultivator		8.09	8.09	8.08	0.17	0.17	0.18	1.31b	1.34b	1.37b	18.27b	19.00b	20.04b
Chisel plough		8.08	8.08	8.08	0.17	0.17	0.17	1.37a	1.38a	1.40a	18.92a	20.41a	21.98a
LSD (0.05)		NS	NS	NS	NS	NS	NS	0.0044	0.0048	0.0035	17.89	18.18	19.00
	Control	8.14a	8.14a	8.13a	0.18	0.17	0.18	1.35a	1.38a	1.41a	17.3d	18.09d	18.8c
	0	8.13a	8.13ab	8.12ab	0.17	0.17	0.17	1.34ab	1.38a	1.38b	17.7cd	18.45cd	19.8bc
	25	8.10b	8.11ab	8.09abc	0.17	0.17	0.18	1.31bc	1.35ab	1.37bc	18.3bcd	19.1bcd	20.2ab
	50	8.08b	8.08bc	8.07bc	0.17	0.17	0.17	1.30bc	1.34bc	1.36bcd	18.7abc	19.4abc	20.7ab
	75	8.05c	8.04cd	8.05cd	0.17	0.18	0.18	1.30bc	1.33bc	1.35cd	18.9ab	19.82ab	21.0ab
	100	8.02d	8.01d	8.01d	0.17	0.18	0.17	1.28c	1.31c	1.34d	19.3a	20.34a	21.5a
LSD (0.05)		0.009	0.011	0.0123	NS	NS	NS	0.0137	0.0123	0.0091	0.3474	0.3949	0.4378
Significance													
Tillage	NS	NS	NS	NS	NS	NS	***	**	***	NS	**	**	***
INM	***	**	**	NS	NS	NS	**	**	***	***	**	**	**
T x INM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

FYM= farmyard manure, the remain % (to provide a pool 120 kg N ha^{-1}) was supplied from urea
Means followed by different letter (s) are significantly different from each other in each category at $P \leq 0.05$ *,** and *** means significant at 0.05, 0.01 and 0.001 levels, respectively

Table 3: Soil organic matter (%), total nitrogen ($g\ kg^{-1}$), total phosphorus, and total potash in response to integrated nutrient management and soil depths under various tillage practices

Tillage practices	% of FYM	Organic matter (%)			Total nitrogen ($g\ kg^{-1}$)			Phosphorous($mg\ kg^{-1}$)			Potash ($mg\ kg^{-1}$)		
		at various soil depth (cm)											
		0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Rotavator		1.00a	0.98a	0.89a	0.43a	0.43a	0.41a	3.97a	3.79a	3.12a	95.08a	89.44a	83.85a
Field cultivator		0.93b	0.93a	0.87a	0.41b	0.42a	0.39a	3.57b	3.18a	2.97b	92.00b	87.75a	80.47b
Chisel plough		0.89b	0.84b	0.78b	0.39c	0.39b	0.35b	3.08c	2.83b	2.61c	89.40c	85.16b	76.13c
LSD (0.05)		1.00	0.98	0.89	0.43	0.43	0.41	0.0702	0.0225	0.0571	0.5817	0.4222	0.7172
	Control	0.79e	0.76e	0.69e	0.31d	0.30e	0.28e	3.10c	2.88d	2.63c	82.83c	79.80d	71.77c
	0	0.89d	0.86d	0.78d	0.40c	0.40d	0.37d	3.39bc	3.12cd	2.79bc	90.86b	83.39cd	77.67b
	25	0.94c	0.91c	0.81cd	0.44ab	0.42cd	0.39c	3.47b	3.27bc	2.86bc	92.78ab	86.83bc	79.85b
	50	0.98bc	0.94bc	0.87bc	0.43b	0.44bc	0.41bc	3.58ab	3.33ab	2.97ab	93.96ab	90.01ab	81.31b
	75	1.00b	0.97b	0.93b	0.46a	0.45ab	0.42ab	3.76ab	3.41a	3.05ab	95.01ab	91.79ab	83.01ab
	100	1.05a	1.05a	1.00a	0.44ab	0.47a	0.43a	3.95a	3.60a	3.12a	97.52a	92.89a	87.28a
LSD (0.05)		0.0160	0.0160	0.0193	0.0104	0.0085	0.0066	0.1321	0.1017	0.0549	1.9163	1.9729	1.8720
Significance								**	***	**	**	**	**
Tillage	NS	**	**	**	**	**	**	**	***	***	***	***	***
INM	***	***	***	***	***	***	***	NS	NS	NS	NS	NS	NS
T x INM	NS	NS	NS	NS	*	*	*	**	***	**	**	**	**

FYM= farmyard manure, the remain % (to provide a pool 120 kg N ha^{-1}) was supplied from urea
Means followed by different letter (s) are significantly different from each other in each category at $P \leq 0.05$ *,** and *** means significant at 0.05, 0.01 and 0.001 levels, respectively

higher phosphorous content in the soil.

