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RESPONSE OF MAIZE TO DIFFERENT NITROGEN SOURCES AND TILLAGE SYSTEMS UNDER HUMID SUBTROPICAL CONDITIONS

K. Shahzad[1], A. Khan[1], J. Smith[2], M. Saeed[1] and S.A. Khan[1]

[1]Department of Agriculture, University of Haripur, Postal Code: 22060, Khyber Pakhtunkhwa, Pakistan.
[2]Professor, Institute of Biological and Environmental Sciences, University of Aberdeen, 23 St. Machar Drive, Aberdeen, AB24 3UU, Scotland, UK.
[1]Corresponding Author E-mail: s.khuram.50@aberdeen.ac.uk, ks_uaf@yahoo.com

ABSTRACT

Tillage systems (minimum, conventional and deep) with different sources of nitrogen (bioslurry, poultry manure and chemical fertilizer) were studied through field experiments at Gujjar Seed and Nursery Farm, Haripur, Khyber-Pakhtunkhwa, Pakistan, for two consecutive years (2012-2013) in a randomized-complete-block-design with split plots and four replicates. The tillage systems were kept in main plots while nitrogen treatments with different combinations of chemical fertilizer, poultry manure and bioslurry were distributed in sub-plots. The results showed that deep tillage with 100% chemical fertilizer (135 kg N ha^{-1}) produced maximum plant height, stem diameter, cob length, cob diameter and number of grain rows per cob. However, deep tillage with combined application of 50% chemical fertilizer (67.5 kg N ha^{-1}), 25% poultry manure (1.9 t ha^{-1}) and 25% bioslurry (2.1 t ha^{-1}) produced maximum 1000 grain weight, biological yield, grain yield, plant nitrogen, phosphorous and potassium concentrations in maize shoot, and seed protein contents compared to other treatments. It is concluded that integrated use of bioslurry and poultry manure with a reduced rate of chemical fertilizer can improve maize productivity and reduce cost of chemical fertilizers. The results also suggest that, in this soil and climate, deep tillage is needed to maximise yield potential.

Key words: bioslurry, poultry manure, maize productivity, tillage systems, humid subtropical conditions.

INTRODUCTION

Poultry manure and residues from biogas digesters, referred to here as "bioslurry", are good sources of nutrients, and their application can improve soil fertility on a sustainable basis. The poultry industry is developing rapidly in Pakistan, and in the future will produce increasing quantities of poultry manure. This should be used, so that, it is not left to pollute the environment. Poultry manure can be used directly as an organic fertilizer for crops, or can be used to produce biogas by anaerobic digestion leaving a bioslurry residue that may be applied to crops as a stable organic fertilizer. Islam *et al.* (2010) suggested that bioslurry is an environmentally friendly and non-polluting organic fertilizer that could be used as a source of organic matter and nutrients for sustainable crop production. The use of bioslurry as organic fertilizer is not as popular in Pakistan as in other countries, such as China, India and Bangladesh. Sanwal *et al.* (2007) suggested that organic fertilizers are better sources of nutrients than expensive chemical fertilizers because they contain growth promoting agents, important for improving soil fertility as well as crop productivity. Optimum plant production can be achieved by proper selection of tillage practices, fertilizer and organic residues. In these environments, incorporation of organic residues by tillage can also improve productivity and increase the organic matter content of the soil (Khan *et al.*, 2009). Deep tillage improves soil aeration and water infiltration by breaking up hard pans, enhances root growth, increases nutrient availability by accelerating mineralization processes and also improves soil physical properties that lead to high crop growth, hence increasing plant yield (Bennie and Botha, 1986; Memon *et al*., 2013).

In Pakistan, maize ranks third in crop production after wheat and rice. The soil and climate of Pakistan are favourable for maize production, but yield is lower than in many other countries (GOP, 2007). To meet the food requirements of the increasing population, there is a need to determine the best soil and nutrient management practices to sustainably improve the yield of the maize crop.

The objectives of present study were therefore to determine the impact of different tillage practices with different nitrogen sources on maize productivity under humid subtropical conditions of Haripur-Pakistan, and to investigate the potential of different organic fertilizers for reducing expenditure on chemical fertilizers.

MATERIALS AND METHODS

Field Sites: The field experiments were conducted during 2012 and repeated during 2013 at the Gujjar Seed and Nursery Farm, Mang, Haripur, Khyber Pakhtunkhwa, Pakistan (LAT. 33.90˚N, LONG. 72.91˚E and ALT. 565

m). The climate of the experimental site is humid subtropical (Köppen Climate Classification), categorized by high temperature and evenly distributed rainfall throughout the year (Table 1). The soil of the experimental site at 0-30 cm depth had a soil texture of silt loam, pH of 7.8, organic matter content of 0.51%, total nitrogen (N) of 0.24 g kg^{-1}, available phosphorous (P) of 1.35 mg kg^{-1} and extractable potassium (K) of 53 mg kg^{-1}.

