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# Soil Organic Carbon, Nitrate Contents, Physical properties and Maize Growth as Influenced by Dairy Manure and Nitrogen Rates

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## ABSTRACT

This study was conducted for two consecutive years to evaluate the effect of dairy manure (0, 25 & 50 Mg ha$^{-1}$) and nitrogen rate (200, 250 & 300 kg ha$^{-1}$) on soil physical health indices, soil organic carbon and nitrate contents in maize (*Zea mays* L.). The samples were taken at 0-10, 10-25 and 25-40 cm depth for determining the nitrate concentration leached below the root zone. The results showed that the plant height, grain yield and biological yield of maize increased by 28.3%, 15.5% and 20.6%, respectively at nitrogen rate 300 kg ha$^{-1}$ and 50 Mg ha$^{-1}$ dairy manure than the control treatment ($DM_0 \times N_{200}$). Dairy manure increased infiltration rate and soil hydraulic conductivity. But it reduced the soil strength that might be due to better soil aeration and upgrading of soil structure. Dairy manure and nitrogen application significantly increased soil organic carbon contents over control at both 0-5 cm and 5-10 cm depth. Dairy manure and nitrogen caused greater leaching of nitrate than the control at all depths. © 2012 Friends Science Publishers

**Key Words:** Dairy manure; $NO_3$ content; SOC; Soil strength; Soil NPK; Infiltration; Maize yield

## INTRODUCTION

Nitrogen is one of the most common nutrients required for plant growth and productivity as it forms an integral part of proteins, nucleic acids and other essential biomolecules (Bockman, 1997). As energy costs and environmental concerns continue to rise, it is increasingly important to use dairy manure to reduce fertilizer costs, enhance manure N recycling and minimize negative environmental impacts. Dairy manure can serve as a valuable source of N for crop production because it contains urea, $NH_4$-N and organic N (Wilkerson *et al.,* 1997). Organic matter affects crop growth and yield, either directly by supplying nutrients, or indirectly modifying soil physical properties that can improve the root environment and stimulate plant growth (Kononova, 1961). Incorporation of organic matter through farmyard manure has been shown to improve soil structure, water retention capacity, infiltration rate, hydraulic conductivity and decrease bulk density (Edmeades, 2003). Maintenance of optimum soil physical conditions is an important component of soil fertility management. Breakdown of soil aggregates, and poor soil structural condition, often restricts crop root growth and consequently limit their ability to explore the soil profile for water and nutrients (Haynes & Naidu, 1998). Neither inorganic nor organic amendments alone can maintain organic matter status of soil and sustain the productivity in the semi-arid tropics (Prasad, 1996). So, the combined use of organic and inorganic fertilizers in crop production has been widely recognized as a way of increasing farm yield and sustaining or improving productivity of soil (Jadoon *et al.,* 2003). With increasing fertilizer use, a situation similar to developed countries may also arise in developing countries. Thus, developing countries possess a distinct advantage of being late-comers in the development process and are in a position to avoid some of the costly and needless mistakes made by developed countries in the past. Leaching is the translocation of soluble salts that occurs via a descending flux of water in the soil profile (Kiehl, 1987). Nitrogen fertilizer applied in excess of crop needs can cause leaching of $NO_3$-N in the soil profile (Malhi *et al.,* 2002). $NO_3$-N leaching is one main pass way for nitrogen losses, especially in calcareous soil with high pH in which ammonium is easily nitrified to nitrate (Yanan, 1992). Recent studies have shown that agriculture is directly responsible for more than 50% of the nitrogen that is leached into running waters, because of mineral fertilizer application (Hansen *et al.,* 2000). Application of fertilizer amounts greater than that of the recommended, results in low percent N recoveries in crops and greater $NO_3$-N accumulation in the soil profile (Benbi *et al.,* 1991). Combined manure and fertilizer N additions are a significant source of excessive soil $NO_3$-N

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(Jokela, 1992). Elevated nitrate concentrations in drinking water can cause methemoglobinemia in infants and stomach cancer in adults (Lee *et al.,* 1991). The US Environmental Protection Agency has established a maximum contaminant level of 10 mg $L^{-1}$ $NO_3$-N (USEPA, 1995). In some countries ground water contains more than 50 mg $L^{-1}$ $NO_3$-N. Nitrate losses can be reduced with implementation of best nitrogen management practices (Shaffer & Delgado, 2002). The balanced application of chemical fertilizers and manure is important to protectsoil, underground water from $NO_3$-N pollutionand to sustain high crop production (Yang *et al.,* 2004). For realizing higher yields and quality produce, soil health is a critical factor. Therefore, chemical fertilizers must be integrated with organic manures such as FYM, compost, crop residues and green manures, which are renewable and eco-friendly to achieve sustainable productivity with minimum deleterious effects of chemical fertilizers on soil health and environment (Saravanapandian, 1998). The most important of organic materials applications on different soils are their contribution in improving the soil physical properties such as: densities, porosities, structure, aggregation, water retention and transmission due to its direct effect on retention water (hydrophilic nature), and indirect effect because of the modification of the soil structure (Haynes & Swift, 1990). Cheng *et al.* (1998) reported that application of organic materials to soils reduced the loss of soil moisture, enhanced the water retention, increased the biochemical intensity and enhanced the drought resistance of plants. However, application of organic amendments influences the water movement into (infiltration) and out (evaporation & drainage) as well as within (conductivity) a soil, and thus effects the quantity of water retaining in the soil (El-Sedfy, 1998; Qi *et al.,* 2004). Bationo and Mokwunye (1992) also noted that the addition of organic materials either in the form of manures or crop residues has beneficial effects on the soils chemical and physical properties. Application of organics manures, which improves the soil physical, chemical and biological properties and has direct impact on moisture retention, root growth and nutrient conservation. This study was undertaken to find out the optimum dose and best combination of organic manures and inorganic fertilizers to improve the soil health and maize productivity, and minimize the $NO_3^-$ leaching.

## MATERIALS AND METHODS

Field studies were conducted on the Research Farm of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan (31˚26'N; 73˚06'E, & altitude of 184.4 m), to evaluate the effects of dairy manure and nitrogen levels on soil organic carbon, $NO_3$ movement, selected soil physical properties and the yield of maize (*Zea mays* L.). The existing farming system in this region is predominantly based on rotations, which includes irrigated maize, wheat, cotton, sugarcane, rice, fodder, and pulses.

