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ORGANIC AND INORGANIC NITROGEN TREATMENTS EFFECTS ON PLANT AND YIELD ATTRIBUTES OF MAIZE IN A DIFFERENT TILLAGE SYSTEMS

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Abstract

In Pakistan, maize (*Zea mays* L.) is grown following a wheat crop under conventional tillage practices since long ago. The present concern about the soil fertility degradation, soil erosion and environmental pollution due to the intensive tillage practices and high inorganic fertilization is an important issue. The objective of this study was to investigate the effects of various organic and inorganic nitrogen treatments under three tillage systems i.e., Deep tillage (DT), conventional tillage (CT) and minimum tillage (MT) on maize planted after wheat crop. Tillage significantly affected all parameters studied. Minimum tillage and CT proved superior in terms of emergence m^{-2}, plant height, grains per cob, 1000-grain weight, biological yield, grain yield and leaf area index compared to DT and were statistically at par with each other. Likewise, various organic and inorganic nitrogen treatments significantly affected all parameters except grains per cob. Farmyard manure application @ 20 tons ha^{-1} combined with 60 kg N ha^{-1} performed better than all other treatments and resulted in greater emergence, taller plants, higher thousand-grain weight, more leaf area index and greater grain and biological yields. It is concluded that FYM application in combination with minimum N is an alternative and sustainable practice of soil management for crop production either in MT or CT practices.

Introduction

In Pakistan, maize is the third most important cereal crop after wheat and rice and is used as a staple food for humans, as feed for livestock and as raw material for industry. During 2006, it was planted on 1030 thousand hectares in Pakistan, with total production of 3560 thousand tons and having an average yield of 3.458 tons ha^{-1} (Anon., 2006). Maize crop has durations of about 3-4 months. Mostly open-pollinated maize cultivars are sown (Harris *et al.*, 2007).

Tillage is considered the most effective farm activity, improves the physical conditions of soil, which lead to an enhanced nutrient uptake and better yield of crops (Bahadar *et al.*, 2007). Many researchers reported that deep tillage (DT) or conventional tillage (CT) practices improve aeration (Zorita, 2000), soil porosity (Hao *et al.*, 2001), conserve soil moisture and nutrients for plant and microbes (Patil *et al.*, 2006). More grain yield (9%) and biomass (27%) in maize (Zorita, 2000) were achieved in DT or CT practices (Zorita, 2000). In contrast, minimum tillage (MT) plots have greater plant emergence, grain N and lower grain moisture (Wiatrak *et al.*, 2006). Soon *et al.*, (2005) obtained 12% increase in crop yield and 14% N uptake in MT plots.

Nitrogen fertilization plays a significant role in improving soil fertility and increasing crop productivity (Habtegebrial *et al.*, 2007). N fertilization results in increased grain yield (43-68%) and biomass (25-42%) in maize (Ogola *et al.*, 2002). It contributes 18-34% increase in soil residual N (Yang *et al.*, 2007) and 4-9.4 % more mineralization from soil total N (Li *et al.*, 2003). Sole residue incorporation (Anatoliy &

Thelen, 2007) or in combination with N fertilizer have positive effects on plant growth and production as well as on soil physiochemical properties. Synergistic effects of N with organic fertilizers (residue or FYM) accumulate more soil total N (Huang *et al.,* 2007), but sole effects of FYM result in increased yield of maize (Anatoliy & Thelen, 2007), more organic matter (44%) in soil (Rasool *et al.,* 2007), improved porosity (25%) and water holding capacity 16 times (Gangwar *et al.,* 2006).

Soil conditions for optimum plant productivity can be improved with residue and tillage modifications. Maize response in no-till systems after wheat mostly depended on residue N level (Opoku & Vyn, 1997). Dick *et al.,* (1992) obtained similar maize grain yield and N uptake from carryover effects of N and mineralization of organic N under MT or CT practices. However, Fischer *et al.,* (2002) reported that maize after wheat out yielded irrespective of tillage, residue and nitrogen fertilization.

Tillage methods that incorporate residues into soil could improve productivity and retard organic matter decline. However, there is not enough information on influence of residue management, particularly in silt clay loam soil like in Pakistan. The objective of this research was to determine the influence of FYM and soybean residue in combination with inorganic N under various tillage management practices on maize productivity in wheat- maize cropping system.

