Research Article

Nitrogen Sources Incorporation with different Tillage Implements affects Maize Productivity and Soil Organic Matter

Mehran Ali, Inamullah*, Sajjad Ahmad and Arsalan Khan

Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan.

Abstract | A field trial was conducted at Agronomy Research Farm (ARF) of The University of Agriculture Peshawar during summer 2016 to investigate the effect of various tillage implements and nitrogen sources on maize yield and soil organic matter. Randomized complete block design with split plot arrangement having four replications was used. Tillage implements (mould board plough, rotavator, disk harrow and cultivator) were applied in main plots while nitrogen sources (control, cattle manure, poultry manure, sheep manure, mushroom spent, mungbean residue and urea) in subplots. The results exhibited that, higher plant height (200.4 cm), grains ear^{-1}(351), seed index (228.8 g), grain yield (3522 kg ha^{-1}), and biological yield (10799 kg ha^{-1}) were observed with nitrogen sources incorporated with mould board plough. In case of nitrogen sources; poultry manure (3507 kg ha^{-1}), sheep manure (3468 kg ha^{-1}) and mushroom spent (3450 kg ha^{-1}) gave at par grain yield with urea (3667 kg ha^{-1}). However, soil organic matter was significantly higher in organic fertilizer applied plots compared to urea treatments. Conclusively, organic sources incorporated with mould board plough could be better alternative urea to improve maize productivity and soil fertility on sustainable basis.

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***Correspondence** | Inamullah, Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan; **Email:** drinam@aup.edu.pk
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Keywords | Maize (*Zea mays* L.), Tillage implements, Nitrogen sources, Yield, Fertility

Introduction

Maize (*Zea mays* L.) is a high yielding cereal crop grown throughout the world. In Pakistan it is the third largest cereal crop grown after wheat and rice and the second largest after wheat in Khyber Pakhtunkhwa (KP). Maize contributes 2.7 % to the value added products in agriculture and 0.5 % to the GDP of Pakistan (GoP, 2016). Yield of maize is lower in KP mainly because of lack of high yielding hybrids/ varieties, unavailability of quality seed, higher prices of chemical fertilizers, perpetual decline in soil organic matter, a conventionally operated tillage practices, weed infestation and no access to market. Nitrogen fertilization of maize is an important management practice which plays vital role throughout the life span of crop for higher yield (Ibrahim and Khan, 2017). Maize dry matter production increased linearly with increasing N application (Shaheen and Sabir, 2017, Ali et al., 2016). The increase in N levels up to 150 kg ha^{-1} increased its availability in soil, resulting in higher uptake by the plant and production of larger leaves, more photosynthesis, and dry matter accumulation (Shahid et al., 2016 and Inamullah et al., 2011), which ultimately gave higher yield and its attributes in maize (Azeem and Inamullah, 2016). In the changing climate scenario there has been increasing interest in incorporating organic manures to step forward towards sustainable food production (Chadwick et al., 2015). Organic material incorporation improved soil aggregation and structural stability and resulted in higher C content in soil aggregates (Yang et al., 2015). However, the kind and source of organic inputs strongly influenced the C accumulation in aggregates. Organic fertilizers are the best option for both to compensate the supply of nutrients and avoid hazardous effects of chemical fertilizers but there is severe problem of weeds infestation attached with it. Organic fertilizer incorporation with suitable tillage implement, will give a hand in use of livestock wastes properly. It also improves soil fertility and other soil physical, biological and chemical properties (Meng et al., 2016; Maltas et al., 2013).

Tillage plays role in proper incorporation of organic fertilizers. It is the mechanical manipulation of soil to enhance its productivity while the sequence of operations that allow handling the soil to produce a crop is referred as tillage system (Inamullah and Khan, 2015). It incorporates organic manures in soil and helps in maintaining good soil tilth. It also improves the availability of water and nutrients present in soil (Zhang et al., 2016). 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., 2009). 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. Conventional tillage compact the lower soil layers which adversely affect seed germination and growth of plant (Inamullah and Khan, 2015). Proper attention is required to match different tillage practices with the soil physical condition for developing a methodical approach.

In light of the above generalization, an experiment was performed to determine the influence of a variety of organic and inorganic N fertilizers incorporated with various tillage implements for higher maize yield and soil fertility.

Materials and Methods

Field experiment was conducted at Agronomy Research Farm (ARF), The University of Agriculture Peshawar (UAP), during summer 2016. The experimental site has continental climate and is located at 34.01^0 N, 71.58^0 E at an altitude of 359 meter above sea level (Amin et al., 2006). The physico-chemical properties of experimental site are given in Table 1. Metrological data were obtained from weather station located at ARF UAP (Figure1).