The soil of the study area is a well-drained Hafizabad sandy clay loam mixed, semi-active, isohyperthermic Typic Calciargids, USDA and contains 530, 210, 260 g $kg^{-1}$ sand, silt and clay, respectively. This soil is generally has low organic matter, N, and P contents to support productive agriculture. Soil physical and chemical characteristics of the study area and the nutrient composition of the dairy manure applied are presented in Table I. The climate of the region is subtropical to semi-arid with an annual average rainfall of 29.2 mm out of which >70% occurs as heavy shower during June to September. Mean monthly minimum temperature is 13˚C in January and maximum temperature is 39˚C in July. Average temperature, total rainfall and average relative humidity of research area are presented in Table II.

Three dairy manure rates (0, 25, 50 Mg $ha^{-1}$) and three nitrogen levels (200, 250, 300 kg $ha^{-1}$) were applied depending on treatments. Dairy manure levels were kept on the main plots, while nitrogen levels were applied to the sub-plots. Recommended rates of P and K were applied as triple super phosphate (TSP) and sulphate of potash (SOP) at planting. Nitrogen was applied in three splits. One third of each nitrogen level was applied at planting, another third at first irrigation and the last third at tassling stage.Hoeing along with weedicides were used to control weeds. The seeding rate for maize was 25 kg $ha^{-1}$ and planting was done using a dibbler with an inter-row spacing of 75, while plant to plant distance was 22.5 cm. Maize variety DK-919was planted during both of the years. The first crop was planted in August, 2008 and the second crop in August, 2009. The experimental layout was a split plot design with the dairy manure application rates as the main plots and the inorganic nitrogen levels as the sub-plots. Each treatment was replicated thrice. The dimension of the sub-plots was 10×10 m. Soil samples were collected randomly from 0.0-0.05, 0.05-0.1, 0.1-0.25 and 0.25-0.4 m depth before planting and at harvest at six different locations on each plot. Samples from each plot were mixed to form a composite. These samples were analyzed for soil organic carbon (SOC) and $NO_3$-N content during both years. Soil samples were air dried and ground to pass a 2 mm sieve before analyzing for total organic carbon and other soil properties. Total organic carbon was determined by potassium dichromate ($K_2Cr_2O_7$) method (Ryan *et al*., 2001); $NO_3$-N was measured using a spectrophotometer method (Sims & Jackson, 1971); pH was determined in water (McLean, 1982); electrical conductivity of soil extract was measured by the method developed by Rhoades (1982); cation exchange capacity was measured according to Page *et al*. (1982); and soil texture was determined using Bouyoucos hydrometer method (Moodie *et al*., 2001); soil moisture by gravimetric method (Jalota *et al*., 1998), Total N by Bremner and Mulvancy (1982); Available P by spectrophotometer (Olsen & Sommers, 1982), Available K by flame photometer (Richards, 1954). Total N was determined by Sulfuric-salicylic acid digestion method (Buresh *et al*., 1982), Total P by spectrophotomer (Chapman & Pratt, 1961) and Total K by flame photometer

(Chapman & Pratt, 1961). Field measurements that were determined included the soil infiltration rate using Double ring infiltrometer; the soil hydraulic conductivity using a Guelph permeameter; and the soil strength using a Cone penetrometer.

**Statistical analysis:** A split-plot analysis of variance was performed on data collected from this trial and means were separated with Duncan Multiple Range test after significant F-ratio was detected (Steel & Torrie, 1980).

**Economic and marginal analysis:** The data collected from the studies were used for economic and marginal analysis. Expenditures on different nutrient sources were as follows: N, 0.262 US $ kg$^{-1}$; $P_2O_5$, 0.59 US $ kg$^{-1}$; $K_2O$, 0.48 US $ kg$^{-1}$. Sowing expenditures were as follows: ploughing and seed bed preparation, 15.26 US $; seed, 115.87 US $; weedicide, 48.18 US $; irrigation, 28.04 US $; 28.04 US $; dairy manure 5.75 US $ Mg$^{-1}$. Price of the maize produce is as follows: maize grain, 179.97 US $ Mg$^{-1}$; Mazie straw=28.79 US $ kanal. The N was applied @ 200, 250, 300 kg N ha$^{-1}$. P and K were applied @ 150:105 kg $P_2O_5$:$K_2O$ ha$^{-1}$ in all treatments, respectively.

Cost that vary = It is the sum of all the costs (both costs & opportunity cost) that vary for a particular treatment,

Marginal costs = the increase in variable cost which occurs in changing from one production alternative to another,

Marginal net benefits = the increase in net benefit, which can be obtained by changing from one production alternative to another,

$$\text{Marginal rate of return (MRR)} = \frac{\text{Marginal net benefits}}{\text{Marginal costs}} \times 100 = (\%)$$

## RESULTS

Result from two years study revealed that both dairy manure and nitrogen rates affected significantly SOC content at 0-5 cm and 5-10 cm depth. Inyear-1, a maximum increase of 18.9% was observed in SOC content, over control ($DM_0$) in treatments, where DM was applied @ 50Mg ha$^{-1}$ (Table III) at 0-5 cm depth. In year-2, dairy manure application @ 50 Mg ha$^{-1}$ gave best results (22%, more SOC content than control) at 0-5 cm depth. Similarly at 5-10 cm depth, dairy manure application @ 50 Mg ha$^{-1}$ had 21 and 25% more SOC content as compared to control ($DM_0$) during 1 and 2 year, respectively. The effect of nitrogen rates was also significant at both soil depths (Table III). Mean maximum value was observed in $N_{300}$ (0.71%), followed by $N_{250}$ (0.67%) and minimum in $N_{200}$ (0.65%) at 0-5 cm depth during first year. Similarly, mean maximum value was observed in $N_{300}$ (0.74%), followed by $N_{250}$ (0.69%) and minimum in $N_{200}$ (0.68%) at 0-5 cm depth during second year. Similar results were noted at 5-10 cm depth in case of nitrogen application during both the years. The interactive effect of dairy manure and nitrogen rateswas also significant