Materials and Methods

A field experiment was carried out on maize (cv. Kisan-90) with a crop sequence of wheat-maize-wheat at the Research Farm of NWFP Agricultural University Peshawar Pakistan during summer 2006. The soil was a silt clay loam and well drained. The experimental site has a warm to hot, semi-arid subtropical continental climate with a mean annual rainfall of about 360 mm. The soil is deficient in mineral N (< 0.08 mg kg^{-1} soil) and phosphorus <20 g kg^{-1} soil, but has adequate potassium >120 g kg^{-1} soil with a pH of 8.2 and organic matter content <1%.

The experiment was conducted in Randomized Complete Block (RCB) design with split plot arrangement having three replications. Twelve treatments of organic and inorganic N were arranged in subplots and three tillage practices [deep (DT), conventional (CT) and minimum (MT)] in main plots. The organic and inorganic N treatments were 0 (N0), 60 (N1) and 120 kg N ha^{-1} (N2), 10 tons Farm yard manure ha^{-1} (FYM1), 20 tons FYM ha^{-1} (FYM2), FYM1 + ½ N1, FYM1 + ½ N2, FYM2 + ½ N1, FYM2 + ½ N2, 10 tons soybean residue ha^{-1} (SR), SR + ½ N1, SR + ½ N2.

Deep tillage practices were carried out by chisel plough that tilled the soil up to 45 cm followed by a common cultivator. Common cultivator was used for CT, which tilled the soil for 30cm. In both DT and CT, the soil was ploughed two times horizontally as well as vertically and planking was done to break the clods and level the field. Minimum tillage practice was done by the use of rotivators to bury only the FYM/SR up to the depth of 4-6cm. Farm yard manure was obtained from the dairy farm of NWFP Agricultural University Peshawar Pakistan, and was well decomposed. Soybean was used as residue crop, harvested last year and was partially decomposed. The chemical composition of FYM and soybean residue is reported by Ahmad *et al.,* (2008). Urea (46 % N) was used as inorganic N source. Incorporation of FYM/SR was made 45 days before sowing in specific plots of 5 x 3m. Urea was applied in split application, half at sowing and the other half just after 1st irrigation (27 days after sowing).

Table 1. Mean air temperature and rainfall values during the corn growing months at the experimental site.

Month	Average remperature (°C)		Monthly rainfall (mm)	
	Growing season[a]	1975-2006[b]	Growing season[a]	1975-2006[b]
June	30.88	32.67	18.60	19.44
July	31.63	32.29	80.00	46.20
August	30.12	30.97	46.60	63.03
September	28.52	28.96	6.80	36.58
October	24.33	23.62	25.20	33.00

[a]Unpublished data, taken at the experimental site NWFP Agricultural University Peshawar, Pakistan.
[b]Unpublished data, taken at the Peshawar weather station, NWFP, Pakistan.

Planting was done on 15th June in 2006 after wheat harvest, using a tractor-mounted planter equipped with row cleaner wheels. The fertilizer broadcast at sowing time consisted of 120 kg ha^{-1} sulphate of potash (60% K) and 200 kg ha^{-1} single super phosphate (18% P_2O_5) to supply recommended 60 and 90 kg ha^{-1} K and P, respectively. Plots were irrigated fortnightly and uniformly by flood irrigation. Weeds were mechanically controlled.

Emergence m^{-2} was recorded by counting the number of seedling emerged in two central rows (when almost all the seedling were emerged in each subplot) and were converted into square meter accordingly. Leaf area was recorded in five randomly selected plants in each sub plot using leaf area meter (Li-COR Model-3100) at anthesis to calculate leaf area index (LAI). Grains per cob were recorded by counting the grains in five randomly selected cobs, after threshing manually. Plant height data were recorded on randomly selected ten plants in each sub plot. The two central rows of each plot were harvested in late October to determine 1000-grains weight, biological and grain yields.

Statistical analysis: The experimental data were subjected to the analysis of variance appropriate for RCB design with split plot arrangement using statistical software GenState 8.1 (GenState, 2005). Upon significant F-value, the means were separated by least significant test at $p \leq 5\%$ using the procedure outlined by Gomez & Gomez (1983).

Results

The mean values of temperature and rainfall during the crop season are shown in Table 1. Mean air temperature was 24.33 to 30.88°C, whereas rainfall varied between 6.80 and 80.00 mm per month at different growth stages of the maize crop. Complete silking in all plots, took place on 7 August 2006, fixing a vegetative period of 51 days, and reproductive period was ended in 49 days, including the period of maturity till harvesting.