Organic Fertilizers: The bioslurry was collected from a shaded outlet of a 35 m^3 biogas plant located at Muhammad Siddique Farm, Changi Bandi, Haripur Pakistan and then it was air-dried under shaded conditions and distributed evenly in each treatment plot three weeks before sowing maize during 2012 and 2013. The bioslurry was mixed into the soil using a disc plough to avoid N losses from surface application. The poultry manure (poultry excreta mixed with bedding material) was collected from an environmentally controlled poultry shed (temperature 24°C and relative humidity 60-70%) of ~ 8000-16000 broiler birds located at the same farm. The collected poultry manure was allowed to decompose naturally by heaping it into pits under shade for three months and then distributed evenly in each treatment plot three weeks before sowing of the maize crop during both years, followed by disk plough to mix the manure into soil to avoid N losses. The bioslurry contained 0.016 g g^{-1} N, 0.0157 g g^{-1} P, 0.0135 g g^{-1} K and 0.59 g g^{-1} organic matter, while poultry manure contained 0.018 g g^{-1} N, 0.0142 g g^{-1} P, 0.0126 g g^{-1} K and 0.62 g g^{-1} organic matter.

Field Trials: The field experiments were laid out using a randomized complete block design (RCBD) with a split plot arrangement. The tillage systems (minimum, conventional and deep) were kept in the main plots while organic and inorganic N treatments were distributed in sub plots. The treatments were N_1 (no N applied), N_2 (100% recommended N applied as chemical fertilizer = 135 kg N ha^{-1}), N_3 (100% Recommended N applied as poultry manure = 7.5 t poultry manure ha^{-1}), N_4 (100% recommended N applied as bioslurry = 8.4 t bioslurry ha^{-1}), N_5 (50% recommended N applied as chemical fertilizer = 67.5 kg N ha^{-1} and 50% recommended N applied as poultry manure = 3.8 t poultry manure ha^{-1}), N_6 (50% recommended N applied as chemical fertilizer = 67.5 kg N ha^{-1} and 50% recommended N applied as bioslurry = 4.2 t bioslurry ha^{-1}), N_7 (50% recommended N applied as poultry manure = 3.8 t poultry manure ha^{-1} and 50% recommended N applied as bioslurry = 4.2 t bioslurry ha^{-1}), N_8 (50% recommended N applied as chemical fertilizer = 67.5 kg N ha^{-1}, 25% recommended N applied as poultry manure = 1.9 t poultry manure ha^{-1} and 25% recommended N applied as bioslurry = 2.1 t bioslurry ha^{-1}), N_9 (25% recommended N applied as chemical fertilizer = 33.8 kg N ha^{-1}, 50% recommended N applied as poultry manure = 3.8 t poultry manure ha^{-1} and 25% recommended N applied as bioslurry = 2.1 t bioslurry ha^{-1}) and N_{10} (25% recommended N applied as chemical fertilizer = 33.8 kg N ha^{-1}, 25% recommended N applied as poultry manure = 1.9 t poultry manure ha^{-1} and 50% recommended N applied as bioslurry = 4.2 t bioslurry ha^{-1}). Minimum tillage was carried out using rotavator followed by planking to the depth of 4-6 cm. In the case of conventional tillage, the soil was cultivated twice with the help of tractor-mounted cultivator (tine plough) followed by planking to the depth of 30 cm, while in the deep tillage system, the soil was ploughed with a chisel plough followed by planking to the depth of 45 cm. Each treatment was replicated four times. Net plot size was 4.5 m $\times$ 4.5 m. The maize variety Azam was sown at a rate of 40 kg ha^{-1} (recommended seeding rate) using the hand-pull drill method on 8th and 7th of July in 2012 and 2013. The recommended levels of N, P and K were 135, 125 and 125 kg ha^{-1} respectively. The chemical fertilizer N was applied as urea and di-ammonium phosphate, P as di-ammonium phosphate and K as potassium sulphate. The recommended doses for P and K were incorporated into the soil at the time of sowing, while N was applied in two splits (at sowing and at flowering). The crop was irrigated at two weekly intervals whenever required in addition to the rainfall received during both years. The crop was grown up to maturity. Agronomic parameters, plant height (cm), stem diameter (cm), cob length (cm), cob diameter (cm), number of grain rows per cob, 1000-grain weight (g), biological yield (t ha^{-1}), grain yield (t ha^{-1}) and harvest index (%) were determined at maize harvest on 4th and 9th of November in 2012 and 2013. The plant samples of maize shoot were digested by the method described by Moore and Chapman (1986) and then N concentrations in plant shoots were measured by the Kjeldhal method, P by spectrophotometer (Yoshida *et al*., 1976) and K by flame photometer. Seed protein contents were measured by the method described by Jackson (1962).

Statistical analysis: Data collected from crop growth and yield parameters from each year were analysed separately according to procedures relevant to RCBD split plot design using software "Statistix 8.1". Each data point was obtained from the mean of four replicates (n = 4). The lease significant difference (LSD) test was used to compare the significant differences among treatment means at 5% probability (Steel *et al*., 1997).

RESULTS

Tillage system and N treatment significantly ($p \leq 0.05$) affected all crop growth and yield parameters during 2012 and 2013, while tillage system had a non-significant ($p \geq 0.05$) effect on harvest index (Tables 2 and 3). A similar trend was observed during both years.