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

Soil physic-chemical properties	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

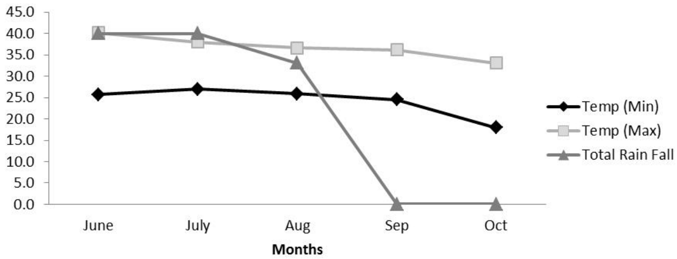

Figure 1: *Monthly mean maximum and minimum temperatures and rainfall recorded during maize growing season 2016 at ARF (UAP).*

The experiment was laid out in randomized complete block design with split plot arrangement having three replications. Maize OPV AZAM was planted on 18th June 2016. Tillage implements were used in main plots with total of four types (mould board plough, rotavator, disk harrow and cultivator). Only mould board plough was followed by cultivator while the other implement were used alone. Nitrogen (N) sources were applied to subplots with six types (cattle manure, poultry manure, sheep manure, mushroom spent, mungbean residue and urea). Chemical composition of different N sources is shown in Table 2. Mushroom Spent (MS) is solid waste of edible fungi industry, a by-product of mushroom culture which is potentially an important soil amendment and easily available good source of organic matter. Mungbean residue represents the bulk of the crop biomass including straw, stalk, stubble, trash and husks, which left after removal of the main produce (grain) from the field. A control plot with no N treatment was used as check. All the N sources were incorporated on 29th May 2016 with implements considered in the study except urea which was applied in two splits, one at the time of sowing and the other at V4 stage. Other agronomic practices including irrigation and weed control etc. were kept uniform in all experimental plots. Plant height was recorded by measuring the height of five randomly selected plants at maturity from ground level up to the tip of tassel in each sub-plot and then average was calculated. Number of grains ear^{-1} was calculated by randomly selecting five ears at maturity in each subplot. All these five ears were shelled, grains counted and divided by five. Thousand grains were counted with the help of seed counter from each treatment, weighed with the help of sensible electronic balance and reported as seed index. Soil organic matter (SOM) was determined through wet digestion method of Nelson and Sommers (1982). For above ground biological yield, four rows were harvested, sundried for few days, weighed and converted into kg ha^{-1} according to formula given below:

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

For grain yield, ears were detached, shelled and grains were weighed with balance. This grain yield was changed into kg ha^{-1} using the following formula:

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

The data were statistically analyzed with appropriate ANOVA outlined by Gomez and Gomez (1984) using LSD at 0.05 level of probability using Statistix 8.1 software.

Results and Discussion

Plant height

Data regarding plant height (PH) were significantly affected by tillage implements, N sources and interaction of TI x NS (Table 3). Taller plants (200.4 cm) were produced by plots ploughed with mould board plough which was statistically same with PH of 195.3cm when disk harrow was used. Dwarf plants (188.1 cm) were observed from experimental units where rotavator was used. The reason for significant results with tillage instruments might be increasing soil loosening. Mould board plough shaped an ideal seedbed condition which influenced the growth of the crop resulting in the tallest plants (Dikgwatlhe et al., 2014). These results are in line with Karuma et al. (2016) and Memon et al. (2013) who reported higher PH in improved tillage practices. In case of different N sources, plots fertilized with urea produced taller plants (203.0 cm), followed by PH of 201.8, 201.1 and 199.4 cm observed in plots supplied with N from PM, SM and MS respectively. Among different organic N sources, MR produced short statured plants (190.2 cm). However shortest plants (172 cm) were observed in control plots. This might be due to N application increased photosynthetic activity owing to the adequate supplies of N (Akmal et al., 2015). These results are in agreement with Boomsma et al. (2010) and El-Gizawy (2009) who noted dwarf plants with low N application rate. Various N sources incorporated with deeper tillage instruments (mould board plough), improved its incorporation and nutrient availability which increased plant growth as compared to conventional ones (Figure 2).