Plant attributes

Emergence m^{-2}: Tillage practices had significant effect on emergence m^{-2} (Table 2). Emergence m^{-2} was significantly higher in the MT plots as compared to the DT plots. There were no significant differences for emergence m^{-2} between MT and CT practices

(Table 3). Various organic and inorganic N treatments had significant effects on emergence m^{-2} (Table 2). Generally, Farmyard manure (FYM) applied plots had more emergence than sole N or control plots (Table 3). Plots that received soybean residue (SR) + N resulted in similar emergence m^{-2} to those that received sole FYM. The highest emergence m^{-2} was recorded in plots, in which 20 tons FYM ha^{-1} was incorporated along with 60 kg N ha^{-1}, but it was not significantly different from emergence observed in plots, applied with lower amount of FYM whether alone or N combined.

Plant height: Both tillage practices and various organic and inorganic N-treatments significantly affected plant height, whereas their interaction was not significant (Table 2). The tallest plants were noted in CT or MT plots as compared to DT plots (Table 3). Plants in MT or CT practiced plots were not significantly different from each other. Application of FYM has resulted in taller plants than sole N or SR, with the exception to higher level of sole N (Table 3). The taller plants were recorded in FYM incorporated plots, followed by higher N level, whereas the short stature plants were observed in control, lower N level or sole SR incorporated plots. Significantly tallest plants were recorded in plots incorporated with 20 ton FYM ha^{-1} amended with 60 kg N ha^{-1}, as compared to lower level of N or SR either in sole or amended with N.

Leaf area index (LAI): Differences in LAI among tillage practices and various organic and inorganic N-treatments (Table 2) at the boot stage of growth were significant. Leaf area index was the highest in CT plots as compared to MT and DT (Table 3). LAI was greater in FYM applied plots either in sole or in combination with N when compared to lower level of sole N, sole SR and control (Table 3). Generally, the LAI was higher in FYM combined with N, and higher levels (120 kg ha^{-1}) of sole N plots. The highest LAI (3.05) was recorded in plots where FYM and N were combined. Sole FYM application resulted in LAI, which was statistically at par with N amended SR incorporated plots. No significant differences were observed for LAI in the control plots or plots where sole SR was incorporated.

Yield and yield components

Grain per cob: Grains per cob were significantly affected by tillage practices and various organic and inorganic N-treatments (Table 2). More gains per cob were recorded in MT plots as compared to the DT plots. Grains per cob in MT or CT plots were statistically at same level (Table 4). No variation in sole FYM incorporated plots and/or combined with fertilizer N were observed. However, FYM plots had significantly higher grain per cob as compared to sole SR, control or lower sole N applied plots (Table 4). The greater grain per cob was recorded in plots incorporated with 20 tons FYM ha^{-1} amended with 60 kg N ha^{-1}.

Thousand grain weight: Thousand grain weights were significantly affected by tillage practices and various organic and inorganic N-treatments (Table 2). The DT plots had lighter grains as compared to MT and CT plots (Table 4). The later mentioned tillage practices resulted in grains of similar weight. Generally, the sole FYM incorporated plots or combined with N, had heavier grains than control, sole SR or lower N level (Table 4). Grains weight was greater in plots applied with 20 tons FYM ha^{-1} and 60 kg N ha^{-1} but was statistically at par with other FYM and N combinations. The sole N plots had lighter grains than FYM plots with the exception to higher level of N (120 kg ha^{-1}). Similarly, the performance of sole SR applied plots was worse than SR amended with N plots.

Biological yield: The effects of tillage practices and various organic and inorganic N-treatments were significant on biological yield (Table 2). Conventional tillage plots out yielded for biological yield as compared to DT plots. However, there was no significant difference in CT and MT in terms of biological yield (Table 4). The control treatment produced significantly lower biological yield than the other N treatments. The incorporation of 20 tons FYM ha^{-1} reinforced with 60 kg N ha^{-1} produced significantly more biological yield than control, sole SR or lower doses of sole N (Table 4). There were no significance differences in biological yield production among FYM incorporated plots. However, the mixed treatments produced more biological yield than the control treatments.

