Research Article

Soil Physical Properties, Total N and Maize Yield Response to Various N Sources Incorporated with Different Tillage Implements

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Abstract | Organic manures if properly incorporated in soil with suitable tillage implement might better enhance grain yield and soil fertility. To investigate the influence of tillage systems and nitrogen (N) sources incorporation on soil physical properties, total N and maize productivity, a field experiment was conducted at Agronomy Research Farm, The University of Agriculture Peshawar during summer 2016. The design used was randomized complete block design with split plot arrangement having four replications. Tillage implements (mould board plough, rotavator, disk harrow and cultivator) were used as main plot factor and N sources (control, cattle manure, poultry manure, sheep manure, mushroom spent, mungbean residue and urea) as subplot. The results exhibited that, improved bulk density, grain yield, harvest index and soil total N (STN) were observed when N incorporated with MB plough. In case of N sources poultry manure, sheep manure and mushroom spent gave at par yield with urea. However, STN and other soil physical properties were significantly higher in organic fertilizer applied plots compared to urea treatments. Conclusively, urea incorporated with cultivator gives higher yield but organic sources incorporated with MB plough could be better alternate for urea to improve maize productivity on sustainable basis.

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Introduction

Maize (*Zea mays* L.) is a high yielding cereal crop grown throughout the world. In Pakistan it is fourth largest crop grown after cotton, wheat and rice and second largest after wheat in Northwest Pakistan (Ibrahim and Khan, 2017). Yields of maize varieties are shockingly lower particularly in Khyber Pakhtunkhwa. Apart from the genetic and other environmental variables, yield losses in maize are mainly caused by weeds infestation, availability of quality seed, perpetual decline in soil organic matter (SOM) by exhaustive cereal based cropping system, conventionally operated tillage practices and ever escalating prices of chemical fertilizers.

Tillage can play role in proper incorporation of various organic fertilizers (Inamullah and Khan, 2015). It helps in providing proper temperature for plant growth makes easy to incorporate organic manures or materials in soil and helps in maintaining good soil tilth (Zhang et al., 2016). It also improves the availability of water and nutrients present in soil (Zhang et al., 2015). Tillage operations can vary from zero-tillage i.e. less soil disturbance to deep-tillage by MB plough for inversion of soil. The most common conventional tillage practiced in Pakistan involves the use of cultivator and rotavator for seedbed preparation (Ahamd et al., 2010). Consequently, in many areas, conventional tillage practices led to a decline in crop yields and profitability when compared to areas with higher rainfall and improved tillage system (Khan et al., 2009). It compacts the lower soil layers which adversely affects seed germination and growth of plant (Zhang et al., 2015). Proper attention is required to match different tillage practices with the soil physical condition for developing a methodical approach (Inamullah and Khan, 2015).

It is well acknowledged that yield of maize can be increased by N fertilization (Azeem and Inamullah, 2016; Liu et al., 2016; Shehzad et al., 2015) along with other inputs like varieties, seed rate, and irrigation etc. N application plays a vital role in enhancing crop productivity and improving soil fertility (Zotarelli et al., 2012). Recently there has been increasing interest in organic manures incorporation for sustainable crop production (Chadwick et al., 2015). Organic manures mainly provide SOM and improve physico-chemical properties of soil, key to sustainable productivity (Shaheen and Sabir, 2017; Abdollahi et al., 2014).

Keeping in view the importance of soil properties and yield of maize, an experiment was conducted to study the influence of tillage implements and different N sources on maize yield and soil fertility.

Materials and Methods

A field experiment was conducted at The University of Agriculture Peshawar, during kharif 2016. The site of field trail has continental climate and is located at 34.01^0 N, 71.58^0 E at an altitude of 359 meter above sea level. The physico-chemical properties of the site are given in Table 1. Meteorological data were obtained from Pak. Met. Department (Figure 1).

The field trail was carried out in RCB design with split plot arrangements having three replications. AZAM (OPV) was planted and a subplot size of 4.5m × 3m was used. Tillage implements (a: Mould board plough, b: Rotavator, c: Disk harrow and d: Cultivator) were used as main plot factor while nitrogen (N) sources (a: Cattle manure, b: Poultry manure, c: Sheep manure, d: Mushroom spent and e: Mungbean residue, f: Urea and e: control) as subplot factor.