The response of the different N treatments for different agronomic parameters during 2013 as follows;
plant height (N_2=N_8 > N_5 > N_6=N_9 > N_3 > N_7 > N_{10} > N_4 > N_1),
stem diameter (N_2 > N_8=N_5 > N_6 > N_9 > N_3 > N_7 > N_{10} >N_4 > N_1),
cob length (N_2=N_8 > N_5 > N_6 > N_9> N_3> N_7> N_{10} > N_4=N_1),
cob diameter (N_2 > N_8 > N_5 > N_6=N_3 > N_9 > N_7 > N_{10} > N_4 > N_1),
grain row count per cob (N_2=N_8 > N_5=N_6 > N_9 > N_3 > N_7 > N_{10} > N_4 > N_1),
1000-grain weight (N_8=N_2 > N_5=N_6 > N_9 > N_3 > N_7 > N_{10}=N_4 > N_1),
grain yield (N_8=N_2 > N_5 > N_6 > N_9=N_3 > N_7 > N_{10} > N_4 > N_1),
biological yield (N_8=N_2 > N_5 > N_6 > N_9 > N_3 > N_7 > N_{10} > N_4 > N_1),
harvest index (N_8=N_2 > N_5=N_4=N_3=N_9 = N_7= N_6 =N_1> N_{10}),
N in maize shoots (N_8 > N_2 > N_5 > N_6=N_9 > N_3=N_7 > N_{10} > N_4 > N_1),
P in maize shoots (N_8 > N_6 > N_{10} > N_5 > N_9 > N_7 > N_4 > N_3 > N_2 > N_1),
K in maize shoots (N_8 > N_6 > N_{10} > N_5 > N_9 > N_7 > N_4 > N_3 > N_2 > N_1), and
seed protein contents (N_8=N_2 > N_5 > N_6 > N_9 > N_3 > N_7 > N_{10} > N_4 > N_1).

The tallest plants, greatest stem diameters, longest cobs, maximum cob diameter and number of grains per row were observed in treatment N_2. Other agronomic parameters were highest in treatment N_8, with a mean increase observed over the control treatment N_1 (no N was applied) in plant height (22 %), stem diameter (40 %), cob length (53 %), cob diameter (27 %), number of grains per row (55 %), 1000-grain weight (84 %), biological yield (67 %), grain yield (92 %), harvest index (15 %), plant N (212 %), P (175 %) and K (105 %) contents in maize shoots, and seed protein contents (55 %). The higher value to cost ratio (Table 4) was also observed in treatment N_8 as compared to other treatments.

The combined effects of tillage systems with different N treatments were also significant at $p \leq 0.05$ (Figure 1). The treatment deep tillage with N_2 produced maximum plant growth parameters with mean values of plant height (159.0 cm), stem diameter (2.07 cm), cob length (17.1 cm), cob diameter (4.72 cm) and number of grain rows per cob (15.2), followed by treatment deep tillage with N_8 with the mean values of plant height (157.2 cm), stem diameter (1.96 cm), cob length (16.5 cm), cob diameter (4.61 cm), number of grain rows per cob (15.2), 1000-grain weight (279.4 g), biological yield (16.8 t ha^{-1}), grain yield (4.81 t ha^{-1}), harvest index (28.6 %), plant N (15.41 g kg^{-1}), P (2.11 g kg^{-1}) and K (18.12 g kg^{-1}) in maize shoot, and seed protein contents (8.92 %) with a mean increase observed over the control treatment N_1 (no N was applied) in plant height (26 %), stem diameter (46 %), cob length (67 %), cob diameter (31 %), number of grain rows per cob (57 %), 1000-grain weight (94 %), biological yield (73 %), grain yield (110 %), harvest index (22 %), plant N (270 %), P (225 %) and K (109 %) contents in maize shoot, and seed protein contents (60 %).

Table 1. Meteorological data of the experimental site

	Average monthly evaporation over pan (mm)		Average monthly air temperature (°C)		Average monthly rainfall (mm)	
	2012	**2013**	**2012**	**2013**	**2012**	**2013**
Jan	53.7	40.1	9.9	11.0	30.0	13.1
Feb	45.9	36.3	11.3	13.4	57.3	290.3
Mar	92.1	90.0	18.4	19.3	20.4	69.4
Apr	116.6	118.9	24.5	23.5	35.9	32.3
May	166.1	205.6	29.0	29.1	15.1	13.1
Jun	195.7	156.0	33.6	32.1	12.5	119.3
Jul	175.2	124.1	32.7	30.1	145.1	317.5
Aug	112.9	90.5	29.4	28.0	410.3	670.3
Sep	102.3	98.7	26.9	27.5	182.3	336.0
Oct	99.3	100.4	22.9	24.8	8.2	58.1
Nov	62.0	51.1	17.6	16.6	5.1	12.1
Dec	43.3	39.3	13.1	11.0	87.1	59.0

Table 2. Effect of tillage systems and nitrogen treatments on growth and yield of maize

