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Optimum Utilization of Different Nitrogen Fertilizer Sources for Improving Soil Properties and Agro-Physiological Indices of Maize Crop under Humid Subtropical Conditions of Pakistan

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ABSTRACT

Purpose: The purpose of this research was to assess the production potential of maize by examining its agro-physiological traits under different combinations of organic and inorganic nitrogen fertilizers, as well as to evaluate the resulting changes in soil properties.

Material and Methods: The study was conducted for two years using randomized complete block split-plot arrangement. Three tillage systems (minimum, conventional and deep) were used in the main plots, while ten different nitrogen treatments, with different proportions of single and combined applications of chemical fertilizer, poultry manure and bioslurry, were used in sub-plots. Further, detail is given in section-2.

Findings: The treatment where deep tillage was used in combination with 50% of the recommended nitrogen from chemical fertilizer (67.5 kg ha^{-1}), 25% from poultry manure (1.9 t ha^{-1}) and 25% from bioslurry (2.1 t ha^{-1}) showed the greatest increase in agro-physiological crop growth compared to the control (zero nitrogen application with minimum tillage), with a 76% increase in leaf area index (75 days after sowing), 86% increase in average mean crop growth rate and 38% increase in mean net N assimilation rate. This might be due to a 43% increase in recovery efficiency of fertilizer nitrogen in this treatment compared to the control. This treatment also decreased soil bulk density by 5% and increased soil porosity by 6%, total soil nitrogen by 21%, available soil phosphorous by 55% and available soil potassium by 20% compared to the control.

Implications to Theory, Practice and Policy: These results suggest that, in this soil, this treatment provides the optimum nutrient management, both improving soil properties and achieving maximum agro-physiological growth due to enhancing fertilizer nitrogen recovery efficiency.

Keywords: *Agro - Physiological Growth, Bioslurry, Nitrogen Sources, Poultry Manure, Soil Properties*

JEL Codes of Classification: *Q01, Q14, Q15, N55, O13*

INTRODUCTION

The agriculture sector is crucial in reducing poverty and improving food security in Pakistan, contributing 24% to the country's gross domestic product (GOP, 2023-24). Among the various crops, maize ranks as the third most important cereal crop after wheat and rice. It is used for human consumption, livestock feed, and increasingly in a variety of commercial products. In the 2023-24 season, maize production in Pakistan reached 9.847 million tons.

However, maize production faces several significant challenges related to land cultivation, seed availability, fertilizer use, and soil management. The widespread inefficiency in nitrogen fertilizer use often leads to nutrient imbalances that reduce crop yields and increase costs. Additionally, over-application or poor timing of fertilizers can degrade soil health, resulting in nutrient leaching and environmental issues such as water contamination. Unsustainable soil management practices, such as inadequate crop rotation, inefficient irrigation, and improper tillage, further deplete soil fertility and impact long-term productivity. These challenges are exacerbated by limited awareness and access to modern agricultural techniques, underscoring the need for improved fertilizer use and sustainable soil management practices.

Excessive reliance on chemical fertilizers can result in decreased crop yields due to low fertilizer use efficiency (Farhad *et al.*, 2009). Organic fertilizers, like bioslurry (a byproduct of biogas digesters) and poultry manure, present viable alternatives. These organic sources are rich in essential micro- and macronutrients and enhance soil organic matter, improving soil structure, aeration, water infiltration, nutrient retention, and water-holding capacity, thus boosting fertilizer use efficiency (Deksissa *et al.*, 2008). Poultry manure, in particular, provides readily available nutrients, especially phosphorus (Garg & Bahla, 2008), while bioslurry offers highly accessible nutrients (Islam *et al.*, 2010; Shahariar *et al*., 2013). With an estimated 50 million metric tonnes of organic waste produced annually in Pakistan (Nasir *et al.*, 2010), these wastes could be utilized in biogas digesters to produce both energy and high-quality organic fertilizer rich in soluble nutrients.

The rising prices of chemical fertilizers, coupled with low fertilizer use efficiency and growing environmental concerns, have spurred interest in organic nutrient sources. While chemical fertilizers cannot be entirely replaced, integrating tillage with both organic and inorganic nutrient sources can supply essential nutrients to plants and mitigate the environmental risks associated with excessive chemical fertilizer use (NFDC, 1997). Tillage is crucial for incorporating organic residues into the soil, removing weeds, loosening the soil to enhance water infiltration, and preparing the seedbed for optimal germination conditions. It also improves soil aeration, accelerates residue decomposition, and promotes the mineralization of organic nitrogen (N), increasing the availability of nitrogen to plants (Dinnes *et al*., 2002).

Problem Statement

Pakistani soils are relatively very low in soil organic matter, leading to a heavy reliance on chemical fertilizers to achieve high crop productivity. This over-dependence on chemical inputs rising fertilizer prices in the country. The prevailing agricultural practices are unsustainable, impacting both crop yields and long-term soil health. Therefore, there is an urgent need to explore and implement integrated approaches that combine chemical fertilizers with organic sources to enhance soil fertility, reduce environmental impacts, and ensure sustainable crop production. This research aims to address these issues by evaluating the effectiveness of integrated nutrient management strategies in improving soil health and agricultural productivity in Pakistan.

While various studies have explored the integrated use of organic and inorganic fertilizers in Pakistan, there is a notable gap in research regarding the specific application of biogas slurry. Specifically, there is a need to investigate how biogas slurry affects soil properties and agro-physical indices of maize crops under different tillage practices. Addressing this gap will provide valuable insights into the potential benefits of biogas slurry in improving soil health and crop performance, thereby contributing to more sustainable agricultural practices and enhanced crop productivity. Therefore, this study is conducted with the objectives to investigate the impact of different nitrogen (N) sources and tillage systems on agro-physiological growth of maize and soil properties under humid subtropical conditions of Pakistan. The null hypotheses to be tested are

1. Application of the crop requirement of nitrogen as dairy cattle bioslurry does not increase the agro physiological growth of maize and improve soil properties compared to application as chemical fertilizer.
2. Application of the crop requirement of nitrogen as composted poultry manure does not increase the agrophysical growth of maize crop and soil properties compared to application as chemical fertilizer.
3. Application of the crop requirement of nitrogen as dairy cattle bioslurry does not increase the agro physiological growth of maize crop and soil properties compared to application as composted poultry manure.
4. Depth of tillage does not impact the agro physiological growth of maize crop and soil properties.