Table 1: *Soil physico-chemical properties of the experimental site.*

Property	Values
Organic matter (%)	0.73
Total nitrogen (%)	0.044
Mineral nitrogen (mg kg^{-1})	0.843
pH	8.02
EC (dSm^{-1})	0.17
Bulk density (g cm^{-3})	1.24
Textural class	Silty clay loam

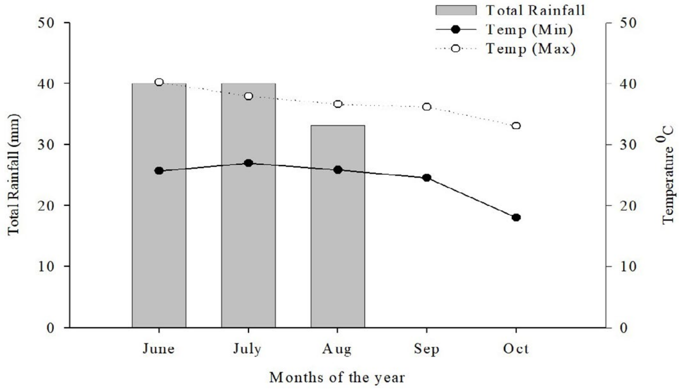

Figure 1: *Monthly mean maximum and minimum temperature (^{0}C) and total rainfall (mm) recorded during the maize growing season in Peshawar in 2016.*

Chemical composition of various N sources is given in Table 2. All the N sources were incorporated 20 days before sowing except urea which was applied in two splits (i.e. at sowing and with first irrigation). The soil total N was examined through Kjeldhal method as illustrated by Bremner and Mulvaney (1982). Representative sample of 10-gram soil was taken from each experimental unit and mixed with 50 ml distilled water and shaked in shaker for 10 minutes. Then soil pH and EC of the solution was determined by digital pH meter (Ino-Lab pH720) and EC meter (JENWAY 4510 Conductivity meter). Bulk density of soil was determined with soil bulk density meter and reported as:

Soil bulk density (g cm^{-3}) = Mass of soil sample (g)/volume occupied (cm^3)

For grain yield, four central rows were harvested, sundried for few days, shelled, and weighed. Data obtained were converted according to formulas given below.

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{Grain yield of four central rows}}{\text{R} - \text{R distance(m)} \times \text{Row length(m)} \times \text{no.of rows}} \times 10000\text{m}^2$$

Harvest index was calculated according to the formula given below:

$$\text{Harvest Index } (\%) = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

The data obtained were statistically analyzed with appropriate ANOVA using LSD at 0.05 level of probability using Statistix 8.1 software (Jan et al., 2009).

Table 2: *Chemical composition of the N sources used in the field experiment.*

N Source	N (%)	P (%)	K (%)
Cattle Manure (CM)	1.09	0.67	0.97
Poultry Manure (PM)	2.13	1.72	1.58
Sheep Manure (SM)	1.68	1.49	1.5
Mushroom Spent (MS)	1.39	0.8	ND
Mungbean Residue (MR)	0.92	0.71	ND
Urea	46.0	-	-

ND: *Not Determined.*

Results and Discussion

Grain yield (kg ha⁻¹)

Statistical analysis of data showed that tillage implements, N sources and interaction of (TI × NS) had significant effect on grain yield of maize (Table 3). Among different tillage implements, plots ploughed with MB plough resulted in higher grain yield (3522 kg ha^{-1}). It was followed by disk harrow with grain yield (3305 kg ha^{-1}), which was statistically at par with plots tilled with cultivator (3207 kg ha^{-1}). However lowest grain yield (3067 kg ha^{-1}) was reported in plots where rotavator was used. The relatively positive influence of deeper tillage operations on overall productivity might be endorsed to better soil physical and hydrological conditions (Feng et al., 2014; Mazzoncini et al., 2011). These results were similar to those related by (Shaheen and Sabir, 2017; Mafongoya et al., 2015; Iqbal et al., 2013) who documented higher maize grain yield in deep tilled plots than conventional ones. In case of different N sources, plots fertilized with urea performed relatively better resulting higher grain yield (3667 kg ha^{-1}) which was statistically similar with PM, SM and MS with grain yield (3507 kg ha^{-1}), (3468 kg ha^{-1}) and (3450 kg ha^{-1}), respectively. Plots where MR incorporated produced lower (3094 kg ha^{-1}) grain yield. Lowest grain yield (2468 kg ha^{-1}) was observed in plots where no N was applied. These results were supported by Shaheen and Sabir (2017), Shehzad et al. (2015) and Negassa et al. (2003) who reported that the recommended rate of inorganic fertilizers had similar maize yieldas with integrated application of FYM along with NP fertilizers. The interaction of tillage implements and N sources had significant effect on grain yield of maize (Figure 2). Higher grain yield was obtained with organic sources of N fertilizer incorporated with MB plough or inorganic N fertilizer incorporated with cultivator.