**Table I: Physical and Chemical Properties of Soil and Dairy Manure**

| Soil properties (0-0.04 m) | Values |
|---|---|
| Sand (%) | 53 |
| Silt (%) | 21 |
| Clay (%) | 26 |
| Textural Class | Sandy Clay Loam |
| pH | 7.5 |
| Electrical Conductivity (d Sm$^{-1}$) | 1.35 |
| Bulk Density (Mg m$^{-3}$) | 1.31 |
| Hydraulic conductivity (mm h$^{-1}$) | 35 |
| Organic carbon contents (%) | 0.35 |
| Nitrate Contents (mg kg$^{-1}$) | 12.5 mg kg$^{-1}$ |
| Dairy manure properties | |
| Total N (%) | 1.56 |
| Total P (%) | 0.46 |
| Total K (%) | 1.49 |
| Organic Carbon Contents (%) | 53 |
| Moisture Contents (%) | 74.7 |

(Table III), the mean maximum value of organic carbon content was observed in $DM_{50}$ (0.73%) in combination with $N_{300}$ and minimum (0.53%) in $DM_0$ x $N_{200}$ combination during first year at 0-5 cm depth. Similarly, maximum value of organic carbon content was observed with treatment combination $DM_{50}$x $N_{300}$ (0.78%) and minimum in $DM_0$ X $N_{200}$ treatment (0.56%) at 0-5 cm depth during second year. Similar results were noted at 5-10 cm depth.

The effect of dairy manure and nitrogen application on $NO_3$ content was statistically significant at 0-10, 10-25 and 25-40 cm depths. In year-1, maximum $NO_3$ content was observed in treatment, where DM @ 50 Mg ha$^{-1}$ was applied and it showed 7.6% increase over control, (Table IV) at 0-10 cm depth. In year -2, dairy manure response was also significant. Maximum $NO_3$ content (13.3% more than control) was observed with treatment receiving 50 Mg ha$^{-1}$ at 0-10 cm depth. Similarly at 10-25 cm depth, dairy manure application @ 50 Mg ha$^{-1}$ had 9.4 and 14.8% more $NO_3$ content as compared to control ($DM_0$) during 1 and 2 year respectively. At 25-40 cm depth, maximum $NO_3$ content was observed in treatment where DM @ 50 Mg ha$^{-1}$ was applied and it showed 6.7% increase over control during first year. Similarly during second year $DM_{50}$ gave 14.2% increase in $NO_3$ content over control. . The effect of nitrogen rates was also significant on $NO_3$ contentat all soil depths (Table IV). Mean maximum value was observed in $N_{300}$ (65.2 mg kg$^{-1}$), followed by $N_{250}$ (54 mg kg$^{-1}$) and minimum in $N_{200}$ (50.8 mg kg$^{-1}$) at 0-10 cm depth during first year. Similarly, mean maximum value was observed in $N_{300}$ (68.1 mg kg$^{-1}$), followed by $N_{250}$ (57.4 mg kg$^{-1}$) and minimum in $N_{200}$ (55.3 mg kg$^{-1}$) at 0-10 cm depth during second year. Similar results were found at 10-25 and 25-40 cm depths in case of nitrogen rate during both the years. The interactive effect of dairy manure and nitrogen rates was also significant (Table IV), the mean maximum value of $NO_3$ content content was observed in $DM_{50}$ (55.4 mg kg$^{-1}$) in combination with $N_{300}$ and minimum (41.1 mg kg$^{-1}$) in $DM_0$ x $N_{200}$ combination during first year at 0-10 cm depth. Similarly, maximum $NO_3$ contents were observed with

**Table II: Average temperature, total rainfall and average relative humidity of research area at meteorological cell of UAF**

| Year | Temperature °C | | | Total Rainfall (mm) | RH (%) |
|---|---|---|---|---|---|
| **2008** | **Maximum** | **Minimum** | **Mean** | | |
| August | 35.1 | 26.8 | 30.9 | 204.5 | 65.0 |
| September | 36.0 | 24.0 | 30.0 | 28.8 | 64.0 |
| October | 33.1 | 20.2 | 26.7 | 0 | 57.6 |
| November | 27.3 | 12.2 | 19.7 | 0 | 58.9 |
| **2009** | | | | | |
| August | 36.6 | 27.6 | 32.1 | 116 | 65.8 |
| September | 36.3 | 23.2 | 29.7 | 20.6 | 61.0 |
| October | 32.7 | 17.1 | 24.9 | 17.5 | 57.9 |
| November | 25.7 | 10.8 | 18.2 | 0.70 | 64.7 |