Grain yield: Maize grain yields varied considerably both among tillage practices as well as organic and inorganic N-treatments. However, no interactive effect of tillage and N on maize grain yield was observed (Table 2). Grain yield of MT practiced plots was statistically at par with CT practiced plots, but was significantly higher than DT plots (Fig. 1). FYM incorporated plots out yielded in comparison to control, sole N application or soybean residue with exception to higher level of sole N application. Generally, the higher yield was obtained in FYM practiced plots amended with N. Sole N application showed an increasing trend for grain yield production (Fig. 2). Soybean residue in sole or in combination with N was better than control treatment in terms of grain yield. Maximum Grain yield was achieved in plots where 20 tons FYM ha^{-1} and 60 kg N ha^{-1} were applied.

Discussion

Crop yield efficiency depends on the available nutrients status of the soil. Increase in N fertilizer increases yield in wheat (Dang *et al.,* 2006), more seed yield in chickpea by carryover effects of N applied to wheat crop (López-Bellido *et al.,* 2004), average leaf area index, crop growth and yield attributes in wheat (Kibe *et al.,* 2006). Integration of tillage practices with N fertilization in organic or inorganic form would result in more amount of soil water (Al-Kaisi & Yan, 2005), soil organic carbon (Dolan *et al.,* 2006), and active C and N fraction (Sainju *et al*., 2007).

Maize productivity invariably responded to organic and inorganic N-treatments. It would probably be due to the carry-over effects of organic and inorganic N for optimum growth of the crop from the previous wheat crop. The lower N level in the soil results in lower yield due to less unavailable N for the optimum plant growth (Lemcoff & Loomis 1994). Leaf area index indirectly controls crop growth rate by influencing light interception and net assimilation rate (Carpenter & Board, 1997). The enhanced growth observed in the FYM treatments over the control could be partly due to more favourable moisture regime in the root zone and partly due to more efficient utilization of nutrients released from decomposition of the added FYM (Chiroma *et al.,* 2006). The application of residue and its incorporation in the soil have thought to reduce the evaporation demand, thus have adequate water for plant root growth, or perhaps due to the softness of soil caused by manure in which the roots may expand rapidly enough into wet soil to meet plant water requirements (Jama & Ottman, 1993).

Table 3. Effect of various organic and inorganic N treatments and tillage systems on plant attributes of maize.

Treatment	Emergence m^{-2}	Plant height (cm)	Leaf area index
Minimum tillage	8.36 a	221 a	2.97 a
Conventional tillage	8.03 ab	219 a	3.07 a
Deep tillage	7.53 b	206 b	2.62 b
LSD	0.628 *	11.33 *	0.34 *
N_0	6.67 d	203 d	2.41 c
N_1	7.89 abc	209 cd	2.85 ab
N_2	7.78 abc	221abc	3.01 ab
FYM1 + N_0	7.67 bc	210 cd	2.81 b
FYM1 + N_0	7.78 abc	217 a-d	2.95 ab
FYM1 + ½ N_1	8.11 abc	213 bcd	2.92 ab
FYM1 + ½ N_2	8.44 ab	226 ab	3.05 ab
FYM1 + ½ N_1	8.56 ab	227 ab	3.05 ab
FYM1 + ½ N_2	8.67 a	231 a	3.19 a
SR + N_0	7.33 cd	205 d	2.68 bc
SR + ½ N_1	8.33 ab	206 d	2.79 b
SR + ½ N_2	8.44 ab	217 a-d	2.91 ab
LSD	0.9917 *	14.91 *	0.3765 *
Interaction			
T x N	NS	NS	NS

Means followed by same letter(s) in each column are not significantly different using LSD test at $p \leq 0.05$.

Table 4. Effect of various organic and inorganic N treatments and tillage systems on yield and yield attributes of maize.

Treatment	Grains cob^{-1}	Thousand grain weight (g)	Biological yield (kg ha^{-1})
Minimum tillage	281 a	272 a	8620 ab
Conventional tillage	281 a	273 a	8839 a
Deep tillage	281 b	248 b	8215 b
LSD	10.94 *	21.14 *	441.2 *
N_0	281 b	218 c	7021 c
N_1	289 ab	254 cd	8019 ef
N_2	308 a	272 abc	8654 de
FYM1 + N_0	296 ab	264 a-d	8191 def
FYM1 + N_0	305 a	271 abc	8746 b-e
FYM1 + ½ N_1	303 ab	273 abc	8984 a-d
FYM1 + ½ N_2	308 a	279 abc	9180 abc
FYM1 + ½ N_1	309 a	283 ab	9528 ab
FYM1 + ½ N_2	310 a	287 a	9723 a
SR + N_0	294 ab	244 ac	7609 fg
SR + ½ N_1	298 ab	257 bcd	8399 c-f
SR + ½ N_2	303 ab	269 a-d	8640 cde
LSD	23.13 *	26.50 *	875.0 *
Interaction			
T x N	NS	NS	NS

Means followed by similar letter(s) in each column are not significantly different using LSD test at $p \leq 0.05$.