The soil potash contents were higher for MT, followed by CT, and least for DT at 0–10 cm soil depth (Table 3). Likewise, at 10–20 and 20–30 cm soil depths, maximum K content was observed for MT statistically at par with CT, but significantly higher from DT plots. More soil potash content was observed in plot receiving sole FYM or in combination with fertilizer nitrogen as compared to CK (Table 3) both at the top and below soil surfaces. This greater K in sole FYM might be due to greater soil microbial activity, higher soil organic matter content, and due to greater soil moisture conservation in these plots.

Microbial Biomass C and N

Averaged across fertilizer application, MT had higher soil microbial biomass (MBC) compared to CT or DT 0–10, 10–20 and 20–30 cm soil depths (Table. 4). The greater organic carbon in topsoil served as a food for micro-organism might have increased the soil microbial activity and hence MBC. The plots ploughed with CT and DT systems might have decreased the SOM content and thus might have destroyed the soil structure, which ultimately reduced the soil microbial activity and hence MBC. Integrated nutrient increased the soil MBC (Table 4) and greater soil MBC was observed for application of 25% N from urea and 75% N from FYM followed by plots having 50% N from urea and FYM, while lower MBC was observed for CK. This trend of MBC was observed across all the sampling depth. Microbial biomass nitrogen (MBN) was significantly affected by tillage and INM (Table 4). The MT had

Table 4: Soil Microbial biomass carbon (μg C g^{-1}) and microbial biomass nitrogen (μg N g^{-1}) in response to integrated nutrient management and soil depths under various tillage practices

Tillage practices	% of FYM	Microbial biomass carbon (μg C g^{-1})			Microbial biomass nitrogen (μg N g^{-1})		
		At various soil depth (cm)					
		0-10	10-20	20-30	0-10	10-20	20-30
Rotavator		402.39a	397.33a	382.72a	70.2a	67. 9a	70.0a
Field cultivator		368.56b	357.67b	344.28b	69.1a	64.0b	62.83b
Chisel plough		318.56c	323.72c	315.94c	64.72b	59.06c	58.11c
LSD (0.05)		6.1784	5.8656	4.8352	0.5514	0.6294	0.7632
	Control	296.33e	292.56d	285.11e	61.44c	54.67d	54.33c
	0	325.33d	322.00cd	313.67d	62.22c	61.22c	61.44b
	25	350.78c	340.22c	325.67d	67.78b	63.22bc	63.78ab
	50	406.89a	398.56ab	383.22b	70.33ab	64.11bc	64.89ab
	75	418.67a	419.78a	425.00a	72.78a	66.67ab	67.78ab
	100	381.00b	384.33b	353.22c	73.4a	72.0a	69.7a
LSD (0.05)		8.3016	10.8990	7.2273	1.5257	1.7859	2.1984
Significance		**	**	**			
Tillage		***	***	***	**	**	**
INM		NS	NS	NS	***	***	***
T x INM		**	**	**	NS	NS	NS

FYM= farmyard manure, the remain % (to provide a pool 120 kg N ha^{-1}) was supplied from urea
Means followed by different letter (s) are significantly different from each other in each category at P ≤ 0.05 *,** and *** means significant at 0.05, 0.01 and 0.001 levels, respectively

Table 5: Soil mineralizable carbon (µg C g^{-1}) and mineralizable nitrogen (µg N g^{-1}) in response to integrated nutrient management and soil depths under various tillage practices

Tillage practices	% of FYM	Mineralizable carbon (µg C g^{-1})			Mineralizable nitrogen (µg N g^{-1})		
		At various soil depth (cm)					
		0-10	10-20	20-30	0-10	10-20	20-30
Rotavator		120.4a	118.1a	109.3a	64.56a	63.6a	61.56a
Field cultivator		100.6b	94.3b	93.9b	49.22b	48.5b	46.39b
Chisel plough		75.59c	74.63c	74.51c	37.00c	34.8c	36.00c
LSD (0.05)		1.6724	1.7419	1.6516	1.0666	1.1039	0.8723
	Control	85.16d	84.98c	84.45d	40.44c	40.8c	39.78d
	0	92.60cd	88.88bc	87.25cd	48.56b	47.2b	46.22c
	25	96.27bcd	91.81bc	90.06bcd	49.22b	49.6ab	47.22bc
	50	100.58abc	96.13b	94.06abc	51.78b	50.6ab	49.33abc
	75	106.97ab	105.04a	97.63ab	53.44ab	51.8a	51.56ab
	100	111.5a	107.0a	102.0a	58.11a	53.8a	53.78a
LSD (0.05)		3.743	2.797	2.636	1.6932	1.475	1.7769
Significance							
Tillage		***	***	***	***	***	***
INM		***	***	***	***	***	***
T x INM		NS	NS	NS	NS	NS	NS