Table 3: *Grain yield (kg ha⁻¹), harvest index (%) and soil pH of maize as affected by tillage implements and nitrogen sources.*

Tillage Implements (TI)	Grain yield (kg ha^{-1})	Harvest index (%)	Soil pH
Mould Board Plough	3522 a	32.8	7.79
Disk harrow	3305 b	32.5	7.78
Cultivator	3207 bc	32.4	7.80
Rotavator	3067 c	31.9	7.81
LSD(0.05)	203	ns	ns
Nitrogen Sources (NS)			
Control	2468 c	28.7 b	7.85
Cattle Manure	3273 b	32.6 a	7.78
Poultry Manure	3507 ab	33.6 a	7.78
Sheep Manure	3468 ab	33.3 a	7.79
Mushroom Spent	3450 ab	33.0 a	7.78
Mungbean Residue	3094 b	31.2 ab	7.78
Urea	3667 a	34.5 a	7.82
LSD(0.05)	259	3.40	Ns
Interaction			
TI × NS	518	ns	ns

Ns: non-significant; Means in the same category followed by at least one common letter are not significantly different at ($P \leq 0.05$) level.

Harvest index (%)

Physiological efficiency of crop plants to translocate more photo assimilates from source towards sink is referred to HI (Ali et al., 2016). Data analysis revealed that harvest index was significantly influenced by various N sources however tillage instruments and interaction (TI × NS) had non-significant effect (Table 3). Higher harvest index (34.5 %) was recorded from plots fertilized with urea, which was statistically similar with plots where poultry manure, sheep manure, and mushroom spent was applied. It is followed by cattle manure and mungbean residue incorporated plots with 32.6 % and 31.2 % harvest indexes. Plots where no N applied resulted lowest (28.5 %) harvest index. The insignificant effect of tillage