	Plant height (cm)		Stem diameter (cm)		Cob length (cm)		Cob diameter (cm)		No. of grain rows per cob		1000-grain weight (g)		Grain yield (t ha^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Tillage systems														
MT	145.4^{b}	145.7^{b}	1.610^{b}	1.623^{b}	12.1^{b}	12.3^{b}	4.14^{b}	4.16^{a}	13.9^{b}	13.9^{b}	233.6^{b}	233.8^{b}	3.07^{b}	3.16^{b}
CT	146.3^{ab}	146.7^{ab}	1.614^{ab}	1.648^{ab}	13.1^{a}	13.3^{ab}	4.17^{ab}	4.19^{ab}	14.0^{ab}	14.0^{ab}	236.5^{ab}	240.3^{ab}	3.22^{ab}	3.37^{ab}
DT	147.0^{a}	148.0^{a}	1.648^{a}	1.696^{a}	13.3^{a}	13.6^{a}	4.21^{a}	4.25^{a}	14.1^{a}	14.2^{a}	239.6^{a}	246.3^{a}	3.40^{a}	3.58^{a}
Nitrogen treatments														
N_1	125.4^{f}	125.6^{f}	1.321^{h}	1.347^{g}	9.6^{f}	10.3^{f}	3.49^{g}	3.52^{g}	9.7^{h}	9.7^{g}	146.1^{h}	147.9^{f}	2.14^{e}	2.37^{e}
N_2	155.5^{a}	155.2^{a}	1.845^{a}	1.970^{a}	16.1^{a}	16.6^{a}	4.58^{a}	4.62^{a}	15.0^{a}	15.0^{a}	264.3^{b}	270.6^{a}	4.28^{a}	4.44^{a}
N_3	147.9^{bcd}	148.3^{bcd}	1.603^{e}	1.616^{d}	12.8^{cd}	12.9^{cd}	4.22^{de}	4.25^{cd}	14.4^{d}	14.5^{c}	240.2^{e}	244.3^{cd}	3.23^{c}	3.37^{c}
N_4	143.1^{e}	143.4^{e}	1.481^{g}	1.476^{f}	10.8^{e}	11.0^{f}	4.04^{f}	4.08^{f}	13.6^{g}	13.7^{f}	223.5^{g}	226.1e	2.58^{d}	2.67^{de}
N_5	149.8^{bc}	150.0^{b}	1.778^{b}	1.820^{b}	14.1^{b}	14.2^{b}	4.33^{bc}	4.34^{c}	14.8^{bc}	14.9^{ab}	260.6^{b}	262.9^{b}	3.67^{b}	3.78^{b}
N_6	149.6^{bc}	149.8^{bc}	1.719^{c}	1.739^{c}	13.6^{bc}	13.8^{bc}	4.26^{cd}	4.25^{cd}	14.8^{abc}	14.8^{ab}	254.6^{c}	257.3^{b}	3.28^{c}	3.44^{bc}
N_7	146.4^{cde}	146.5^{cde}	1.531^{f}	1.544^{e}	11.8^{de}	12.0^{de}	4.12^{ef}	4.14^{ef}	14.2^{e}	14.2^{d}	233.4^{f}	238.9^{d}	2.84^{d}	2.95^{d}
N_8	150.8^{b}	153.7^{a}	1.826^{a}	1.887^{b}	15.6^{a}	15.8^{a}	4.40^{b}	4.48^{b}	14.9^{ab}	15.0^{a}	270.5^{a}	272.7^{a}	4.38^{a}	4.56^{a}
N_9	149.3^{bc}	149.6^{bc}	1.663^{d}	1.675^{cd}	12.9^{cd}	13.1^{c}	4.20^{de}	4.19^{de}	14.7^{c}	14.7^{b}	246.8^{d}	249.8^{c}	3.22^{c}	3.37^{c}
N_{10}	145.3^{de}	145.6^{de}	1.472^{g}	1.483^{ef}	11.0^{e}	11.2^{ef}	4.09^{f}	4.09^{ef}	13.9^{f}	13.9^{e}	225.7^{g}	230.5^{e}	2.69^{d}	2.76^{d}
LSD 5%														
TS	1.52	2.27	0.035	0.067	0.96	1.14	0.06	0.08	0.10	0.14	5.26	12.42	0.29	0.42
NT	3.51	3.43	0.047	0.068	1.11	1.01	0.09	0.11	0.19	0.23	4.63	6.80	0.31	0.38
TS X NT	5.95	6.06	0.084	0.062	2.05	1.85	0.16	0.19	0.34	0.41	9.21	12.44	0.57	0.69

Note: Means in a column not sharing the same letters differ significantly from each other at $p \leq 0.05$ (n=4).
Tillage systems (TS), Nitrogen treatments (NT), MT (minimum tillage), CT (conventional tillage), DT (deep tillage), N_1 (no N applied), N_2 (135 kg N ha^{-1}), N_3 (7.5 t poultry manure ha^{-1}), N_4 (8.4 t bioslurry ha^{-1}), N_5 (67.5 kg N ha^{-1} and 3.8 t poultry manure ha^{-1}), N_6 (67.5 kg N ha^{-1} and 4.2 t bioslurry ha^{-1}), N_7 (3.8 t poultry manure ha^{-1} and 4.2 t bioslurry ha^{-1}), N_8 (67.5 kg N ha^{-1}, 1.9 t poultry manure ha^{-1} and 2.1 t bioslurry ha^{-1}), N_9 (33.8 kg N ha^{-1}, 3.8 t poultry manure ha^{-1} and 2.1 t bioslurry ha^{-1}) and N_{10} (33.8 kg N ha^{-1}, 1.9 t poultry manure ha^{-1} and 4.2 t bioslurry ha^{-1}).