FYM= farmyard manure, the remain % (to provide a pool 120 kg N ha^{-1}) was supplied from urea
Means followed by different letter (s) are significantly different from each other in each category at P ≤ 0.05*,** and *** means significant at 0.05, 0.01 and 0.001 levels, respectively

higher MBN over DT but statistically similar to field CT at 0–10 cm soil depth. Likewise, in 10–20, 20–30 cm soil depth the MBN was higher in MT followed by CT, while lower MBN was observed for DT. In case of INM, the MBN was higher in plot receiving 100% N from the sole application of FYM, followed by the plots received 25% N from urea and 75% N from FYM over the CK at 0–30 cm soil depth.

Mineralizable C and N

The potential carbon mineralization (PCM) was higher in MT when compared to either CT or DT at 0–30 cm soil depth (Table 5). Greater PCM was observed in the plots where the total recommended N was provided either from FYM or 75% from FYM + 25% from urea. However, the CK had resulted in minimum PCM in each soil depth.

The greater potential nitrogen mineralization (PNM) was observed for MT than CT and DT at 0–10 and 10–20 cm soil depths averaged crossed fertilizer application (Table 5). The higher SOC in MT plots might be the probable reasons for improved PNM in these plots. INM significantly affected PNM, which was greater when 100% of N demand was fulfilled by FYM followed plots having 75% N from FYM and 25% N from urea, over the least PNM observed for CK. Across the three sampling depths, the PNM was higher in either sole FYM or mixed with 25% urea over the minimum PNM observed in CK.

Discussion

Our results showed that tillage had non-significant effect might be due to the moderate clay contents of the soil (Kirchhof and Daniells, 2009). The buffering capacity of added FYM might decrease the soil pH, while having no effects on soil EC (Table 2).

Reduced tillage practices have significantly lower soil bulk density than plots ploughed deeply, which could be associated with improved aggregate stability, or improved microorganism activity in reduced tillage (Table 2). The probable reasons for lower bulk density at 0–10 cm top soil might be the improved microbial activity in the upper soil surface, or might be due to higher soil porosity (Chan *et al*., 2003). Lower bulk density in minimum tillage as a result of increasing soil porosity had been reported (Gangwar *et al*., 2006). The decrease in soil bulk density would be the result of improved soil porosity and microbial activity after FYM application (Diosma *et al.,* 2006).

The moisture content increased with increasing the ploughing depth, which could be due to high infiltration rates (Gangwar *et al.,* 2006) or greater number of soil pores (Chiroma *et al*., 2005), or might be due to higher ploughing intensity in case of DT (Table 2). The lower moisture content in the surface soil might be due to more evaporation from the soil and utilization by crop. Wilson *et al.* (2003) reported less moisture content in surface soil due to greater evaporation. More water was retained in the soil having FYM compared to control plots, which prevented runoff and increased water holding capacity (Gangwar *et al*., 2006). Incorporation of manure reduced evaporation losses which might increase moisture contents (Olasantan, 1999).

These results are in the agreements with the finding of Edwards *et al.* (1992), who reported higher soil organic matter content in MT plots compared to DT. Tarnocai *et al.* (2009) reported that higher soil organic matter in top soil than bottom soil. Whereas, the minimum soil organic matter was observed for CK at 0–10 cm depth. Similarly, for 10–20 and 20–30 cm soil depth higher organic matter content were observed for plots receiving 100% N from FYM or in combination with fertilizer N than CK or plot receiving 100% fertilizer N. Ouédraogo *et al*. (2006) reported higher organic matter with manure incorporation into the soil.

The increased soil total nitrogen in reduced tillage might be due to the higher soil organic matter (Varsa *et al.,* 1997), soil porosity (Chan *et al.,* 2003) or greater residue return from the previous crops. Veenstra *et al.* (2006) also found higher soil total nitrogen in MT than DT in a four-year cotton-tomato cropping system in San Joaquin Valley, USA. Increased soil total N content due to increased proportion of FYM might be due to the greater N contents of FYM, residual N from the previous crop, or might be due to decomposition of organic source (Gangwar *et al.,* 2006), mineralization of organic source, more soil porosity. Malhi *et al*. (2006) obtained higher soil total N upon FYM incorporation into soil. These results demonstrated that MT and CT work when the crops need shallow ploughing. However, for deep-rooted plant, the DT is better, as the N content under deep tillage system increased when the soil samplings were made up to 30 cm. Similarly the greater total N content under deep surface in deeply ploughed plots (Sadej and Przekwas, 2008), and in the top surface where MT or CT (Sundermeier *et al.,* 2011) elsewhere documented.