MATERIALS AND METHODS

Experimental Site

The field experiments were carried out in 2012 and repeated in 2013 at the same treatment plots at the Gujjar Seed and Nursery Farm, Mang, Haripur, Khyber Pakhtunkhwa, Pakistan. According to the USDA soil classification, the soil of the experimental site belongs to Udic Calciustepts (Sub group). The soil of experimental site from 0-30cm depth has a silt loam texture, pH of 7.8, soil organic matter content of 0.51 %, bulk density of 1.45 g cm^{-3}, total porosity of 0.48 m^3 m^{-3}, total soil N content of 0.024 %, available phosphorous (P) content of 1.35 mg kg^{-1} and extractable potassium (K) content of 53 mg kg^{-1}. The cropping history of the field was a wheat maize crop rotation for the last five years. The last wheat crop was harvested before the start of the experiment.

Field Experiments

The field experiments were conducted for maize crop using a randomized completed block 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 N treatments determined the impacts of single and combined applications of chemical fertilizer, poultry manure and bioslurry, and are listed in Table 1. Each treatment contained four replications. Net plot size was 4.5 m × 4.5 m.

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 was air-dried and distributed evenly in each treatment plot, three weeks before sowing maize. 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 located at the same farm. During both years, the collected poultry manure was decomposed naturally by heaping it into pits for three months and then distributed evenly in each treatment plot three weeks before sowing the maize, followed by disk ploughing to mix the manure into soil to avoid N losses. The bioslurry contained N (1.6%), P (1.57%), K (1.35 %) and organic matter (59 %), while poultry manure contained N (1.8%), P (1.42%), K (1.26%) and organic matter (62%).

Tillage Treatments

Minimum tillage was done by using rotavator followed by planking to the depth of 4-6 cm. For conventional tillage, the soil was cultivated twice to a depth of 30 cm using a tractor-mounted mouldboard plough followed by planking. In the deep tillage system, the soil was ploughed with a chisel plough followed by planking to a depth of 45 cm.

Management of Crop

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. Urea and di-ammonium phosphate fertilizers were applied as the source of N for the chemical fertilizer treated plots. The recommended doses for P and K were applied through di-ammonium phosphate and potassium sulphate, and incorporated into the soil at the time of sowing, while N was applied in two splits (at sowing and at flowering). The rainfall received during the growth period of the maize crop in 2013 than in 2012 in the months of July (317 CF 145mm), August (670 CF 410 mm), September (336 CF 182 mm) and October (58 CF 8.2 mm) as shown in Figure 1. The crop was irrigated at two weekly intervals as per crop requirement to uniformly in all treatment plots. The crop was grown to maturity.

Measurement of Crop Characteristics

The leaf area index *(LAI*), describing the leaf area (assimilatory source) per unit land area, was calculated by the method given by Radford (1967), at 30, 45, 60, 75 and 90 days after sowing (DAS) of maize crop;

$$LAI = A_{\text{plant}} \times n_{\text{plant}}$$

where n_{plant} is the number of plants per m^2 and A_{plant} is the total leaf area of a plant (m^2). The total leaf area, A_{plant}, is given by

$$A_{\text{plant}} = A_{\text{leaf}} \times n_{\text{leaf}}$$

where n_{leaf} is the number of leaves on each plant and A_{leaf} is the mean area of a leaf (m^2). The mean leaf area, A_{leaf}, is given by

$$A_{\text{leaf}} = L \times w \times 0.75$$

where L is the average length of a leaf (m), and w is the average width of a leaf (m).

The rate of crop growth, R (g m^{-2} day^{-1}), was calculated using the formula given by Hunt (1978);

$$R = \frac{W_2 - W_1}{t_2 - t_1}$$

where W_1 is the dry weight at first harvest (g m^{-2}), W_2 is the dry weight at second harvest (g m^{-}

^{2}), t_1 is the time of the first harvest (days), and t_2 is the time of the second harvest (days). The crop growth rate (CGR) were calculated at 30, 45, 60, 75, 90and 105 DAS of the maize crop and then averaged to determine mean CGR, $\bar{R}$(g m^{-2} day^{-1}).

Similarly, the net assimilation rate, *NAR* (g m^{-2} day^{-1}), was calculated at at30, 45, 60, 75, 90and 105 DAS using the formula provided by Hunt (1978) and then averaged:

$$NAR = \frac{W_{\text{hary}}}{LAD}$$

where W_{hary} is the dry weight at harvest (g m^{-2}) and *LAD* is the leaf area duration (days). The leaf area duration (*LAD*) is given by

$$LAD = \frac{(LAI_1 + LAI_2)\times(t_2 - t_1)}{2}$$

where LAI_1 is the leaf area index at first harvest, LAI_2 is the leaf area index at second harvest, t_1 is the date of harvest 1 and t_2 is the date of harvest 2.

The uptake of N by the maize grain, N_{grain} (kg ha^{-1}), is calculated as follows;

$$N_{\text{grain}} = P_{\text{Ngrain}} \times W_{\text{grain}}$$

where P_{Ngrain} is the N content of the grain (%), and W_{grain} is the grain yield (kg ha^{-1})

Recovery efficiency of N fertilizer, *RE* (%), is calculated by using formula:

$$RE = \frac{N_{\text{up,treat}} - N_{\text{up,control}}}{N_{\text{app}}} \times 100$$

where $N_{\text{up,treat}}$ is the N uptake in the treatment (kg ha^{-1}), $N_{\text{up,control}}$ is the N uptake in the control (kg ha^{-1}), and N_{app} is the N applied (kg ha^{-1}).

Soil Analysis

After the maize harvest on 4th and 9th of November in 2012 and 2013, soil samples were taken to a depth of 0-30 cm. Samples were air dried, ground and then passed from 2 mm sieve. These samples were stored and analysed for total soil N by the method of Bremner & Mulvancy (1982), available P by the method of Watanabe & Olsen (1965), available K by the method of Knudsen *et al.* (1982), soil bulk density (ρb) by the method of Blake & Hartage (1986), and total porosity of the soil (f_t) by the method of Lowery *et al.* (1996).

Statistical Analysis of Experimental Data

The data collected for the different plant growth and soil parameters were collected using a randomized complete block split plot design. Data from the two years collected separately, then averaged the data over both years and analysed using the software package "Statistix 8.1". The Honestly Significant Difference Test (HSD) at 5% probability was used to compare the differences among treatment means (Steel & Torrie, 1984).