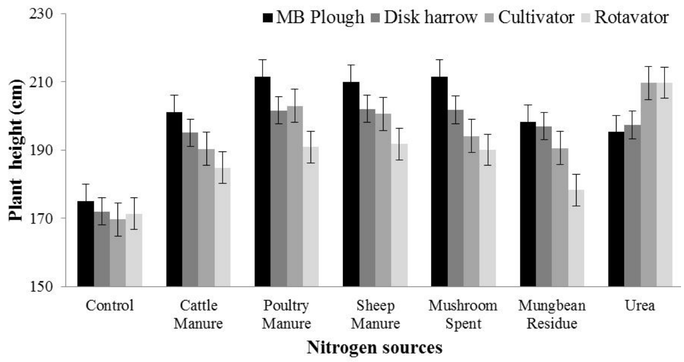

Figure 2: *Interaction of tillage implement and N source for plant height of maize.*

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

Grains ear^{-1}

Tillage implements and N sources had considerable however interaction (TI x NS) had non considerable effect on grains ear^{-1} (GPE) of maize (Table 3).

Plots ploughed with mould board plough resulted in more GPE (351), which was statistically similar with disk harrow. It was followed by plots tilled with cultivator. However fewer GPE (306) was reported in plots tilled with rotavator. Our results are in line with Shahid et al. (2016), Guan et al. (2014) and Memon et al. (2013) who reported more GPE in plots where improved tillage practices were done. Urea fertilized plots resulted in higher GPE (360), which was statistically at par with PM, MS and SM, that resulted in 351, 339 and 338 GPE, respectively. It was followed by plots fertilized with CM and MR. Lowest GPE (273) were recorded in control plots. Similar results were given by Akmal et al. (2015), and Ali et al. (2010) who reported more number of grains in N fertilized plots compared to control plots. GPE were improved with application of various organic sources incorporated with deeper tillage instrument (mould board plough) when compared to shallower instruments (cultivator and rotavator). Increase in GPE was observed in plots fertilized with CM, PM, SM and control plots when tillage instruments were changed from rotavator to cultivator, disk harrow and mould board plough. In contrast, plots fertilized with urea showed an increase in GPE when cultivator or rotavator used (Figure 3).

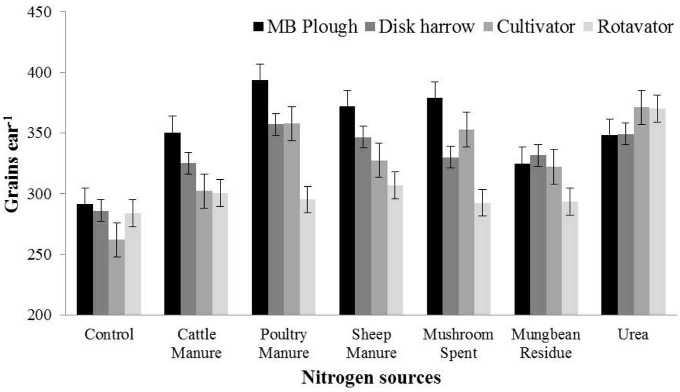

Figure 3: *Interaction of tillage implement and N source for grain era^{-1} of maize.*

Seed index

Analysis of data showed that both tillage instruments and N sources had statistically significant while interaction (TI x NS) had non-significant effect on seed index of maize (Table 3). Heavier grains (228.8 g) were observed where mould board plough was used, which was statistically similar with seed index recorded in disk harrow used plots. However lower seed index (199 g) was recorded in plots where rotavator was used. Increased seed index was also observed by Shahid et al. (2016) and Anjum et al. (2014) when deep tillage was carried out. Among different N sources urea fertilized plots resulted in higher seed index (226 g) which was statistically similar with PM, SM and MS, that resulted in 221.9 g, 218.7 g and 216.8 g seed index respectively. Plots incorporated with CM and MR produced 213.4 g and 203.8 g seed index respectively. Lowest seed index (192.9 g) was recorded in control plots. Significant positive effect on seed index with N application was also confirmed by Inamullah et al. (2011) and Ashraf et al. (2016).

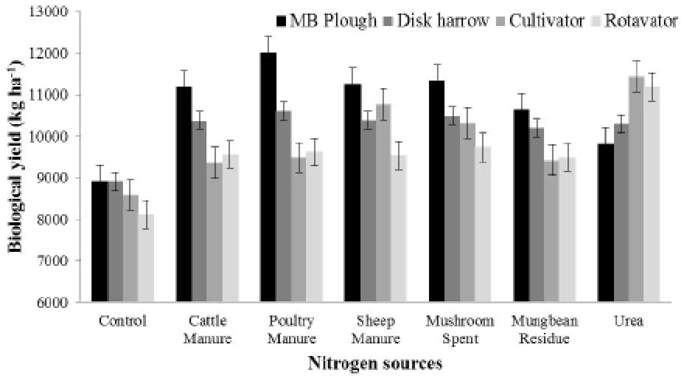

Figure 4: *Interaction of tillage implement and N source for biological yield of maize.*