Data were collected from meteorological cell of UAF

**Table III: Effect of dairy manure and nitrogen rates on soil organic carbon (%) in maize**

| Treatments | | Soil organic carbon (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-5 cm | | | 5-10 cm | | | 10-20 cm | | |
| **Years** | - | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** |
| **Dairy manure (DM)** | $DM_0$ | 0.58 c | 0.59 c | 0.58 | 0.38 c | 0.40 c | 0.39 | 0.35 | 0.37 | 0.36 |
| | $DM_{25}$ | 0.65 b | 0.68 b | 0.66 | 0.43 b | 0.47 b | 0.45 | 0.36 | 0.35 | 0.35 |
| | $DM_{50}$ | 0.69 a | 0.72 a | 0.70 | 0.46 a | 0.50 a | 0.48 | 0.38 | 0.36 | 0.37 |
| **Nitrogen (N)** | $N_{200}$ | 0.65 c | 0.68 c | 0.66 | 0.42 b | 0.45 b | 0.43 | 0.38 | 0.40 | 0.39 |
| | $N_{250}$ | 0.67 b | 0.69 b | 0.68 | 0.43 b | 0.46 b | 0.44 | 0.39 | 0.40 | 0.39 |
| | $N_{300}$ | 0.71 a | 0.74 a | 0.72 | 0.46 a | 0.47 a | 0.46 | 0.40 | 0.41 | 0.40 |
| **DM * N** | $DM_0$ x $N_{200}$ | 0.53 e | 0.56 e | 0.54 | 0.53e | 0.56 e | 0.54 | 0.37 | 0.38 | 0.37 |
| | $DM_0$ x $N_{250}$ | 0.59 d | 0.60 d | 0.59 | 0.59 d | 0.60 d | 0.59 | 0.38 | 0.40 | 0.39 |
| | $DM_0$ x $N_{300}$ | 0.61 cd | 0.62 cd | 0.61 | 0.61 cd | 0.63 c | 0.62 | 0.39 | 0.40 | 0.39 |
| | $DM_{25}$x $N_{200}$ | 0.62 d | 0.64 c | 0.63 | 0.62 c | 0.64 c | 0.63 | 0.37 | 0.38 | 0.37 |
| | $DM_{25}$x $N_{250}$ | 0.66 b | 0.69 b | 0.67 | 0.66 b | 0.68 b | 0.67 | 0.38 | 0.40 | 0.39 |
| | $DM_{25}$x $N_{300}$ | 0.66 b | 0.67 b | 0.66 | 0.66 b | 0.69 b | 0.67 | 0.40 | 0.42 | 0.41 |
| | $DM_{50}$x $N_{200}$ | 0.66 b | 0.68 b | 0.67 | 0.66 b | 0.70 b | 0.68 | 0.36 | 0.37 | 0.36 |
| | $DM_{50}$ x $N_{250}$ | 0.69 b | 0.69 b | 0.69 | 0.69 b | 0.72 b | 0.70 | 0.39 | 0.40 | 0.39 |
| | $DM_{50}$x $N_{300}$ | 0.73 a | 0.78 a | 0.75 | 0.73 a | 0.77 a | 0.75 | 0.40 | 0.43 | 0.41 |

**Table IV: Effect of dairy manure and nitrogen rates on soil $NO_3$ (mg kg$^{-1}$) in maize**

| Treatments | | Soil $NO_3$ (mg kg$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-10 cm | | | 10-25 cm | | | 25-40 cm | | |
| **Years** | - | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** |
| **Dairy manure (DM)** | $DM_0$ | 48.6 b | 52.4 c | 50.5 | 47.7 b | 51.2 b | 51.2 | 47.6 b | 51.4 c | 49.5 |
| | $DM_{25}$ | 49.5 b | 56.7 b | 53.1 | 48.7 b | 53.6 b | 53.6 | 47.7 b | 55.4 b | 51.5 |
| | $DM_{50}$ | 52.3 a | 59.7 a | 56.0 | 52.2 a | 58.8 a | 58.8 | 50.8 a | 58.7 a | 54.7 |
| **Nitrogen (N)** | $N_{200}$ | 50.8 c | 55.3 b | 53.0 | 49.0 b | 54.5 c | 54.5 | 48.8 c | 53.5 c | 51.1 |
| | $N_{250}$ | 54.0 b | 57.4 b | 55.7 | 54.5 a | 59.4 b | 59.4 | 53.1 b | 58.5 b | 55.8 |
| | $N_{300}$ | 65.2 a | 68.1 a | 66.6 | 71.8 c | 74.2 a | 74.2 | 78.4 a | 84.5 a | 81.4 |
| **DM * N** | $DM_0$ x $N_{200}$ | 41.1 e | 43.2 d | 42.1 | 40.3 e | 41.2 d | 40.7 | 41.2 d | 44.5 d | 42.8 |
| | $DM_0$ x $N_{250}$ | 51.0 bc | 54.5 b | 52.7 | 48.4 cd | 51.2 c | 49.8 | 48.3 c | 50.2 c | 49.2 |
| | $DM_0$ x $N_{300}$ | 53.7 ab | 55.4 ab | 54.5 | 54.4 b | 58.4 ab | 56.4 | 53.3 ab | 56.6 ab | 54.9 |
| | $DM_{25}$x $N_{200}$ | 46.2 d | 49.9 c | 48.0 | 48.1 d | 49.8 c | 48.9 | 43.0 d | 45.5 d | 44.2 |
| | $DM_{25}$x $N_{250}$ | 49.4 cd | 50.8 bc | 50.1 | 47.1 d | 49.8 c | 48.4 | 48.8 bc | 49.5 c | 49.1 |
| | $DM_{25}$x $N_{300}$ | 52.9 abc | 53.3 b | 53.1 | 50.9 d | 53.3 bc | 52.1 | 51.2 abc | 53.4 b | 52.3 |
| | $DM_{50}$x $N_{200}$ | 49.7 c | 51.4 bc | 50.5 | 46.9 d | 47.5 c | 47.2 | 48.2 c | 50.1 c | 49.1 |
| | $DM_{50}$ x $N_{250}$ | 51.9 bc | 53.3 b | 52.6 | 51.4 c | 54.5 bc | 52.9 | 49.3 bc | 53.4 b | 51.3 |
| | $DM_{50}$x $N_{300}$ | 55.4 a | 59.8 a | 57.6 | 58.3 a | 62.2 a | 60.2 | 54.9 a | 59.7 a | 57.3 |

Means for treatments within columns for each experiment followed by the same letter are not significantly different at α=0.05

$DM_0$ = Dairy manure @ 0 Mg ha$^{-1}$, $DM_{25}$ = Dairy manure @ 25 Mg ha$^{-1}$, $DM_{50}$ = Dairy manure @ 50 Mg ha$^{-1}$

$N_{200}$ = Nitrogen @ 200 kg ha$^{-1}$, $N_{250}$ = Nitrogen @ 250 kg ha$^{-1}$, $N_{300}$ = Nitrogen @ 300 kg ha$^{-1}$

treatment combination $DM_{50}$x $N_{300}$ (59.8 mg kg$^{-1}$) and minimum in $DM_0$x $N_{200}$ treatment (43.2 mg kg$^{-1}$) at 0-10 cm depth during second year. Similar trend was noted at 10-25 and 25-40 cm depths.

The data regarding the effect of dairy manure and nitrogen rates on soil physical indicators indicated that both dairy manure and nitrogen rates had significant effect on soil physical indicators. The effect of dairy manure application on infiltration rate was statistically significant. In year-1, maximum infiltration rate was observed in treatment, where 50 Mg DM ha$^{-1}$ was applied and it showed 2.65% increase over control (Table V).