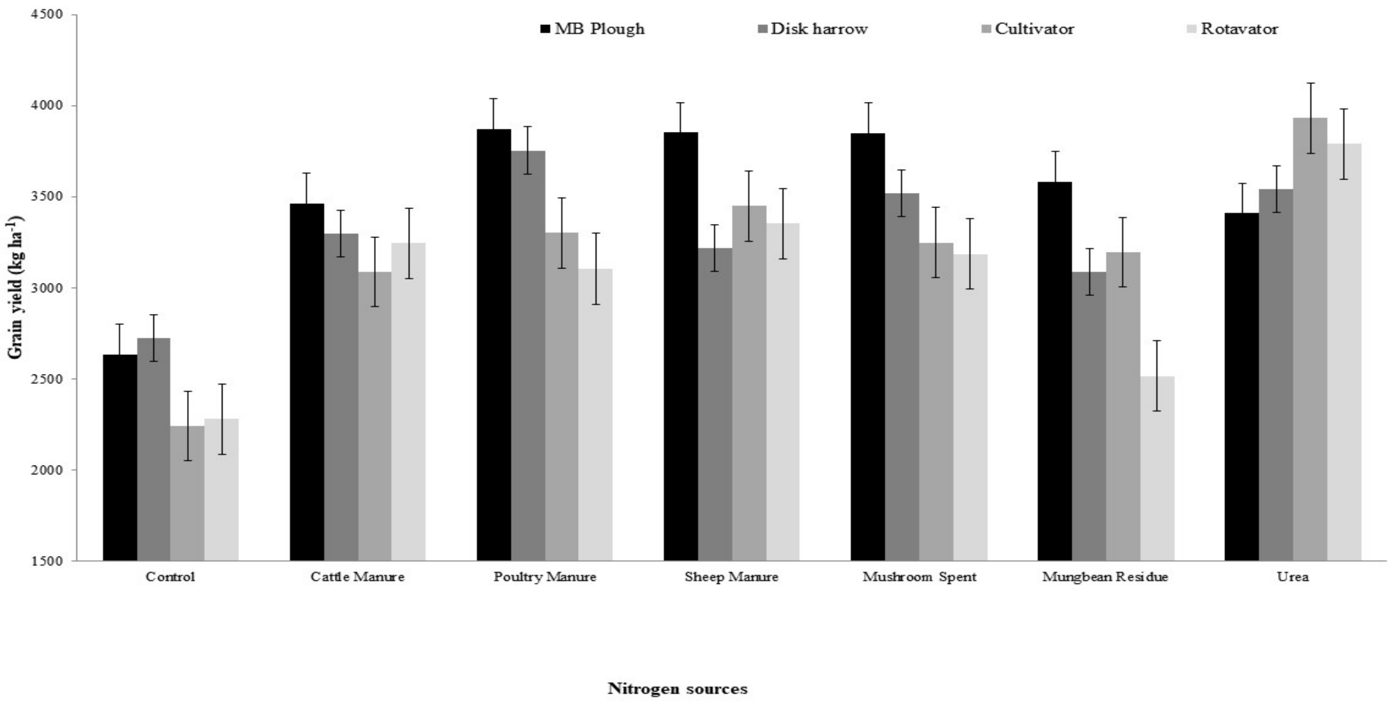

Figure 2: *Interaction of tillage implements and N sources for grain yield (kg ha^{-1}) of maize.*

on harvest index was also demonstrated by Shaheen and Sabir (2017); Shehzad et al. (2015) and Wasaya et al. (2012). Comparing various N sources significant increase could be referred to optimum supply of nutrients and its availability to the crop during the life span. These results corroborate the findings of Mahmood et al. (2017), Shaheen and Sabir (2017), Afsar and Khalil (2016) and Shehzad et al. (2015) who affirmed that N applied from both natural and synthetic sources had substantial positive impact on harvest index of maize crop compared with control plots.

Soil pH

Statistically non-significant effect of tillage implements and N sources was found on soil pH at 0-30 cm soil depth (Table 3). Although the results were found non-significant, however mean values showed that slight reduction in soil pH was observed in all the treatments (tillage implements and N application). Thus, the results suggest that soil pH can be reduced or at least any further increase in soil pH can be avoided on alkaline silty clay loam soils, if tried to provide maximum nutrient requirements from the organic sources instead of inorganic. Our results are in accordance with the results of the Shaheen and Sabir (2017), Agbede et al. (2008) and Ahmad et al. (2013) who reported insignificant reduction in soil pH with application of organic manures plus inorganic fertilizers, in the absence of lime. Furthermore, the reduction in soil pH might be the consequence of two concurrent processes, i.e. the organic acids production during decomposition of organic fertilizers (Nyakatawa et al., 2001; Bolan, 1994) and the downward movement of lime with water peculation (Hao and Chang, 2003).

Soil electrical conductivity (dSm^{-1})

Analysis of data showed that N sources had statistically significant effect on soil electrical conductivity (EC). Tillage implements and interaction of (TI × NS) was found non-significant (Table 2). Plots fertilized with cattle manure resulted in higher EC (0.183 dSm^{-1}) which was statistically similar with poultry manure and sheep manure. Among organic fertilizers mushroom spent and mungbean residue showed lower soil EC (0.173 dSm^{-1}). Control plots resulted in lowest soil EC (0.169 dSm^{-1}). The increment in soil EC could be inferred to the account of salt concentration in live-stock manures, which in turn accumulated in the upper horizons and ultimately resulted in higher soil EC (Hao and Chang, 2003). In addition to that mineral fertilizer also contains soluble salts which possibly increase the EC. These results are in conformity with Ahmad et al. (2013); Dai et al. (2014) and Shaheen and Sabir (2017) who documented profound increase in soil EC with N application whether the source is organic or inorganic.