RESULTS AND DISCUSSION

Leaf Area Index

The leaf area index (LAI) provides a characterization of agro-physiological plant growth, a higher value of LAI indicating a higher dry matter content of the crop. The higher values of LAI in 2013 than in 2012 were due to more favorable environmental conditions for vegetative growth of the crop in 2013 (Figure 1). The average values for LAI at 30, 45, 60, 75 and 90 DAS during 2012 and 2013 are presented in Table 2. Tillage systems and N treatments significantly ($p \leq 0.05$) affected LAI at 75 DAS (Figure 2), with maximum values observed in the deep tillage and minimum values in the minimum tillage system, and maximum values observed in treatment N8 (50% N from chemical fertilizer + 25% N from poultry manure + 25% N from bioslurry) and minimum values in N1 (control – no N application). The response of LAI at 75 DAS to the different N treatments was as follows;

LAI at 75 DAS (N8 >N2> N5 > N6>N9 > N3 > N7 > N10 > N4 > N1)

The interaction between tillage systems and different N treatments was also significant at $p \leq 0.05$ (Figure 3a), with the largest increase for deep tillage with treatment N8 of 76% for LAI at 75 DAS compared to minimum tillage with the control (N1). The increase in LAI with N supply occurs due to more cell enlargement and cell division that ultimately leads to increased expansion of the leaf in terms of length and breadth. This might be due to timely availability of N and slow release of nutrients from the decomposition/mineralization process of bioslurry and poultry manure throughout the season. Our results are consistent with the findings of Yohannes *et al.* (2024, Krismawati & Sugiono (2019) & Chiroma *et al.* (2006), who reported that high rates of organic and inorganic fertilizers produced superior growth and high LAI. Our results are also supported by Khan *et al.* (2009), who reported that application and incorporation of organic residues by tillage operations increased LAI due to increased crop growth resulting from increased uptake of nutrients and water from the soil.

Crop Growth Rate and Net Assimilation Rate

Tillage systems and N treatments significantly ($p \leq 0.05$) affected CGR and net assimilation rate (NAR) (Table 2), with maximum values observed in the deep tillage and minimum values in the minimum tillage system, and maximum values observed in treatment N8 (50% N from chemical fertilizer + 25% N from poultry manure + 25% N from bioslurry) and minimum values in N1 (control). The response of CGR and NAR to the different N treatments was as follows;

Mean CGR (N8> N2=N5 = N6 > N9 > N3 > N7 > N10 >N4 > N1)

Mean NAR (N8 >N2> N5 = N6 > N9 > N3 = N7> N10 > N4>N1)

The CGR is the product of LAI and NAR (Valero *et al.*, 2005), increased CGR resulting from increased LAI, NAR or a combination of both, and ultimately leading to increased crop yield. In general, CGR is more closely related to LAI than to NAR.

The interaction between tillage systems and different N treatments was also significant at $p \leq 0.05$ (Figure 3a), with the largest increase observed for deep tillage with treatment N8 of 86% for CGR and 38% for NAR compared to minimum tillage with the control (N1). Increased CGR and NAR were observed with integrated use of bioslurry, poultry manure and chemical fertilizer. This might be due to the low C:N ratio of bioslurry and poultry manure, so contributing timely mineralization of nutrients to be available to the crop (Amanullah *et al.* 2006; Khan, 2008). Our results are supported by the findings of Yohannes *et al.* (2024), who reported that the combined use of N and liquid bio-slurry enhanced the growth and yield of maize crop.

Soil Bulk Density and Total Porosity

The tillage system and N treatment significantly impacted the conditions provided by the soil for crop growth. After the harvest of the maize crop in both years, the maximum ρb was observed with minimum tillage, and minimum ρb in the deep tillage plots. By contrast, the maximum ft was observed with deep tillage while minimum values were observed in the minimum tillage plots (Table 3).

The N treatments also significantly ($p \leq 0.05$) affected soil properties (Table 3). After harvest of the maize crop in 2013, the maximum mean *ft* and minimum *ρb* were observed in the treatment N4 (100% N from bioslurry).

The interaction between tillage systems and N treatments was also significant at $p \leq 0.05$ (Figure 3a &b). The maximum *ρb* was observed in minimum tillage with treatment N1 (control), while the minimum value was observed in deep tillage with treatment N4 (8.4 t ha^{-1}bioslurry). The maximum *ft* was recorded in the deep tillage plot with treatment N7 (3.8 t ha^{-1} poultry manure and 4.2 t ha^{-1} bioslurry). This is in agreement with the findings of Iqbal *et al.* (2005) who observed decreased *ρb* in deep tillage system as compared to minimum and conventional tillage systems. The lowest *ρb* was also observed in the bioslurry and manure treated plots due to lower penetration resistance and increase in soil porosity, soil aggregation and water holding capacity due to increase in soil organic matter contents that ultimately lead to feasible crop environment for higher yield. Our results are consistent with the observations of Shirani *et al.* (2002), who found lower *ρb* and higher *ft* in farmyard manure treated plots than in plots fertilized with chemical fertilizers alone.

Total Soil Nitrogen Contents

The tillage systems and N treatments significantly ($p \leq 0.05$) affected total N contents of the soil (Table 3). The maximum total soil N was observed with deep tillage while minimum values were observed in the minimum tillage plots; maximum total soil N was observed in the treatment N8 (67.5 kg ha^{-1} N as chemical fertilizer, 1.9 t ha^{-1} poultry manure and 2.1 t ha^{-1} bioslurry) while minimum values were observed in control plots.

The integrated use of chemical fertilizer, poultry manure and bioslurry increased the soil N available for plant growth (Figure 3b) and in turn produced maximum grain yield in the deep tillage system with treatment N8 (67.5 kg ha^{-1} N in chemical fertilizer, 1.9 t ha^{-1} poultry manure and 2.1 t ha^{-1} bioslurry) was applied, suggesting it is the soil N that is limiting crop growth in these plots (Shahzad *et al.*, 2015). These results are in agreement with Muqaddas *et al.* (2005) who observed maximum N concentration in plots where deep tillage with farmyard manure was applied and reported that deep tillage mixed the soils and increased the rate of soil organic matter decomposition by exposing decomposable organic matter to the decomposers and hence, increasing the nutrient availability to crops. Our results are also supported by Mdlambuzi *et al*. (2021) who reported that Biogas slurry raised total N over time.

Soil Available P and K Contents

The maximum available soil P and K were observed in the deep tillage plots with treatment N4 (8.4 t ha^{-1} bioslurry). The available soil P and K were also increased by application of organic residues in the deep tillage system (Table 3). Similar results were observed by Nasir *et al.* (2012) who observed the significant increase of N, P and K in the bioslurry treated plot. Our results are also supported by Mdlambuzi *et al*. (2021) who reported that Biogas surry raised available P, over time.

Nitrogen Recovery Efficiency

The results given in Table 3 showed that crop N recovery efficiency in maize grain was increased with application of chemical fertilizer in conjunction with bioslurry and poultry manure. The maximum crop N recovery efficiency in maize grain (42 %) was recorded in treatment N8 (50% N from chemical fertilizer + 25% N from poultry manure + 25% N from bioslurry), followed by 40 % in treatment N2 (100% N from chemical fertilizer).