**Table V: Effect of dairy manure and nitrogen rates on soil physical indicators in maize**

| Treatments | | Soil physical indicators | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Infiltration rate (mm h$^{-1}$) | | | Hydraulic conductivity (mm h$^{-1}$) | | | Soil strength (kPa) | | |
| **Years** | - | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** |
| **Dairy manure (DM)** | DM$_{0}$ | 11.3 b | 12.5 b | 11.9 | 17.4 b | 23.4 b | 20.4 | 525.3 a | 520 a | 522.6 |
| | DM$_{25}$ | 11.5 ab | 13.3 b | 12.4 | 17.8 b | 24.2 b | 21.0 | 529.5 a | 505.5 b | 517.5 |
| | DM$_{50}$ | 11.6 a | 14.6 a | 13.1 | 18.2 a | 26.6 a | 22.4 | 507.5 b | 497.5 b | 502.5 |
| **Nitrogen (N)** | N$_{200}$ | 11.8 b | 13.1 b | 12.4 | 18.3 b | 21.2 c | 19.7 | 532.7 c | 525.6 b | 529.1 |
| | N$_{250}$ | 12.1 a | 15.5 a | 13.8 | 18.9 a | 24.7 b | 21.8 | 543.0 b | 530.5 b | 536.7 |
| | N$_{300}$ | 12.1 a | 14.9 a | 13.5 | 18.3 b | 26.5 a | 22.4 | 565.5 a | 545.0 a | 555.2 |
| **DM * N** | DM$_{0}$ x N$_{200}$ | 10.65 c | 10.84 c | 10.74 | 16.38 d | 16.78 d | 16.58 | 496.0 bcd | 461.2bc | 478.6 |
| | DM$_{0}$ x N$_{250}$ | 11.51 b | 11.60 b | 11.55 | 17.82 c | 18.23 c | 18.02 | 534.4 a | 496.9 a | 515.6 |
| | DM$_{0}$ x N$_{300}$ | 11.76 ab | 12.10 ab | 11.93 | 18.17 bc | 18.55 bc | 18.36 | 545.6 a | 507.4 a | 526.5 |
| | DM$_{25}$x N$_{200}$ | 10.30 c | 10.35 c | 10.32 | 15.91 d | 16.36 d | 16.13 | 489.7 cd | 455.4 b | 472.5 |
| | DM$_{25}$x N$_{250}$ | 12.06 ab | 12.24 ab | 12.15 | 18.65 bc | 18.70 bc | 18.67 | 544.9 a | 506.7 a | 525.8 |
| | DM$_{25}$x N$_{300}$ | 12.25 a | 12.39 z | 12.32 | 18.92 b | 19.30 b | 19.11 | 554.2 a | 515.4 a | 534.8 |
| | DM$_{50}$x N$_{200}$ | 10.48 c | 10.54 c | 10.51 | 16.19 d | 16.75 d | 16.47 | 474.5 d | 441.2bc | 457.8 |
| | DM$_{50}$ x N$_{250}$ | 12.03 ab | 12.30 a | 12.16 | 18.72 bc | 18.95 bc | 18.83 | 518.9 abc | 482.5ab | 500.7 |
| | DM$_{50}$x N$_{300}$ | 12.29 a | 12.42 a | 12.35 | 19.86 a | 20.25 a | 20.05 | 529.2 ab | 492.6ab | 510.6 |

**Table VI: Effect of dairy manure and nitrogen levels on yield and yield contributing factors of maize**

| Treatments | | Plant growth parameters | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant height (cm) | | | Cob length (cm) | | | Grain yield (Mg ha$^{-1}$) | | | Biological yield (Mg ha$^{-1}$) | | |
| **Years** | - | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** | **2008** | **2009** | **Mean** |
| **Dairy manure (DM)** | DM$_{0}$ | 208.6 c | 212.5 b | 210.5 | 16.6 b | 16.8 c | 16.7 | 7.53 b | 7.65 b | 7.59 | 14.6 c | 14.7 b | 14.6 |
| | DM$_{25}$ | 217.6 b | 220.1 ab | 218.8 | 16.9 a | 17.2 b | 17.0 | 7.69 ab | 7.76 ab | 7.72 | 14.9 b | 15.3 ab | 15.1 |
| | DM$_{50}$ | 222.7 a | 227.5 a | 225.1 | 17.3 a | 17.4 a | 17.3 | 7.73 a | 7.81 a | 7.77 | 15.2 a | 15.4 a | 15.3 |
| **Nitrogen (N)** | N$_{200}$ | 224.4 c | 230.3 b | 227.3 | 17.4 c | 17.5 c | 17.4 | 7.90 a | 8.02 b | 7.96 | 13.7 c | 13.8 c | 13.7 |
| | N$_{250}$ | 231.6 b | 235.5 ab | 233.5 | 17.5 b | 17.7 b | 17.6 | 8.06 ab | 8.15 ab | 8.10 | 15.4 b | 15.6 b | 15.5 |
| | N$_{300}$ | 237.5 a | 240.2 a | 238.8 | 18.0 a | 18.3 a | 18.1 | 8.11 a | 8.25 a | 8.18 | 15.8 a | 15.9 a | 15.8 |
| **DM * N** | DM$_{0}$ x N$_{200}$ | 186.7 f | 190.5 d | 188.6 | 15.59 e | 15.74 d | 15.66 | 7.09 c | 7.30 d | 7.19 | 13.73 d | 13.82 d | 13.77 |
| | DM$_{0}$ x N$_{250}$ | 217.4 d | 220.5 b | 218.9 | 16.98 d | 17.14 c | 17.06 | 7.67 b | 7.90 c | 7.78 | 14.99 c | 15.20 c | 15.09 |
| | DM$_{0}$ x N$_{300}$ | 221.7 cd | 225.6 b | 223.6 | 17.33 cd | 17.50 c | 17.41 | 7.84 ab | 8.07bc | 7.95 | 15.18 bc | 15.25 bc | 15.21 |
| | DM$_{25}$x N$_{200}$ | 194.2ef | 197.5 c | 195.8 | 15.14 e | 15.29 e | 15.21 | 6.86 c | 7.06 e | 6.96 | 13.34 d | 13.45 d | 13.39 |
| | DM$_{25}$x N$_{250}$ | 227.6bc | 231.0 ab | 229.3 | 17.77bc | 17.94 b | 17.85 | 8.03ab | 8.27 b | 8.15 | 15.67 bc | 15.75 bc | 15.71 |
| | DM$_{25}$x N$_{300}$ | 230.9 b | 235.8 ab | 233.3 | 18.01 e | 18.19 b | 18.10 | 8.16 a | 8.40 a | 8.28 | 15.87 ab | 16.13 ab | 16.00 |
| | DM$_{50}$x N$_{200}$ | 197.7 e | 198.0 c | 197.8 | 15.42 e | 15.57 d | 15.49 | 6.98 c | 7.18 de | 7.08 | 13.63 d | 13.75 d | 13.69 |
| | DM$_{50}$ x N$_{250}$ | 228.3bc | 232.6 b | 230.4 | 17.81 bc | 17.98 b | 17.80 | 8.02ab | 8.26 b | 8.14 | 15.53 bc | 15.65 bc | 15.59 |
| | DM$_{50}$x N$_{300}$ | 242.2 a | 246.4 a | 244.3 | 18.90 a | 19.09 a | 18.99 | 8.19 a | 8.43 a | 8.31 | 16.54 a | 16.70 a | 16.62 |