Table 3. Effect of tillage systems and nitrogen treatments on plant growth, plant nutrient concentrations in maize shoot and seed quality parameters

	Biological yield (t ha^{-1})		Harvest index (%)		Plant N Conc. (g kg^{-1})		Plant P Conc. (g kg^{-1})		Plant K conc. (g kg^{-1})		Seed protein contents (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013		
Tillage systems												
MT	13.9^{b}	13.9^{b}	22.0	22.8	13.1^{b}	13.1^{b}	1.59^{c}	1.60^{b}	13.35^{c}	13.42^{b}	7.01^{b}	7.10^{b}
CT	14.2^{ab}	14.2^{ab}	22.5	23.7	13.3^{ab}	13.4^{ab}	1.62^{b}	1.65^{a}	13.59^{b}	13.74^{a}	7.26^{a}	7.29^{ab}
DT	14.3^{a}	14.6^{a}	23.5	24.3	13.6^{a}	13.6^{a}	1.65^{a}	1.68^{a}	13.79^{a}	13.91^{a}	7.36^{a}	7.43^{a}
Nitrogen treatments												
N_1	9.7^{h}	9.8^{h}	22.1^{bc}	24.2^{b}	4.87^{g}	4.89^{g}	0.73^{j}	0.75^{j}	8.65^{j}	8.73^{j}	5.54^{g}	5.66^{g}
N_2	16.4^{a}	16.4^{a}	26.1^{a}	27.2^{a}	15.07^{a}	15.11^{ab}	1.48^{i}	1.47^{i}	10.58^{i}	10.62^{i}	8.53^{a}	8.64^{a}
N_3	14.7^{d}	14.8^{d}	21.9^{bc}	22.6^{b}	14.29^{cd}	14.26^{de}	1.51^{h}	1.53^{h}	11.17^{h}	11.29^{h}	7.11^{cd}	7.15^{cd}
N_4	11.6^{g}	11.8^{g}	22.1^{bc}	22.9^{b}	12.42^{f}	12.35^{f}	1.57^{g}	1.60^{g}	11.77^{g}	11.87^{g}	6.54^{f}	6.60^{f}

N_5	15.8^{b}	15.9^{ab}	23.1^{b}	23.6^{b}	14.70^{b}	14.74^{bc}	1.78^{d}	1.79^{d}	15.07^{d}	15.22^{d}	7.53^{b}	7.62^{b}
N_6	15.6^{b}	15.7^{bc}	20.9^{c}	21.9^{b}	14.51^{bc}	14.55^{cd}	1.92^{b}	1.94^{b}	17.07^{b}	17.22^{b}	7.31^{bc}	7.39^{bc}
N_7	13.4^{e}	13.6^{e}	21.3^{bc}	22.0^{b}	14.11^{de}	14.15^{de}	1.65^{f}	1.66^{f}	13.0^{f}	13.17^{f}	6.88^{de}	6.92^{de}
N_8	16.4^{a}	16.4^{a}	26.7^{a}	27.8^{a}	15.24^{a}	15.26^{a}	2.01^{a}	2.06^{a}	17.88^{a}	17.93^{a}	8.71^{a}	8.77^{a}
N_9	15.1^{c}	15.2^{cd}	21.3^{bc}	22.1^{b}	14.42^{bcd}	14.43^{cd}	1.70^{e}	1.72^{e}	14.0^{e}	14.18^{e}	7.23^{c}	7.25^{c}
N_{10}	12.6^{f}	12.8^{f}	21.4^{bc}	21.7^{c}	13.89^{e}	13.91^{e}	1.88^{c}	1.89^{c}	16.59^{c}	16.66^{c}	6.71^{ef}	6.72^{ef}
LSD 5 %												
TS	0.35	0.67	NS	NS	0.496	0.481	0.016	0.036	0.086	0.242	0.241	0.271
NT	0.45	0.47	2.16	2.67	0.332	0.423	0.019	0.032	0.084	0.209	0.233	0.248
TS X NT	0.81	1.02	4.05	5.25	0.607	0.773	0.035	0.066	0.160	0.418	0.451	0.453