Table 3: *Plant height, grains ear^{-1} and seed index (g) of maize as affected by tillage implements and nitrogen sources*

Tillage Implements (TI)	Plant height (cm)	Grains ear^{-1}	Seed index (g)
Mould Board Plough	200.4 a	351 a	228.8 a
Disk harrow	195.3 ab	332 ab	221.1 ab
Cultivator	194.0 b	324 b	208.8 b
Rotavator	188.1 c	306 b	199.0 b
LSD(0.05)	5.3	25	19.5
Nitrogen Sources (NS)			
Control	172.0 c	273 c	192.9 c
Cattle Manure (CM)	192.9 b	320 b	213.4 b
Poultry Manure (PM)	201.8 a	351 a	221.9 ab
Sheep Manure (SM)	201.1 a	338 ab	218.7 ab
Mushroom Spent (MS)	199.4 a	339 ab	216.8 ab
Mungbean Residue (MR)	191.0 b	318 b	203.8 b
Urea	203.0 a	360 a	226.0 a
LSD(0.05)	5.8	23	10.5
Interaction			
TI x NS	11.7	47	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.

Biological yield

Tillage implements, N sources and interaction of (TI x NS) had significant effect on above ground biological yield (BY) (Table 4). Plots ploughed with mould board plough resulted in higher BY (10799 kg ha^{-1}), which was statistically similar with plots ploughed by disk harrow. It was followed by plots tilled with cultivator (9915 kg ha^{-1}). Lowest BY (9607 kg ha^{-1}) was observed from experimental units ploughed with rotavator. The increment in BY production could be referred to breaking of subsoil compaction, promoting root development (Guan et al., 2014) and conducive condition due to deep tillage operation (Shaheen et al., 2014). These results are confirmed by Karuma et al. (2016), Memon et al. (2013) and Gul et al. (2009) who reported profound increase in BY of maize with improved tillage operations. Comparing different N sources, urea fertilized plots resulted in higher BY (10680 kg ha^{-1}) which was statistically at par with PM, MS, SM and CM. Plots where MR was incorporated produced lower BY (9937kg ha^{-1}) when compared with other organic N sources. Control plots resulted in the lowest BY (8631kg ha^{-1}). Adequate biomass production might be the consequence of better nutrients uptake (Agbede et al., 2010). These results corroborate the findings of (Mahmood et al., 2017; Ashraf et al., 2016 and Shehzad et al., 2015) who concluded that N application from both organic and inorganic sources had significant positive impact on BY of maize compared with non-treated plots. N sources incorporated with deep ploughing instruments (mould board plough), improved environment in the plant rhizosphere, which increased plant growth and ultimately BY. Increase in BY was observed with the application of MS, PM, CM, MR and in control plots when tillage implements were changed from rotavator to cultivator, disk harrow and mould board plough (Figure 4).

Grain yield

Analysis of the data showed that tillage implements, N sources and interaction (TI x NS) had significant effect on grain yield (GY) of maize (Table 4). Among different tillage implements, plots ploughed with mould board plough resulted in higher GY (3522 kg ha^{-1}). It was followed by disk harrow (3305 kg ha^{-1}), which was statistically at par with plots tilled with cultivator (3207 kg ha^{-1}). However lowest GY (3067 kg ha^{-1}) was reported in plots where rotavator was used. The positive effect of deep tillage on crop production might be attributed to better physical and hydrological soil conditions (Feng et al., 2014 and Mazzoncini et al., 2011). These results were similar to those related by Shaheen and Sabir (2017), Mafongoya et al. (2015) and Iqbal et al. (2013) who reported higher maize GY in deep tilled plots than conventional ones. In case of different N sources, plots fertilized with urea performed relatively better resulting in higher GY (3667 kg ha^{-1}) which was statistically similar with PM, SM and MS with GYof 3507, 3468 and 3450 kg ha^{-1}, respectively. Plots where MR was incorporated produced lower GY (3094 kg ha^{-1}). Lowest GY (2468 kg ha^{-1}) was observed in plots where no N was applied. These results were best supported by Shaheen and Sabir (2017), Shehzad et al. (2015) and Negassa et al. (2003) who demonstrated that the recommended rate of inorganic fertilizers had similar maize yield as with integrated application of FYM along with NP fertilizers. Grains yield was improved with N fertilizer incorporated with deeper tillage instrument (mould board plough) compared to shallower instruments (Figure 5).