The results given in Table 3 show that fertilizer N recovery efficiency in maize grain increased with application of chemical fertilizer in conjunction with bioslurry and poultry manure. This might be due to achieving the correct balance of the supply of N due to application of bioslurry and poultry manure with chemical fertilizer. Yu *et al.* (2010) observed slow decomposition in bioslurry which in turn improved nutrient uptake and assimilation in plants throughout the growing season of crop. The crop N use efficiency rarely exceeds 50% in farmer managed fields. Roberts (2008) reported that crop N efficiency of 20-30% in the fields managed by farmers under rainfed conditions and 30-40% under irrigated conditions. Fan *et al*. (2004) observed the average fertilizer N recovery efficiency of 30-35% in cereals. Yadvinder-Singh *et al*. (2009) reported N recovery of 21-56% in maize crop, while Paul & Beauchamp (1993) observed N recovery efficiency of 49% and 18% in corn (grain+stover) of the total applied N in urea and dairy manure, respectively. Roberts (2008) also reported fertilizer N recovery efficiencies averaging 65% in maize, 57% in wheat and 46% in rice for researcher-managed experimental plots as compared to 20 to 40% N recovery efficiencies on working farms.

Our results are in accordance with Alizadeh *et al.* (2012) who observed total N recovery efficiency in maize of 60% in urea treated soils, 42% in poultry manure treated soils, 37% in cow manure + urea fertilizer treated soils, and lowest 15% in cow manure treated soils. Groot *et al.* (2007) reported N recovery efficiency of 20% in surface applied bioslurry treated soils. Our results are also in accordance with (Nicholson *et al.*, 1999) and Takahashi *et al.* (2004), who reported range from 10 to 49% and 14 to 35% of N recovery efficiency from poultry manure treated soils.

The highest value to cost ratio is observed in treatment N8 where organic and inorganic nitrogen sources applied at a ratio of 2:1:1 (50% N applied as chemical fertilizer, 25% as poultry manure and 25% as bioslurry). Detail of each treatment is presented in Shahzad *et al*. (2015).

CONCLUSION AND RECOMMENDATIONS

Conclusion

It is concluded on the basis of this study that maximum agro-physiological growth of the maize crop could be achieved in these soils by applying the recommended dose of N fertilizer through 50 % N from chemical fertilizer, 25 % N from poultry manure and 25 % N from bioslurry instead of sole application of chemical fertilizer. This combination of organic and inorganic nitrogen sources increases availability of nutrients required for plant growth by enhancing fertilizer nitrogen recovery efficiency and improves soil properties, hence achieving maximum yield in a more sustainable way.

Recommendations

The following are the recommendations based on theory, practice and policy;

Theory

Further research should focus on comprehensive comparative studies that systematically evaluate the effectiveness of different types of bioslurries in improving soil health parameters and crop productivity. Such research will advance the theoretical understanding of how bioslurry and poultry manure, when applied under various tillage systems, influence the agro-physiological indices of maize and soil properties. Additionally, long-term studies are essential to assess the sustained effects of bioslurries on soil health and productivity over multiple growing seasons. These investigations will provide valuable insights into promoting long-term soil health sustainability and the lasting benefits of integrating organic amendments in agricultural practices.

In addition to above, future research may also be conducted on the following;

- Investigate the use of poultry manure and other organic manures in biogas digesters to produce slurry, and assess their impact on soil fertility and crop productivity
- Investigate the optimal carbon-to-nitrogen ratio of dairy and poultry slurry for effective integration with chemical fertilizers to achieve maximum crop productivity
- Estimate the reduction in greenhouse gas emissions, soil carbon sequestration and evaluate the potential carbon credits associated with the use of various types of bioslurries.

Practice

Agricultural universities, research institutions, and provincial extension departments should actively disseminate best agricultural practices to farmers, ensuring they can access and benefit from modern farming technologies. Concurrently, banks and financial institutions should play a supportive role by providing agricultural financing and implementing capacity-building programs. These initiatives will help farmers adopt sustainable practices, resulting in increased financial returns and positive environmental impacts.

Policy

- Promote partnerships between provincial agriculture departments and financial institutions to support farmers, provide financial assistance for adoption of sustainable agriculture practices.
- Establish clear targets and offer incentives for farmers who adopt sustainable agri practices and demonstrate increased productivity.
- Provide incentives to farmers for the establishment of biogas digesters and the commercial production of organic fertilizers.
- Utilize biogas plants for generating electricity and producing gas for vehicle fuel.

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Table 1: Combinations of Organic and Inorganic Source of Fertilizer Treatments Used in The Experiment

Applied rate of N source			
	Poultry manure (t ha^{-1})	Bioslurry (t ha^{-1})	Chemical fertilizers (kg ha^{-1})
Control (N1)	0	0	0
100-0-0(N2)	0	0	135
0-100-0 (N3)	7.5	0	0
0-0-100 (N4)	0	8.4	0
50-50-0 (N5)	3.8	0	67.5
50-0-50 (N6)	0	4.2	67.5
0-50-50 (N7)	3.8	4.2	0
50-25-25 (N8)	1.9	2.1	67.5
25-50-25 (N9)	3.8	2.1	33.8
25-25-50 (N10)	1.9	4.2	33.8

Note: Note – P and K added as chemical fertilizer to ensure P and K did not limit crop growth, where

N1 = Without N application

N2 = 100% N from chemical fertilizer + 0% N from poultry manure + 0% N from bioslurry

N3 = 0% N from chemical fertilizer + 100% N from poultry manure + 0% N from bioslurry

N4 = 0% N from chemical fertilizer + 0% N from poultry manure + 100% N from bioslurry

N5 = 50% N from chemical fertilizer + 50% N from poultry manure + 0% N from bioslurry

N6 = 50% N from chemical fertilizer + 0% N from poultry manure + 50% N from bioslurry

N7 = 0% N from chemical fertilizer + 50% N from poultry manure + 50% N from bioslurry

N8 = 50% N from chemical fertilizer + 25% N from poultry manure + 25% N from bioslurry

N9 = 25% N from chemical fertilizer + 50% N from poultry manure + 25% N from bioslurry

N10 = 25% N from chemical fertilizer + 25% N from poultry manure + 50% N from bioslurry

Table 2: Effect Of Different Nitrogen Sources and Tillage Systems on Crop Growth Parameters at Maize Harvest (Average of 1st and 2nd Year)