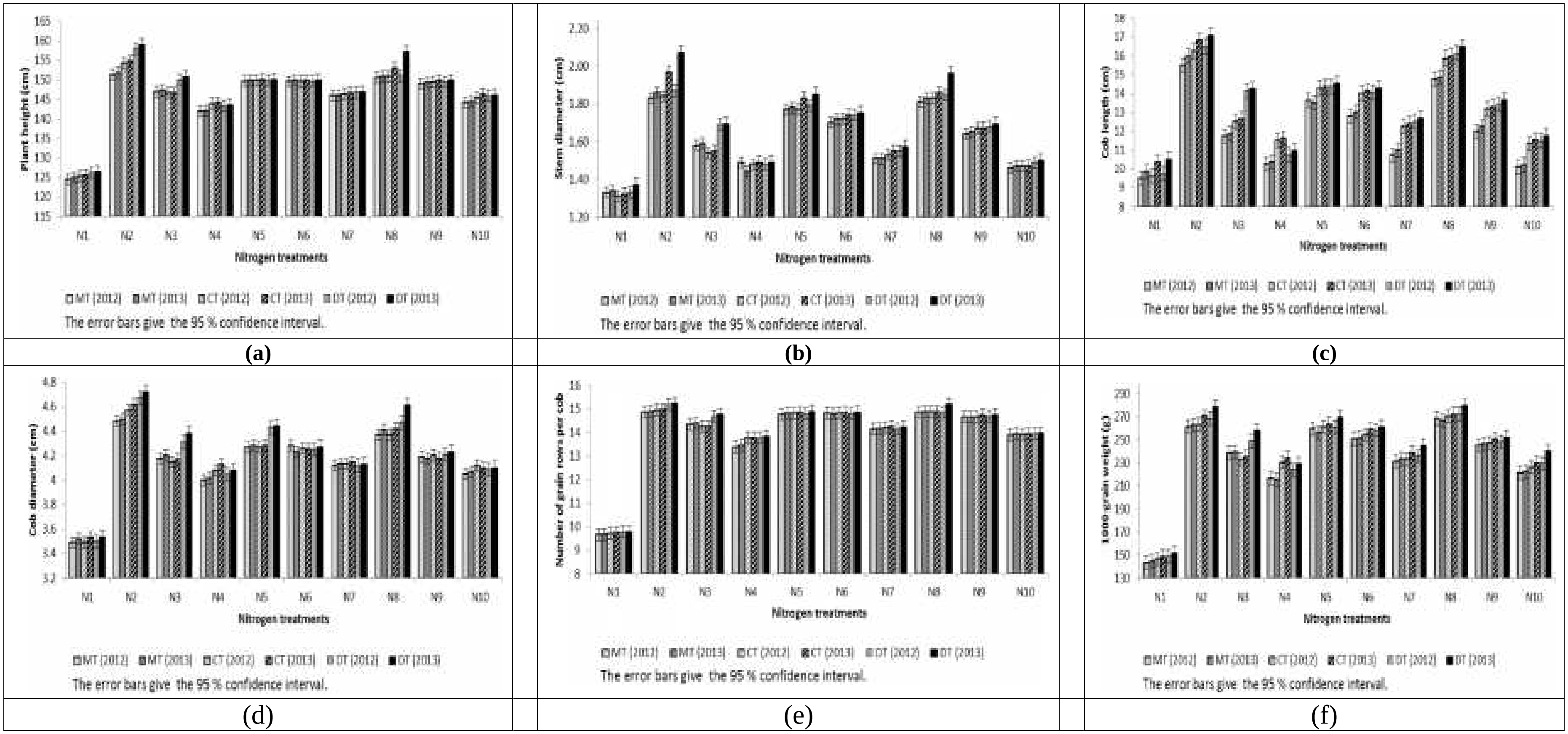
Note: Means in a column not sharing the same letters differ significantly from each other at $p \leq 0.05$ (n=4).
Tillage systems (TS), Nitrogen treatments (NT), MT (minimum tillage), CT (conventional tillage), DT (deep tillage), N_1 (no N applied), N_2 (135 kg N ha^{-1}), N_3 (7.5 t poultry manure ha^{-1}), N_4 (8.4 t bioslurry ha^{-1}), N_5 (67.5 kg N ha^{-1} and 3.8 t poultry manure ha^{-1}), N_6 (67.5 kg N ha^{-1} and 4.2 t bioslurry ha^{-1}), N_7 (3.8 t poultry manure ha^{-1} and 4.2 t bioslurry ha^{-1}), N_8 (67.5 kg N ha^{-1}, 1.9 t poultry manure ha^{-1} and 2.1 t bioslurry ha^{-1}), N_9 (33.8 kg N ha^{-1}, 3.8 t poultry manure ha^{-1} and 2.1 t bioslurry ha^{-1}) and N_{10} (33.8 kg N ha^{-1}, 1.9 t poultry manure ha^{-1} and 4.2 t bioslurry ha^{-1}).

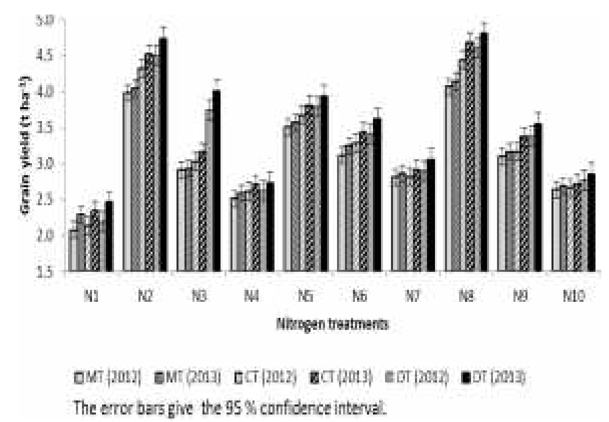
Table 4. Cost economics for the integrated use of N fertilizer

Treatments	Grain yield (kg ha^{-1}) in 2013	Yield increase over control (kg ha^{-1})	Value of increased yield (Rs.)	Cost of fertilizer (Rs.)	Value: Cost ratio
N_1	2400	-	-	-	-
N_2	4400	2000	42904	4509	9.5
N_3	3400	1000	21452	3750	5.7
N_4	2700	300	6436	2953	2.2
N_5	3800	1400	30033	4130	7.3
N_6	3400	1000	21452	3731	5.8
N_7	2900	500	10726	3352	3.2
N_8	4600	2200	47194	3930	12.0
N_9	3400	1000	21452	3741	5.7
N_{10}	2800	400	8581	3541	2.4