**Table VII: Effect of dairy manure and nitrogen levels on nutrients uptake and soil NPK during in maize**

| Treatments | | NPK uptake | | | Soil NPK at the end of experiment | | |
|---|---|---|---|---|---|---|---|
| | - | **N uptake** | **P uptake** | **K uptake** | **N (g kg$^{-1}$)** | **P (mg kg$^{-1}$)** | **K (mg kg$^{-1}$)** |
| **Dairy manure (DM)** | DM$_{0}$ | 152.1 b | 27.6 c | 153.6 c | 0.48 c | 17.3 | 145.2 b |
| | DM$_{25}$ | 148.4 b | 32.0 b | 173.7 b | 0.53 b | 17.5 | 144.9 b |
| | DM$_{50}$ | 164.2 a | 35.0 a | 184.7 a | 0.58 a | 17.8 | 149.1 a |
| **Nitrogen (N)** | N$_{200}$ | 159.8 b | 31.8 c | 171.0 b | 0.53 b | 17.6 a | 146.9 a |
| | N$_{250}$ | 163.1 b | 33.3 b | 171.2 b | 0.49 c | 7.9 a | 147.7 a |
| | N$_{300}$ | 191.7 a | 34.3 a | 219.4 a | 0.60 a | 15.9 b | 122.6 b |
| **DM * N** | DM$_{0}$ x N$_{200}$ | 86.9 c | 23.5 d | 108.9 cd | 0.49 c | 14.5 e | 156.8 cd |
| | DM$_{0}$ x N$_{250}$ | 85.8 c | 26.4 cd | 118.4bc | 0.51 ab | 16.7 ab | 152.5 d |
| | DM$_{0}$ x N$_{300}$ | 84.9 c | 27.4 c | 120.8ab | 0.53 ab | 15.6 d | 151.2 d |
| | DM$_{25}$x N$_{200}$ | 94.1 bc | 27.9bc | 105.8 c | 0.50 c | 15.8 c | 167.6 bc |
| | DM$_{25}$x N$_{250}$ | 99.1 ab | 29.5abc | 124.0ab | 0.52 b | 16.8 ab | 176.6 ab |
| | DM$_{25}$x N$_{300}$ | 101.1ab | 29.5abc | 125.8ab | 0.54 ab | 16.5 b | 176.9 ab |
| | DM$_{50}$x N$_{200}$ | 104.0ab | 29.4bc | 107.6 cd | 0.50 c | 15.9 c | 185.2 a |
| | DM$_{50}$ x N$_{250}$ | 103.0ab | 30.6ab | 124.4ab | 0.57 a | 17.9 a | 183.5 a |
| | DM$_{50}$x N$_{300}$ | 106.2 a | 32.6 a | 132.0 a | 0.62.a | 18.1 a | 185.4 a |

Means for treatments within columns for each experiment followed by the same letter are not significantly different at $\alpha$=0.05
DM$_{0}$ = Dairy manure @ 0 Mg ha$^{-1}$, DM$_{25}$ = Dairy manure @ 25 Mg ha$^{-1}$, DM$_{50}$ = Dairy manure @ 50 Mg ha$^{-1}$
N$_{200}$ = Nitrogen @ 200 kg ha$^{-1}$, N$_{250}$ = Nitrogen @ 250 kg ha$^{-1}$, N$_{300}$ = Nitrogen @ 300 kg ha$^{-1}$

In year -2, dairy manure response was also significant. Maximum infiltration rate (16.8% more than control) was observed with treatment receiving 50 Mg DM ha$^{-1}$. Different nitrogen treatments significantly affected infiltration rate during both the years of study. The highest infiltration rate of 12.1 mm h$^{-1}$ was obtained for the N$_{300}$ treatment and the lowest (11.8 mm h$^{-1}$) for the N$_{200}$ treatment (Table V) during fist year. Similarly during second year, the highest

**Table VIII: Economic analysis for maize (2008-2009)**

| Dairy manure levels | Nitrogen rates (kg ha$^{-1}$) | Grain yield (Mg ha$^{-1}$) | Biological yield (Mg ha$^{-1}$) | Variable cost (US $ ha$^{-1}$) | Permanent cost (US. $ ha$^{-1}$) | Total cost (US $ ha$^{-1}$) | Gross income (US $ ha$^{-1}$) | Net return (US $ ha$^{-1}$) | Net field benefits (US $ ha$^{-1}$) | Benefit cost ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| $DM_0$ | $N_{200}$ | 7.19 | 13.7 | 52.59157 | 900.5282 | 953.1198 | 1869.889 | 916.7692 | 1817.297 | 2.03 |
| | $N_{250}$ | 7.78 | 15.0 | 70.12209 | 900.5282 | 970.6503 | 2407.999 | 1437.349 | 2337.877 | 1.67 |
| | $N_{300}$ | 7.95 | 15.2 | 87.30707 | 900.5282 | 987.8353 | 2444.354 | 1456.519 | 2357.047 | 1.67 |
| $DM_{25}$ | $N_{200}$ | 6.96 | 13.3 | 196.5676 | 900.5282 | 1097.096 | 2211.472 | 1114.376 | 2014.904 | 1.98 |
| | $N_{250}$ | 8.15 | 15.7 | 214.0981 | 900.5282 | 1114.626 | 2494.745 | 1380.119 | 2280.647 | 1.80 |
| | $N_{300}$ | 8.28 | 16.0 | 231.2831 | 900.5282 | 1131.811 | 2526.78 | 1394.969 | 2295.497 | 1.81 |
| $DM_{50}$ | $N_{200}$ | 7.08 | 13.6 | 340.5437 | 900.5282 | 1241.072 | 2241.707 | 1000.635 | 1901.163 | 2.24 |
| | $N_{250}$ | 8.14 | 15.5 | 358.0742 | 900.5282 | 1258.602 | 2487.186 | 1228.584 | 2129.112 | 2.02 |
| | $N_{300}$ | 8.31 | 16.62 | 375.2592 | 900.5282 | 1275.787 | 2550.032 | 1274.245 | 2174.773 | 2.00 |