Leaf Area Index									
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**Mean crop growth rate (g m^{-2} day^{-1})**	**Mean net assimilation rate (g m^{-2} day^{-1})**	***Grain yield (t ha^{-1})**	**N contents (g kg^{-1}) in maize grains**
Tillage Systems									
Minimum	0.67^{b}	2.26^{b}	3.57^{b}	4.69^{b}	3.60^{b}	17.63^{b}	7.39^{b}	3.12^{b}	16.26^{b}
Conventional	0.69^{ab}	2.27^{ab}	3.63^{ab}	4.80^{a}	3.66^{ab}	18.02^{ab}	7.60^{ab}	3.30^{ab}	16.38^{ab}
Deep	0.71^{a}	2.29^{a}	3.66^{a}	4.87^{a}	3.70^{a}	18.61a	7.66^{a}	3.49^{a}	16.49^{a}
HSD 5%	0.0357	0.0211	0.0755	0.0878	0.074	0.8869	0.2157	0.3204	0.164
Nitrogen Sources									
Control (N1)	0.48^{h}	1.50^{h}	2.41^{i}	3.12^{h}	2.29^{h}	12.41^{g}	6.13^{f}	2.25^{e}	10.07^{g}
0-100-0 (N3)	0.68^{e}	2.32^{e}	3.70^{ef}	4.91^{d-f}	3.76^{de}	18.01^{cd}	7.64^{c-e}	3.30^{bc}	16.37^{f}
0-0-100 (N4)	0.52^{gh}	2.21^{g}	3.49^{h}	4.65^{g}	3.49^{g}	14.19^{fg}	7.34^{e}	2.63^{de}	17.21^{cd}
50-50-0 (N5)	0.81^{bc}	2.45^{bc}	3.87^{bc}	5.09^{a-c}	3.94^{bc}	20.68^{ab}	7.86^{a-c}	3.72^{b}	16.90^{de}
50-0-50 (N6)	0.77^{cd}	2.41^{c}	3.82^{cd}	5.05^{b-d}	3.89^{c}	20.31^{ab}	7.78^{a-c}	3.36^{bc}	16.87^{e}
0-50-50 (N7)	0.59^{f}	2.27^{f}	3.65^{fg}	4.88^{ef}	3.64^{ef}	16.61^{de}	7.56^{c-e}	2.90^{cd}	16.45^{f}
50-25-25 (N8)	0.89^{a}	2.49^{a}	3.96^{a}	5.23^{a}	4.10^{a}	22.06^{a}	8.07^{a}	4.47^{a}	17.84^{a}
25-50-25 (N9)	0.74^{de}	2.37^{d}	3.77^{de}	5.01^{c-e}	3.82^{cd}	19.50^{bc}	7.71^{b-d}	3.29^{bc}	17.30^{bc}
25-25-50 (N10)	0.55^{fg}	2.23^{fg}	3.59^{g}	4.91^{f}	3.56^{fg}	15.47^{ef}	7.40^{de}	2.73^{de}	17.25^{bc}
HSD 5%	0.0635	0.0411	0.0871	0.1439	0.1227	2.17	0.3412	0.5407	0.312

Note: Means in a column not sharing the same letters differ significantly from each other at p ≤ 0.05 (n=4). *values from Shahzad *et al*.(2015), wheras DAS (Days after sowing), MT (minimum tillage), CT (conventional tillage), DT (deep tillage), N1 (Without N application), N2 (100%N from chemical fertilizer + 0% N from poultry manure + 0% N from bioslurry), N3 (0%N from chemical fertilizer + 100% N from poultry manure + 0% N from bioslurry), N4 (0%N from chemical fertilizer + 0% N from poultry manure + 100% N from bioslurry), N5 (50%N from chemical fertilizer + 50% N from poultry manure + 0% N from bioslurry), N6 (50%N from chemical fertilizer + 0% N from poultry manure + 50% N from bioslurry), N7 (0%N from chemical fertilizer + 50% N from poultry manure + 50% N from bioslurry), N8 (50%N from chemical fertilizer + 25% N from poultry manure + 25% N from bioslurry), N9 (25%N from chemical fertilizer + 50% N from poultry manure + 25% N from bioslurry), N10 (25%N from chemical fertilizer + 25% N from poultry manure + 50% N from bioslurry)

Table 3: Effect of Different Nitrogen Sources and Tillage Systems on N Uptake in Maize Grains and Soil Properties at 0-30 cm Depth at Maize Harvest (Average of 1st and 2nd Year)

	N uptake in Maize grains (kg ha^{-1})	**N recovery efficiency (%)**	**Soil bulk density (g cm^{-3})**	**Soil total porosity (m^3 m^{-3})**	**Soil total N (g kg^{-1})**	**Soil available P (mg kg^{-1})**	**Soil available K (mg kg^{-1})**
Tillage Systems							
Minimum	51.4^{b}	-	1.39^{a}	0.475^{b}	0.332^{b}	21.1^{c}	113.5^{b}
Conventional	54.9^{ab}	-	1.37^{ab}	0.484^{ab}	0.338^{ab}	22.1^{b}	121.3^{a}
Deep	58.6^{a}	-	1.35^{b}	0.490^{a}	0.3411^{a}	22.8^{a}	126.8^{a}
HSD 5%	6.48	-	0.0274	0.0103	0.0058	0.713	5.721
Nitrogen Sources							
Control (N1)	22.7^{e}	0	1.43^{a}	0.462^{e}	0.295^{g}	15.5^{f}	94.7^{f}
100-0-0(N2)	76.5^{a}	40	1.42^{ab}	0.465^{de}	0.318^{f}	16.2^{e}	95.3^{ef}
0-100-0 (N3)	54.0^{b-d}	23	1.34^{de}	0.493^{ab}	0.359^{a}	22.7^{cd}	121.1^{c}
0-0-100 (N4)	45.3^{d}	17	1.31^{e}	0.504^{a}	0.349^{b}	25.2^{a}	148.9^{a}
50-50-0 (N5)	62.9^{b}	30	1.39^{bc}	0.476^{cd}	0.0342^{cd}	22.4^{d}	107.3^{d}
50-0-50 (N6)	56.7^{bc}	25	1.37^{cd}	0.484^{bc}	0.332^{e}	23.7^{bc}	132.3^{b}
0-50-50 (N7)	47.7^{cd}	19	1.32^{e}	0.500^{a}	0.350^{b}	25.1^{a}	147.2^{a}
50-25-25 (N8)	79.7^{a}	42	1.40^{a-c}	0.472^{c-e}	0.338^{d}	21.9^{d}	104.8^{de}
25-50-25 (N9)	56.9^{bc}	25	1.37^{cd}	0.484^{bc}	0.348^{bc}	22.8^{cd}	111.8^{cd}
25-25-50 (N10)	47.1^{d}	18	1.34^{de}	0.493^{ab}	0.337^{de}	24.7^{ab}	141.3^{ab}
HSD 5%	9.472	-	0.0332	0.0125	0.0063	1.14	10.019