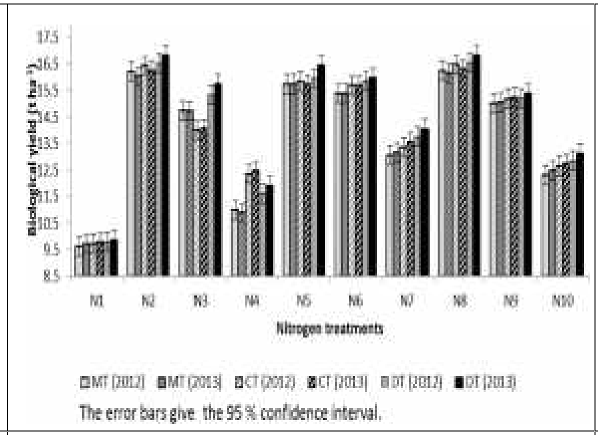
Urea @ Rs.33.4 kg^{-1}, Poultry manure @ Rs. 500 t^{-1}, Bioslurry @ Rs. 350 t^{-1}, Maize Grain @ Rs. 21.45 kg^{-1}
N_1 (no N applied), N_2 (135 kg N ha^{-1}), N_3 (7.5 t poultry manure ha^{-1}), N_4 (8.4 t bioslurry ha^{-1}), N_5 (67.5 kg N ha^{-1} and 3.8 t poultry manure ha^{-1}), N_6 (67.5 kg N ha^{-1} and 4.2 t bioslurry ha^{-1}), N_7 (3.8 t poultry manure ha^{-1} and 4.2 t bioslurry ha^{-1}), N_8 (67.5 kg N ha^{-1}, 1.9 t poultry manure ha^{-1} and 2.1 t bioslurry ha^{-1}), N_9 (33.8 kg N ha^{-1}, 3.8 t poultry manure ha^{-1} and 2.1 t bioslurry ha^{-1}) and N_{10} (33.8 kg N ha^{-1}, 1.9 t poultry manure ha^{-1} and 4.2 t bioslurry ha^{-1}).

Figure 1. Combined effect of tillage systems and nitrogen treatments on different agronomic parameters of maize crop during 2012 and 2013.
Note - MT = minimum till; CT = conventional till; DT = deep till. Year is given in brackets.

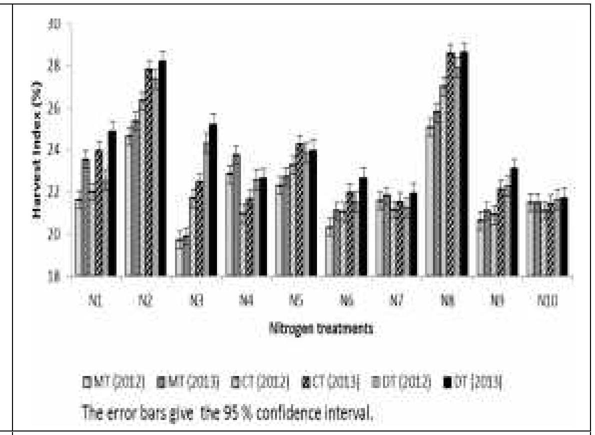



Grain yield (t ha⁻¹)
Nitrogen treatments
MT (2012) MT (2013) CT (2012) CT (2013) DT (2012) DT (2013)
The error bars give the 95 % confidence interval.

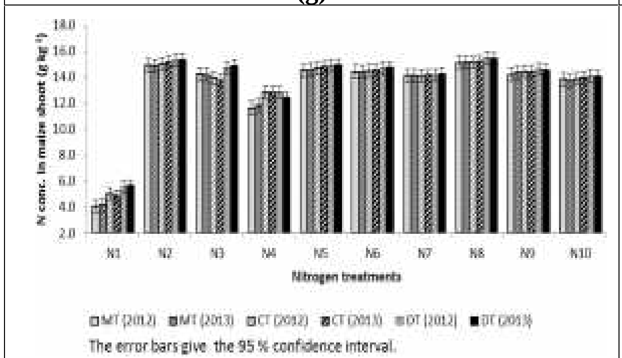
(g)


Biological yield (t ha⁻¹)
Nitrogen treatments
MT (2012) MT (2013) CT (2012) CT (2013) DT (2012) DT (2013)
The error bars give the 95 % confidence interval.

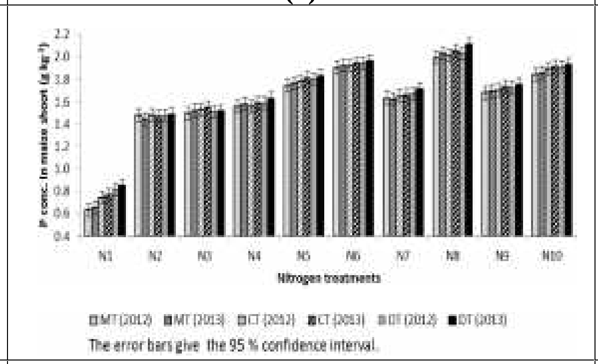
(h)


Harvest index (%)
Nitrogen treatments
MT (2012) MT (2013) CT (2012) CT (2013) DT (2012) DT (2013)
The error bars give the 95 % confidence interval.

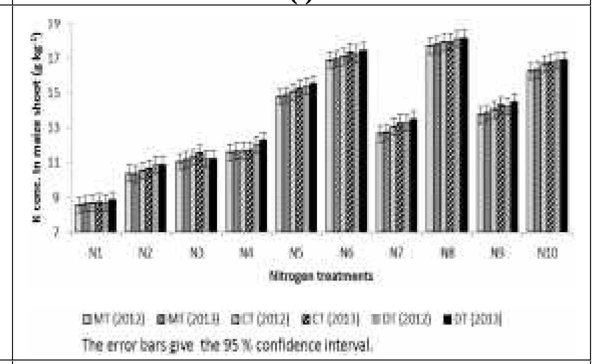
(i)


N conc. in maize shoot (g kg⁻¹)
Nitrogen treatments
MT (2012) MT (2013) CT (2012) CT (2013) DT (2012) DT (2013)
The error bars give the 95 % confidence interval.