Table 4: *Grain yield, biological yield and soil organic matter (%) of maize as affected by tillage implements and nitrogen sources*

Tillage Implements (TI)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Soil organic matter (%)
Mould Board Plough	10799 a	3522 a	0.72
Disk harrow	10184 ab	3305b	0.70
Cultivator	9915 b	3207bc	0.69
Rotavator	9607 b	3067c	0.68
LSD(0.05)	705	203	Ns
Nitrogen Sources (NS)			
Control	8631 c	2468 c	0.57 d
Cattle Manure	10120 a	3273 b	0.76 a
Poultry Manure	10558 a	3507 ab	0.74 a
Sheep Manure	10487 a	3468 ab	0.75 a
Mushroom Spent	10471 a	3450 ab	0.73 a
Mungbean Residue	9937 b	3094 b	0.71 b
Urea	10680 a	3667 a	0.61 c
LSD(0.05)	705	259	0.03
Interaction			
TI x NS	1410	518	0.06

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.

Soil organic matter (%)

SOM was significantly affected by N sources and interaction (TI x NS) while effect of tillage implements was found non-significant (Table 4). Comparing various N sources, CM fertilized plots resulted in higher SOM (0.76 %) which was statistically similar with other organic fertilizers treatments. Urea fertilized plots resulted in lower SOM (0.61 %) when compared to organic fertilizers. Lowest SOM (0.57 %) was reported in control plots. These results are consistent with Zhang et al. (2016); Ahamd et al. (2009) and Mahmood et al. (2017) who documented that various N sources significantly influenced SOM. Overall negative balance of both SOM when compared with pre-sowing is attributed to exhaustive nature of the crop and N losses. Deep tillage operations improved SOM when compared to conventional ones. Increased SOM was observed in PM, MS, MR, SM and control plots when tillage implements were changed from rotavator to cultivator, disk harrow and mould board plough (Figure 6).

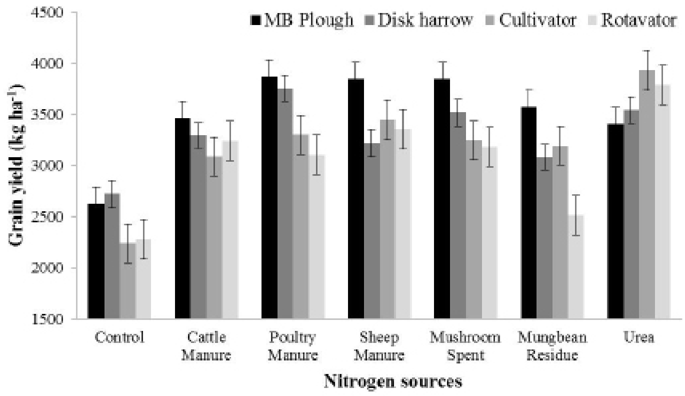

Figure 5: *Interaction of tillage implement and N source for grain yield of maize.*

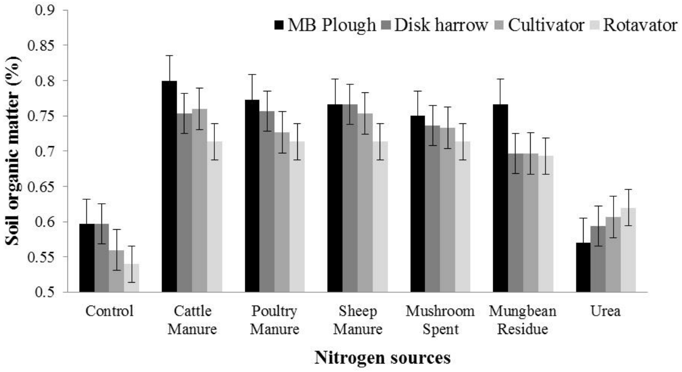

Figure 6: *Interaction of tillage implement and N source for soil organic matter (%).*

Conclusions

Tillage operation with deeper tillage implement (MB plough) resulted in higher yields and yield components. Comparing various N sources, poultry manure, sheep manure and mushroom spent gave at par yields with urea. Furthermore, organic fertilizers incorporated with MB plough or disc harrow (deeper tillage instruments) gave higher yields and improved soil fertility while urea incorporated with cultivator or rotavator gave higher yields of maize.

Author's Contribution

Mehran Ali is the 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. Sajjad Ahmad helped in sowing, data collection and harvesting the experiment. Arsalan Khan helped in data analysis and chemical analysis.

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