Soil bulk density (g cm^{-3})

Tillage implements had significant while N sources and interaction of (TI × NS) had non-significant effect on soil bulk density (SBD). Plots where ploughing was carried out with rotavator resulted in higher SBD (1.25), which was statistically similar with plots where disk harrow (1.23) and cultivator (1.23) was used. Lowest SBD (1.22) was observed from experimental units tilled with MB plough. The possible reason could be that deeper tillage operations provide better soil tilth, reduce soil compaction (Shaheen et al., 2014), increased field saturated hydraulic conductivity, improve water infiltration (Iqbal et al., 2013) and increase soil porosity which ultimately decreased SBD (Martínez-Mena et al., 2013; Iqbal et al., 2005; Dai et al., 2013; Zebarth et al., 1999). These results corroborate the findings of Shaheen and Sabir (2017), Adeleye and Ayeni (2012) and Khan et al. (2009) who reported that various ploughing trails had significantly improved soil capillary water content and reduce SBD.

Table 4: *Soil bulk density (g cm^{-3}), electrical conductivity (dSm^{-1}) and total N (g kg^{-1}) of maize as affected by tillage implements and nitrogen sources.*

Tillage Implements (TI)	**Bulk density (g cm^{-3})**	**Electrical conductivity (dSm^{-1})**	**Total N(mg kg^{-1})**
Mould Board Plough	1.22 c	0.172	0.41
Disk harrow	1.23 b	0.178	0.40
Cultivator	1.23 b	0.178	0.40
Rotavator	1.25 a	0.176	0.40
LSD(0.05)	0.01	ns	ns
Nitrogen Sources (NS)			
Control	1.25	0.169 b	0.33 e
Cattle Manure (CM)	1.23	0.183 a	0.46 a
Poultry Manure (PM)	1.21	0.180 ab	0.42 b
Sheep Manure (SM)	1.23	0.178 ab	0.43 b
Mushroom Spent (MS)	1.23	0.173 b	0.41 b
Mungbean Residue (MR)	1.23	0.173 b	0.38 c
Urea	1.24	0.175 ab	0.39 d
LSD(0.05)	Ns	0.008	0.03
Interaction			
TI × NS	Ns	ns	Ns

ns: *non-significant; Means in the same category followed by at least one common letter are not significantly different at (P≤0.05) level.*

Soil total N (g kg^{-1})

Soil total nitrogen (STN) was significantly affected by N sources, however various tillage instruments and interaction of (TI × NS) had non-significant effect (Table 4). Comparing various N sources, cattle manure fertilized plots resulted in higher STN (0.46). It is followed by sheep manure, poultry manure and mushroom spent with 0.43, 0.42 and 0.41 STN respectively. Urea fertilized plots resulted lower STN (0.39) when compared to organic fertilizers. Lowest STN (0.33) was noted in plots where no N applied. The insignificant variation in STN content in response to tillage implements at 0-30 cm soil was also noted by Kihara et al. (2011), Shaheen and Sabir (2017), Shehzad et al. (2015c) and Iqbal et al. (2005). In case of different N sources, the possible reason might be due to fact that organic fertilizer provides large amount of N, P and K plus micronutrients as well (Gupta, 2007). These results are consistent with many researchers (Zhang et al., 2016; Kihara et al., 2011; Shehzadi et al., 2014; Ahamd et al., 2013; Alijani et al., 2012; Mahmood et al., 2017; Hartmann et al., 2015; Chen et al., 2014) who documented that various N sources significantly influence STN. Overall negative balance of STN when compared with pre-sowing is attributed to exhaustive nature of the crop and N losses.

Conclusions and Recommendations

Comparing main effects of tillage implements and N sources, tillage operation with deeper tillage implement (MB plough) resulted in higher yield (3522 kg ha^{-1}) and improved soil properties. Comparing various N sources, poultry manure, sheep manure and mushroom spent gave at par yield with urea. In interaction effects, organic fertilizers incorporated with MB plough or disc harrow (deeper tillage instruments) gave higher yield and improved soil fertility and physical properties while urea incorporated with cultivator or rotavator gave higher yield of maize.

Author's Contribution

Mehran Ali: Main author who worked on this topic for writing his MSc (Hons) thesis.
Inamullah: Proposed the idea, designed and supervise the research. He shaped and checked the manuscript for publication.
Salman Ali: Helped in data analysis.
Muhammad Bilal: Facilitate the chemical analysis.
Farooq Nawaz and Muhammad Owais Iqbal: Helped in sowing, data collection and harvesting the experiment.

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