Note: Means in a column not sharing the same letters differ significantly from each other at p ≤ 0.05 (n=4). Wheras MT (minimum tillage), CT (conventional tillage), DT (deep tillage), N1

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(Without N application), N2 (100%N from chemical fertilizer + 0% N from poultry manure + 0% N from bioslurry), N3 (0%N from chemical fertilizer + 100% N from poultry manure + 0% N from bioslurry), N4 (0%N from chemical fertilizer + 0% N from poultry manure + 100% N from bioslurry), N5 (50%N from chemical fertilizer + 50% N from poultry manure + 0% N from bioslurry), N6 (50%N from chemical fertilizer + 0% N from poultry manure + 50% N from bioslurry), N7 (0%N from chemical fertilizer + 50% N from poultry manure + 50% N from bioslurry), N8 (50%N from chemical fertilizer + 25% N from poultry manure + 25% N from bioslurry), N9 (25%N from chemical fertilizer + 50% N from poultry manure + 25% N from bioslurry), N10 (25%N from chemical fertilizer + 25% N from poultry manure + 50% N from bioslurry

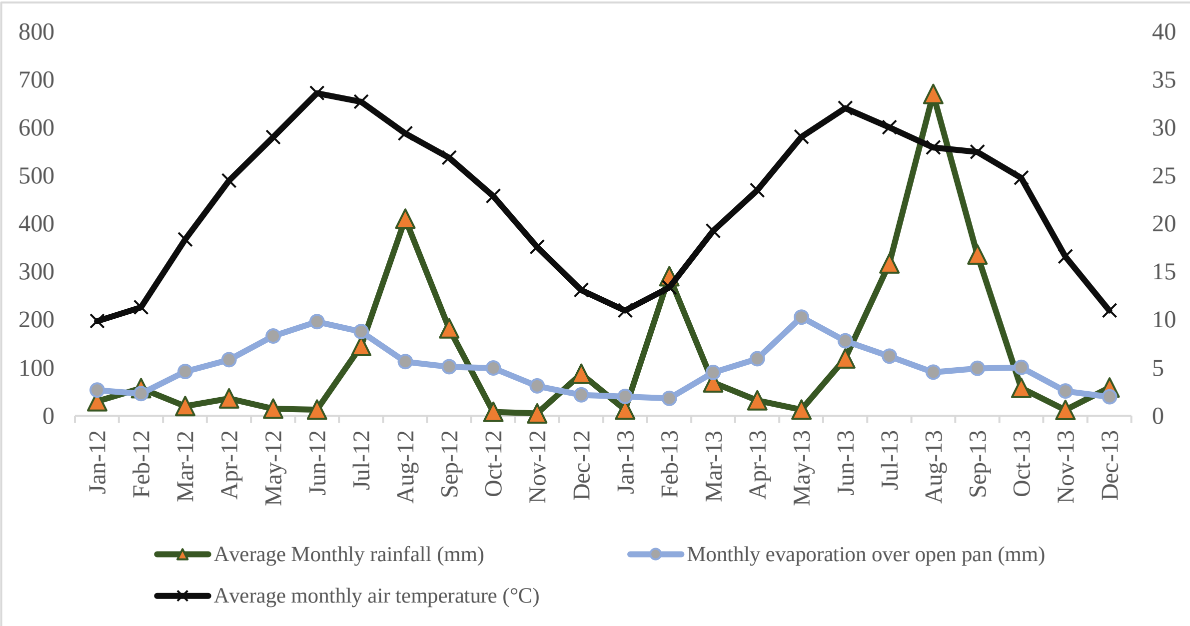
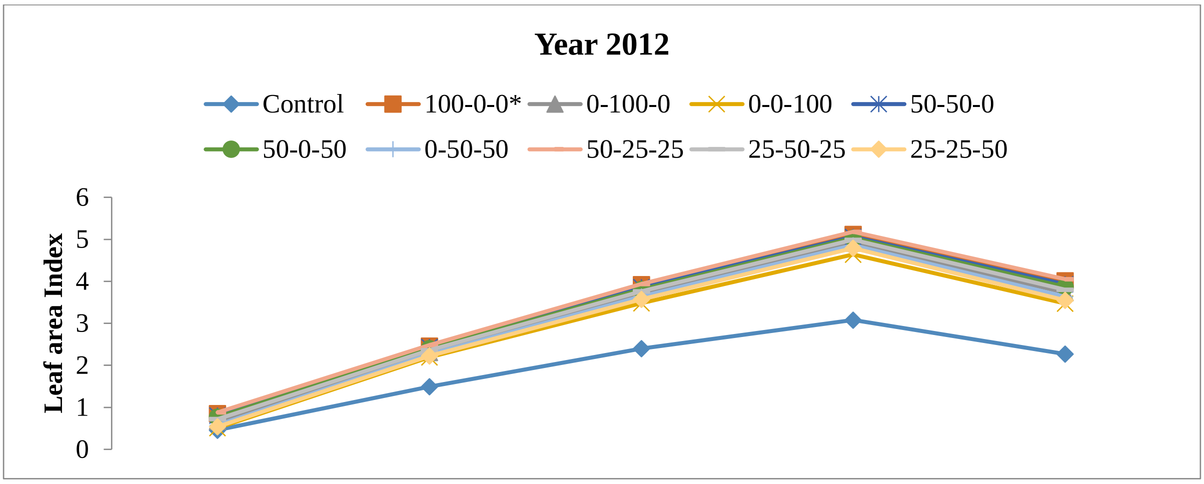


Figure 1: Meteorological Data of the Experimental Site (Research and Development Division, Pakistan Meteorological Department, Islamabad)