The higher soil phosphorous recorded with MT as compared to DT (Table 3) might be due to higher organic matter content associated with plots with minimum ploughing (Papini *et al.,* 2007) or higher microbial activity, which helps in soil phosphorus availability. Edwards *et al.* (1992), reported that higher soil phosphorous was recorded for MT while lower soil phosphorus for DT, which further confirmed by Tarnocai *et al.* (2009). The higher amount of FYM incorporation advocate for higher phosphorous content in the soil. Nziguheba *et al.* (1998) reported that the addition of organic materials causes mineralization of P through increased microbial activity.

The higher potash content in MT might be due to more organic matter content in the surface soil or in reduced tillage (Tarnocai *et al.,* 2009), or due to more microbial activity which decomposes soil organic matter content and thereby increased soil potash content. The results are in contradiction with the results of Veenstra *et al.* (2006) which showed that soil potash content was lower in no-tillage or minimum ploughed plot. These results are supported by Dhanorkar and Kamra (1994) who described that slight increase in values of total K was observed with the addition of FYM.

MT increased soil MBC due to higher microbial activities (Madejón *et al.,* 2007), with the associated higher water retention or less disturbance of the soil. Increased soil MBC in FYM treated soil might be due to greater amounts of biogenic materials like PNM and water-soluble carbon (Mahmood *et al.,* 1997). This higher MBC might be due to mineral nutrition in the soil, which meets the demand of microbes, and hence increased its activity which in turn increased the MBC. Our results are similar to the findings of Leita *et al.* (1999), who reported higher MBC for combined use of FYM and fertilizer nitrogen.

This higher MBN in reduced tillage system might be due to more water retention, aggregates stability and more decomposition of organic matter (Six *et al.,* 2000). In the top soil surface, the higher MBN was due to the large quantity of organic substrate (Table. 4). However, in the deeper soil surface, the readily available C was not accessible to microbes, or could be due to the presence of older aggregates in deeper layers (Six *et al.,* 1999).

These higher MBN may be due to the more microbes and moisture content, which increase the mineralization process, and had assimilated more N. This could be also associated with increasing the soil organic matter contents, which causes an increase in MBN (Chen *et al.,* 2007). Our results are similar to the findings of Wang *et al.* (2004), who also reported greater MBN for plot receiving FYM alone or with in combination with synthetic fertilizer.

The higher PCM with CT might be due to the increases in soil aggregation and microbial activity (Zhang *et al.,* 2012) or may be due to increased soil water holding capacity (Kovar *et al.,* 1992), or increase invertebrate populations which had increased total organic C and hence PCM. Organic amendments generally increase PCM (Goshal and Singh, 1995). However, controversies in literature were founded and it was also observed that PCM content increased with the application of mineral fertilizer (Houot and Chaussod, 1995).

The higher microbial activities enhance CO_2 respiration and microbial biomass (Müller *et al.,* 2009) which might be due to the other possible reasons for higher PNM in top soil as compared to bottom soil, enhanced mineralization and de-nitrification process (Drinkwater *et al.,* 1996). Generally, higher PNM was observed on surface soil compared to deep soil, which might be more organic matter decomposition and microbial activity found on the surface of the soil. Our results are in the agreement with the finding of Hilfiker and Lowery (1988). The greater PNM due to integrated use of N might be due to more soil aeration, microbial activity and organic matter decomposition (Neijna *et al.,* 2016). These results are in line with the findings of Bolton Jr *et al.* (1985), who reported that application of mineral N fertilizers and manures increased soil MBN and hence, PNM.

Conclusion

From the experiment, it was concluded that the MT improved the soil properties with the application of the FYM as a source of N for the wheat crop when tilled with rotavator principally on top soil surface. It was further noted that moisture conservation was improved with deep tillage system. However, increasing the proportion of N derived from organic sources increased the soil properties including mineral N, total N, organic C, phosphorous and potash contents, and soil biological properties like MBC, MBN and mineralizable C and N. Using 50 or 75% FYM form of N had higher soil total N in MT at top soil surface (0–10 cm), whereas 100% urea N had higher total N in CT at 20-30 cm depth. However MT along with 75% of FYM as N source is recommended in irrigated belt for improving soil fertility and sustaining crop production.

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(Received 29 July 2017; Accepted 24 January 2018)