**Table IX: Dominance and Marginal analysis for maize (2008-2009)**

| Dairy manure levels | Nitrogen rates (kg ha$^{-1}$) | Variable cost (US .$ ha$^{-1}$) | Net field benefits (US $ ha$^{-1}$) | Marginal cost that vary | Marginal net field benefits | Marginal rate of return | Dominated treatments |
|---|---|---|---|---|---|---|---|
| $DM_0$ | $N_{200}$ | 52.59157 | 1817.297 | | | | |
| $DM_0$ | $N_{250}$ | 70.12209 | 2337.877 | 17.53052 | 520.5794 | 29.69561 | |
| $DM_0$ | $N_{300}$ | 87.30707 | 2357.047 | 17.18498 | 19.16955 | 1.115483 | |
| $DM_{25}$ | $N_{200}$ | 196.5676 | 2014.904 | - | - | | D |
| $DM_{25}$ | $N_{250}$ | 214.0981 | 2280.647 | 17.53052 | 265.7429 | 15.15887 | |
| $DM_{25}$ | $N_{300}$ | 231.2831 | 2295.497 | 17.18498 | 14.84911 | 0.864075 | |
| $DM_{50}$ | $N_{200}$ | 340.5437 | 1901.163 | - | - | - | D |
| $DM_{50}$ | $N_{250}$ | 358.0742 | 2129.112 | 17.53052 | 227.9486 | 13.00296 | |
| $DM_{50}$ | $N_{300}$ | 375.2592 | 2174.773 | 17.18498 | 45.66114 | 2.657038 | |

$DM_0$ = Dairy manure @ 0 Mg ha$^{-1}$, $DM_{25}$ = Dairy manure @ 25 Mg ha$^{-1}$, $DM_{50}$ = Dairy manure @ 50 Mg ha$^{-1}$
$N_{200}$ = Nitrogen @ 200 kg ha$^{-1}$, $N_{250}$ = Nitrogen @ 250 kg ha$^{-1}$, $N_{300}$ = Nitrogen @ 300 kg ha$^{-1}$

infiltration rate of 14.9 mm h$^{-1}$ was obtained for the $N_{300}$ treatment and the lowest (13.1 mm h$^{-1}$) for the $N_{200}$ treatment. As regard field saturated hydraulic conductivity, statistically significant response was observed, during both years, increasing dairy manurerates significantly increased this parameter. During both the years, treatment receiving 50 Mg DM ha$^{-1}$showed best response causing 5.0 and 13.6% increase over control, during 1$^{st}$ and 2$^{nd}$ year, respectively (Table V). A significant effect of different nitrogen rates on field saturated hydraulic conductivity was also found during the study years. The highest field saturated hydraulic conductivity of 18.9 mm h$^{-1}$ was obtained for $N_{300}$ treatment and the lowest (17.4 mm hr$^{-1}$) for the $N_{200}$ treatment (Table V) during 1-year. Data showed that dairy manurereduced the soil strength significantly as compared to control (Table V). During both years, minimum soil strength (3.4 & 4.3% less than control, during year-1 & 2, respectively) were observed in case of treatments, where DM @ 50 Mg ha$^{-1}$ was applied.

Maximum plant height (222.7 cm) was recorded for $DM_{50}$, which on anaverage was 2.3 and 6.7% higher than $DM_{25}$ and $DM_0$, respectively during first year (Table VI). Similar during second year, maximum plant height (227.5 cm) was recorded for $DM_{50}$, which on an average was 3.3 and 7% higher than $DM_{25}$ and $DM_0$, respectively during first year. Tallest plants (237.5 cm) were produced when crop was fertilized with N @ 300 kg ha$^{-1}$ (Table VI) during 1-year. Similarly during second year, $N_{300}$ treatment resulted in 2 and 4.3% more plant height compared to $N_{250}$ and $N_{200}$ treatments. The effect of dairy manure application on cob length was statistically significant. In year-1, maximum cob lengthwas observed in treatment, where 50 Mg DM ha$^{-1}$ was applied and it showed 4.2% increase over control (Table VI). In year -2, dairy manure response was also significant. Maximum cob length (3.5% more than control) was observed with treatment receiving 50 Mg DM ha$^{-1}$. Different nitrogen treatments significantly affected cob length during both the years of study. The highest cob length of 18 cm was obtained for the $N_{300}$ treatment and the lowest (17.4) for the $N_{200}$ treatment (Table VI) during fist year. Similarly during second year, the highest cob length of 18.1 cm was obtained for the $N_{300}$ treatment and the lowest (17.4 cm) for the $N_{200}$ treatment. Data revealed that grain yield and biological yield were significantly ($P \leq 0.05$) increased by the application of dairy manure and nitrogen application, over the control (Table VI). In year-1 and -2 maximum grain yield and biological yield were observed in treatments, where dairy manure was applied @ 50 Mg ha$^{-1}$ along with $N_{300}$. This treatment increased the grain yield by 15.5 and 15.4%; biological yield by 20.4 and 20.8% more than control ($DM_0$ x $N_{200}$), during 1$^{st}$ and 2$^{nd}$ year, respectively.