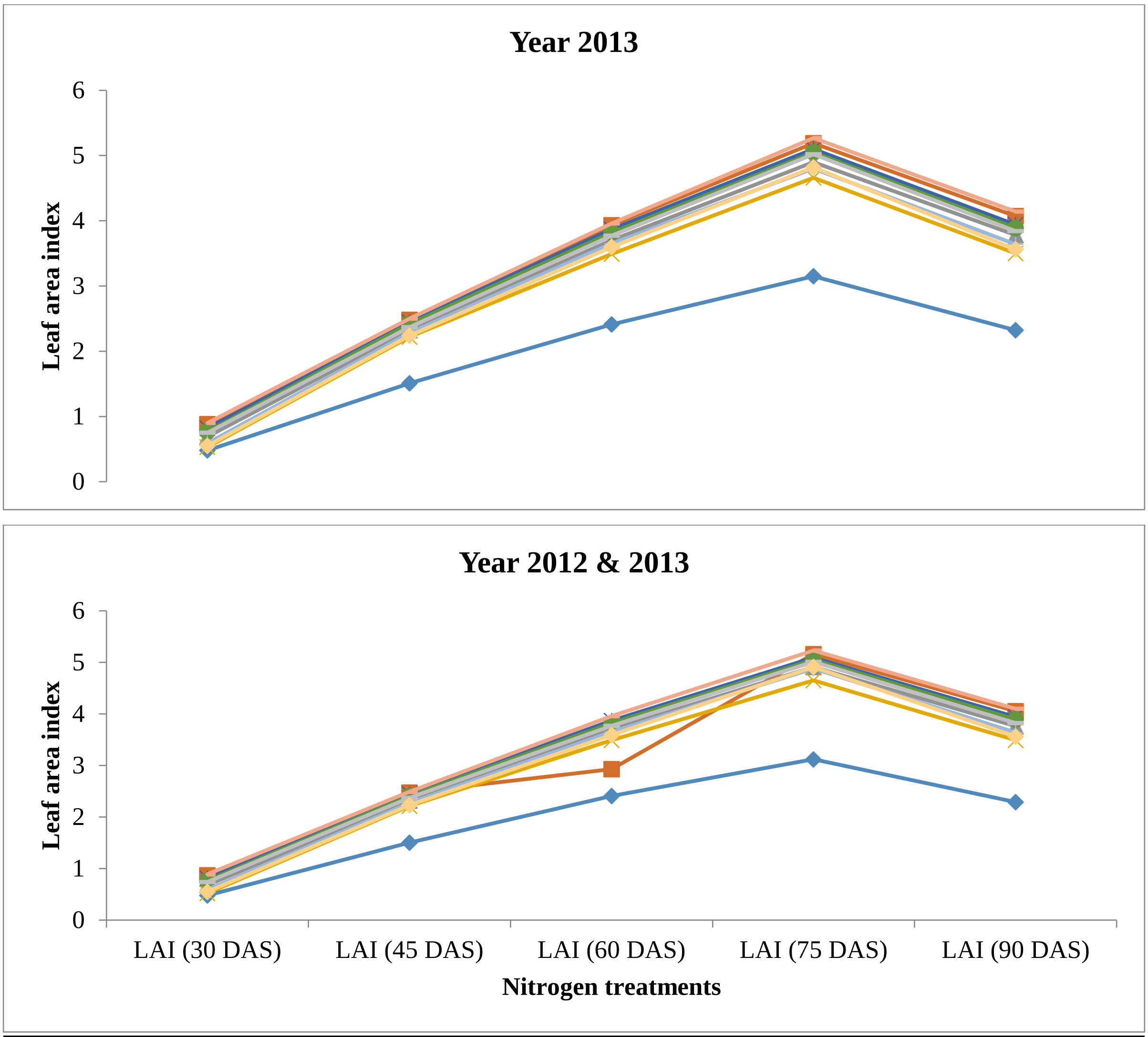
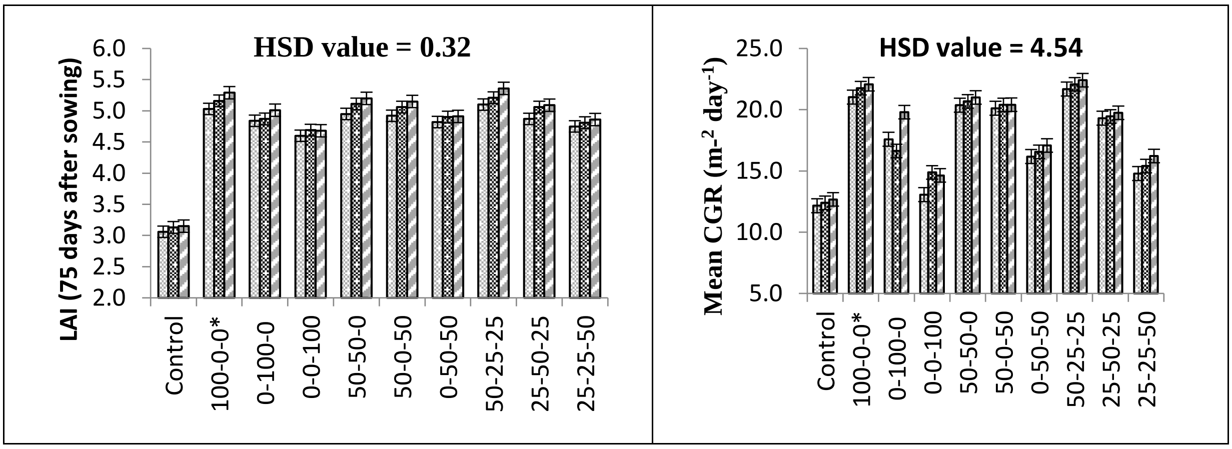


*Figure 2. Effect of Different Nitrogen Treatments on Leaf Area Index of Maize after 30, 45, 60, 75 and 90 DAS Under Field Conditions *% N from Chemical N-% N from Poultry Manure - % N from Bioslurr*