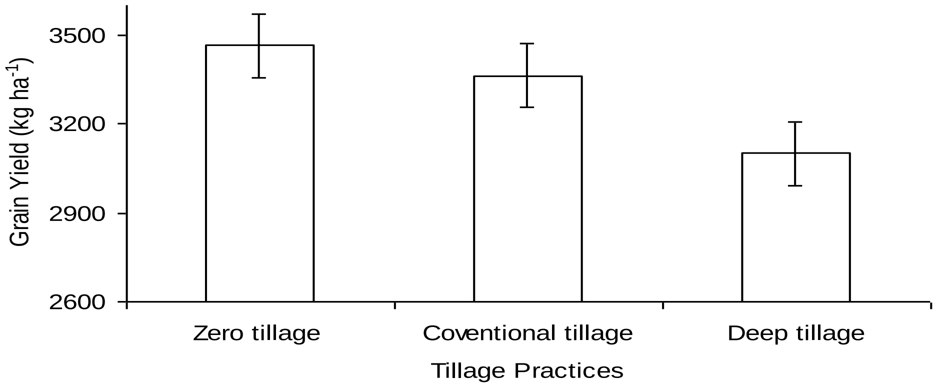

Fig. 1. Grain yield of maize crop as affected by various tillage practices. The vertical bars denote standard errors of means.

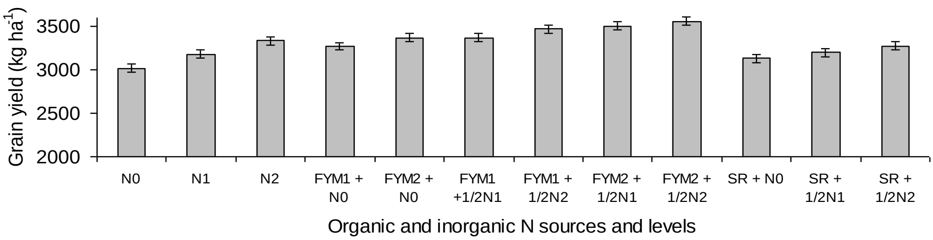

Fig. 2. Maize grain yield (kg ha^{-1}) as affected by various organic and inorganic N treatments. The vertical bars denote standard errors of means.

Both maize grain and biological yields were significantly affected by organic and inorganic N-treatments. However, the maize grain yields in N and incorporated organic N were significantly higher than the sole organic treatments. The improved growth and yield of maize in the FYM combined with N plots were attributed to greater soil water content, higher nutrient availability, and more protection from erosion compared to control treatment (Chiroma *et al.,* 2006). The highest grain yield obtained in FYM amended with N plots could also be attributed to improved uptake of N by maize through enhancing the organic matter decomposition-mineralization process, or indirectly maize root development. Soil decomposer community got starter N from urea, improve mineralization and thus would result in more grain yield in plots incorporated with FYM reinforced with N. Interactions between the organic matter and urea might have caused a temporary immobilization of fertilizer N but subsequent improved synchrony between N supply and demand. Beside the FYM, when all soybean residues were incorporated, either their allelopathic effects reduced grain yield (Einhellig & Leather, 1988), or the residue might have provided cooler conditions for early plant growth (Al-Darby & Lowery, 1987), and/or nitrogen might have been temporally immobilized and become unavailable for attaining optimum crop yield (Jessop & Stewart, 1983*).*

Our results confirm the findings of earlier experiments that tillage practices involving retention of residues on the surface and thus increase crop yields. These results also support data from semi-arid area of India (Selvaraju *et al.*, 1999), who demonstrated similar effects on the sorghum. The lack of superiority of higher FYM application over low FYM application does not necessarily imply the inefficacy of the FYM on these soils. Plants in higher and lower FYM applied plots utilized the water and nutrients in a better way; result in optimum plant growth, which can be attributed to deeper and denser rooting (Sow *et al.,* 1997). It is evident from these results that FYM incorporation in conjunction with minimum N is an alternative and sustainable practice of soil management for crop production. In addition, the gap between the two successive wheat cropping would be filled with maize on sustainable basis, with high output under soybean residue and FYM application under either MT or CT practices.

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