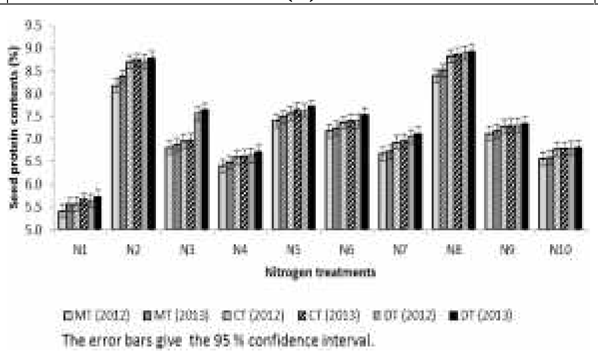
(j)


P conc. in maize shoot (g kg⁻¹)
Nitrogen treatments
MT (2012) MT (2013) CT (2012) CT (2013) DT (2012) DT (2013)
The error bars give the 95 % confidence interval.

(k)


K conc. in maize shoot (g kg⁻¹)
Nitrogen treatments
MT (2012) MT (2013) CT (2012) CT (2013) DT (2012) DT (2013)
The error bars give the 95 % confidence interval.

(l)


Seed protein contents (%)
Nitrogen treatments
MT (2012) MT (2013) CT (2012) CT (2013) DT (2012) DT (2013)
The error bars give the 95 % confidence interval.

(m)

DISCUSSION

A significant difference was observed in plant growth and yield with application of different tillage systems and N treatments during both years of the experiment. Maximum plant growth and yield were recorded in deep tillage system as compared to minimum and conventional tillage systems (Table 2 and 3). This might be due to decreased soil bulk density, more soil aeration and increase in proliferation of roots for uptake of more nutrients by the plant in deep tillage systems (Pathak *et al*., 2004). These results are in agreement with Aikins and Afuakwa (2010) who reported that plant shoot development was dependent on root development and increased with depth of tillage, leading to the more vegetative growth of plants. Adeyemo and Agele (2010) stated that tillage can expose inaccessible organic materials to microbial decomposition and can accelerate mineralization of organic N by increasing microbial activity.

The maximum plant height, stem diameter, cob length, cob diameter and number of grain rows per cob was observed in the deep tillage treatment with N_2, followed by treatment deep tillage with N_8 (Fig 1). This might be due to increased photosynthetic activity due to adequate supplies of N and water from the different sources (Khan, 2008). These results are in line with the findings of Islam *et al*. (2010) who observed increased crop growth in plots treated with cow dung slurry and poultry manure slurry. Similarly, Morsy (2002) observed taller plants from plots treated with organic waste materials than in untreated plots. Our results are also supported by findings of Chiroma *et al.* (2006) and Adeyemo and Agele (2010), who observed that tillage systems with application of different organic and inorganic N sources enhance the mineralization / decomposition rates of organic residues and released more nutrients that were essential for plant growth. Similar results were also reported by Ali *et al*. (2011; 2012) who observed that the fertilizing potential of organic fertilizer is improved when it is applied with mineral fertilizer in deeply tilled soils; the integrated use of organic and inorganic N sources with proper selection of tillage systems being an efficient approach to improve maize productivity compared to sole application of chemical fertilizer or organic manure.

Higher 1000-grain weight and grain yield were observed in the deep tillage treatment with N_8 (Fig 1). This might be due to the larger size of grains as a result of increased accumulation of proteins and food reserves in the seeds. These results are in agreement with the work of Warren *et al.* (2006).

The higher biological yield and harvest index were also observed in the deep tillage treatment with N_8 (Fig 1). This might be due to an increase in availability of soil N and uptake by the plant of the micro and macro nutrients that are required for optimum plant growth. These results are confirmed by Reiad *et al*. (1997), Sarir *et al.* (2005) and Uzoma *et al*. (2011).

Higher concentrations of N, P and K in the maize shoots were also recorded in deep tillage treatment with N_8 (Fig 1). This might be due to increased organic matter, N, P and K in soil and uptake of more soil nutrients by following fertilization with bioslurry and poultry manure. These results are supported by Mathers and Stewart (1984), Juiliana (1991), Singh (2007), Singh and Behera (2007) and Nasir *et al.* (2010). Al-Turki *et al*. (2004) also reported that bioslurry is a good soil conditioner and has the potential to increase N, P and K contents in different crops.

Increased seed protein contents were also observed in deep tillage treatment with N_8 (Fig 1). Pate (1968) suggested that protein synthesis is more active in young leaves. Salisbury and Ross (1978) proposed that application of nitrate enhances the formation of nitrate reductase enzymes in leaves because nitrate is rapidly translocated into leaf cells. Khan (2008) reported higher N contents in the leaves being converted into proteins during seed development and translocated into seed for protein synthesis, suggesting increased leaf area index with increasing N availability were the possible reasons for improved seed protein contents.

The cost analysis given in Table 4, shows that the integrated use of organic and chemical fertilizers as in treatment N_8 at a ratio of 2:1:1 (50% N applied as chemical fertilizer, 25% as poultry manure and 25% as bioslurry) was the most economically profitable treatment and produced a high value cost ratio. These results are further supported by the work of Shah *et al.* (2010).

Conclusion: It is concluded that maize productivity under humid subtropical conditions will be improved if, instead of applying chemical fertilizer alone, the recommended N application rate of 135 kg ha^{-1} is applied in a deep tillage system as 67.5 kg N ha^{-1}, 1.9 t poultry manure ha^{-1} and 2.1 t bioslurry ha^{-1}.

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