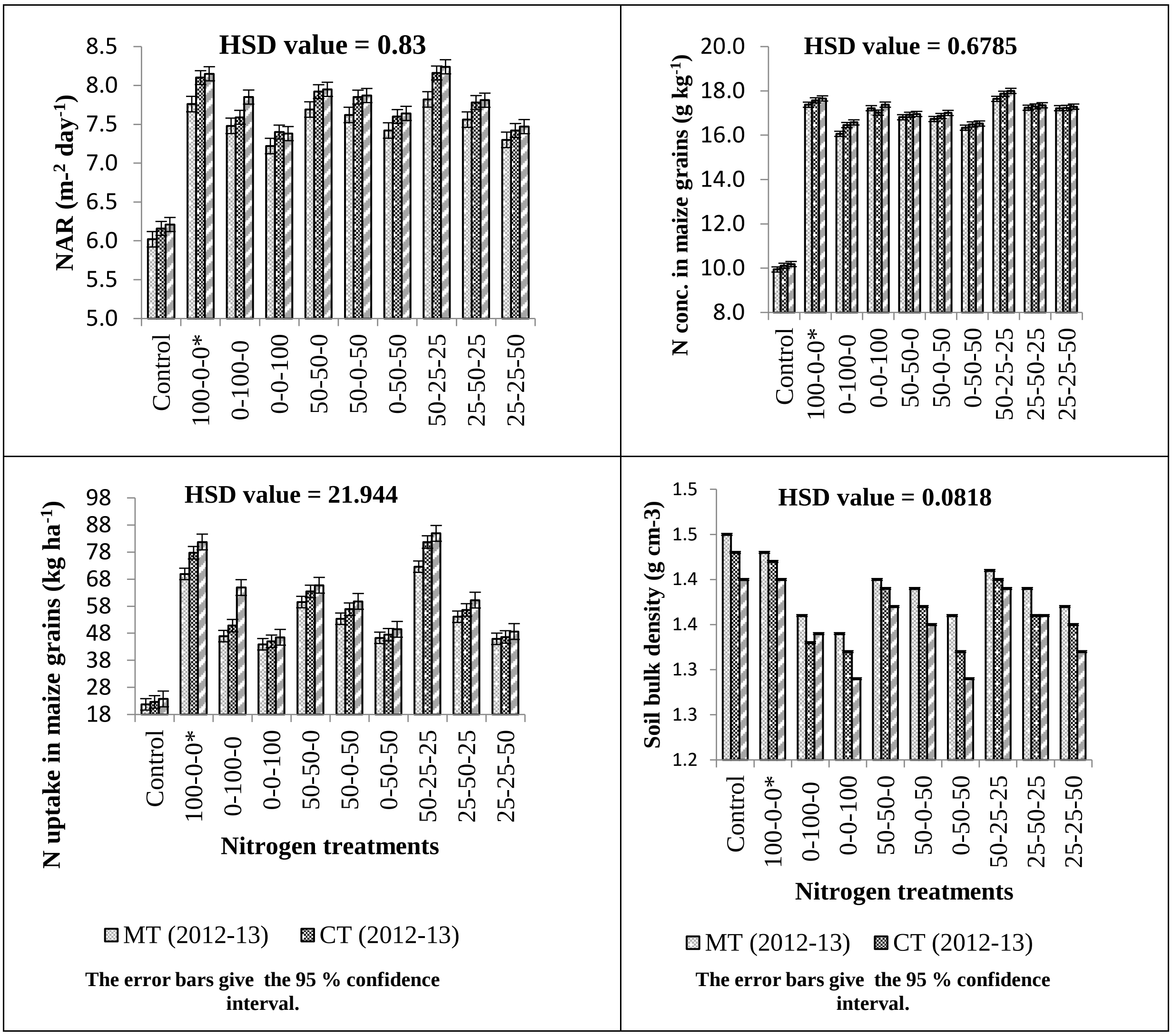


Figure 3 A. Interaction Between Tillage Systems and Nitrogen Treatments on Different Crop Growth Parameters and Soil Properties at Maize Harvest Note - MT = Minimum Till; CT = Conventional Till; DT = Deep Till. Year is Given in Brackets

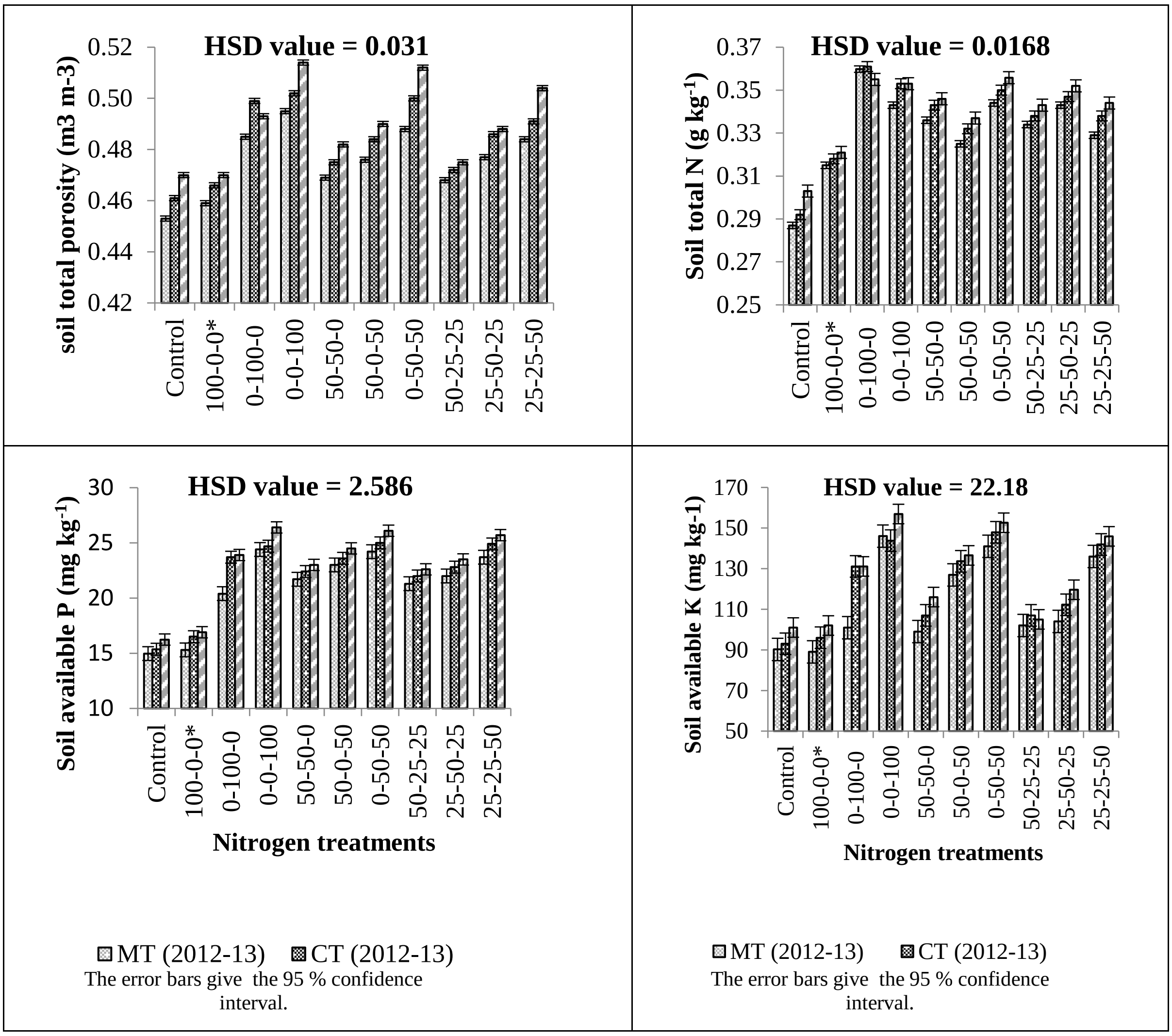


Figure 3 B. Interaction Between Tillage Systems and Nitrogen Treatments nn Different Soil Properties at Maize Harvest 2013 Note - MT = Minimum Till; CT = Conventional Till; DT = Deep Till. Year is Given nn Brackets