The results of our study revealed that the application of dairy manure and nitrogen increased the NPK uptake by maize crop, over control. On average, maximum N uptake (22.2% more than control) was observed in case of treatment receiving dairy manure @ 50 Mg ha$^{-1}$ along with $N_{300}$. This study demonstrated a maximum increase of P, 38.7% and K, 21.2%, respectively over control, in case of treatments, where DM @ 50 Mg ha$^{-1}$ along with $N_{300}$ was applied (Table VII). It was revealed from the data that soil N, P and K were significantly ($P \leq 0.05$) increased by the application of dairy manure and nitrogen application, over the control (Table VII).Maximum soil N, P and K were observed in treatments, where dairy manure was applied @ 50 Mg $ha^{-1}$ along with $N_{300}$. This treatment increased the soil N by 26.3%; soil P by 24.8% and soil K by18.2% more than control ($DM_0$ x $N_{200}$) at the end of experiment.

Data regarding economic analysis of maize yield during 2008-09 indicate that the maximum net field benefit of 2357.04 US $ $ha^{-1}$ was achieved from treatment combination $DM_0 \times N_{300}$ followed by $DM_0 \times N_{250}$ having 2337.8 US $ $ha^{-1}$ and the lowest (1817.2 US $ $ha^{-1}$) in the case of $DM_0 \times N_{200}$ treatment (Table VIII). Dominance and marginal analysis indicate that marginal rate of return was maximum from the treatment combination $DM_0 \times N_{300}$ followed by $DM_{25} \times N_{250}$ and $DM_{50} \times N_{250}$, while all other treatment combinations were un-economical due to higher input cost and low returns (Table IX).

## DISCUSSION

This study demonstrated the effectiveness of different levels of dairy manure and nitrogen fertilizer for improving growth, yield and nutrients (N, P & K) uptake of maize, soil organic carbon and nitrate content. Our results indicated that best results were obtained with application of 300 kg N $ha^{-1}$ combined with 50 Mg $ha^{-1}$ dairy manure. The interactive effect of dairy manure and nitrogen rates was significant, the mean maximum value of organic carbon content was observed in $DM_{50}$ (0.73%) in combination with $N_{300}$ and minimum (0.53%) in $DM_0$ x $N_{200}$ combination during first year at 0-5 cm depth. Similarly, maximum value of organic carbon content was observed with treatment combination $DM_{50}$x $N_{300}$ (0.78%) and minimum in $DM_0$x $N_{200}$ treatment (0.56%) at 0-5 cm depth during second year. Similar results were noted at 5-10 cm depth. These results are in line with those of Rasool *et al*. (2008) who reported that SOC concentration increased up to 21% by balance application of chemical fertilizer ($N_{100}P_{50}K_{50}$). Similar findings were found by Benbi *et al*. (1998), who concluded that addition of organic matter through farmyard manure, enhanced crop growth with concomitantly higher root biomass production could explain the increase in organic carbon concentration in NPK + FYM. Blair *et al.* (2006) also showed that application of FYM can increase SOM and improve soil physical fertility. Similarly, Zhao *et al*. (2009) found that organic matter enhanced in soils amended with organic fertilizers. The increase was particularly important in the soil, where the levels of organic matter in agricultural soils were normally less than 10 g $kg^{-1}$.

The results of our study revealed that increasing the nitrogen rates also increased the $NO_3$ contents combined with 50 Mg $ha^{-1}$. The lower values of $NO_3$ in upper layers of farm manured trials may be due to the activity of plant roots and microbial activity, and high values in third layer were from nitrate accumulation at this layer. These findings are in agreement with those of Rnaol *et al.* (2006) that farmyard manure application could result in $NO_3$-N accumulation increase in the deeper soil profiles compared with mineral fertilization. Higher soil N concentration could promote to leaching (Lee & Jose, 2005). Craswell and Godwin (1984) also reported that plants absorb only about 50% of the N applied to the soil and then a large amount of N is lost through leaching. Zhu *et al.* (2003) also confirmed our results by concluding that flow-weighted $NO_3$-N concentrations and $NO^-_3$-N masses in leachate increased with increasing N-rate (at 0, 100 & 200 kg N $ha^{-1}$, flow-weighted $NO_3$-N concentrations were 3.5, 8.2 & 23.9 mg $L^{-1}$ & $NO_3$-N masses were 17, 39, and 112 kg $ha^{-1}$ $yr^{-1}$, respectively).

Dairy manure and nitrogen fertilizer also improved soil physical properties. These results are in agreement with those of Kumar *et al.* (1985) who reported that application of dairy manure to cropland increased the infiltration rate. Singh *et al.* (2007) carried out an experiment and observed that SOC contents increased by manuring, in turn improved its aggregation status, infiltration rate and decreased the bulk density, dispersion ratio and soil strength correspondingly. Similar results were found in case of second year. Similarly, Edmeades (2003) also reported that manured soils had lower bulk density and higher hydraulic conductivity, relative to fertilized soils. Similar findings were reported by Zhang (1994) who found a significant decline in soil strength with application of organic matter. Singh *et al.* (2007) also showed that soil strength decreased by application of manure.

The results of our study revealed that increasing the nitrogen rates also increased growth, yield the NPK uptake by maize crop, over control ($DM_{50}$ X $N_{300}$). Similar results were recorded by Khoshgoftarmanesh and Kalbasi (2002) who concluded that organic manure significantly increased the plant height over untreated control. This may be attributed to the cell division and enlargement which might be stimulated by nitrogen nutrition. These results were confirmed by Boateng *et al.* (2006) who advocated that increasing N level significantly increased plant height of corn plants. Our work is supported by Hepperly *et al.* (2009) who reported that residual dairy manure and nitrogen had a significant effect on the cob length and cob length linearly increased with increasing the manure level. These results may be attributed to lesser soil compaction and better soil aeration due to application of dairy manure and especially in early growth period and more uniform distribution of nutrients in soil profile due to timely and proper application of the nitrogen fertilizer to the field. These results were similar to Mtambanengwe (2006) that maize biomass increases with increasing dairy manure level. Gana and Ogunremi (2009) also reported that biomass increased with each incremental dose of nitrogen. These results corroborate the findings of Theodora *et al.* (2003) who concluded that application of dairy manure resulted in a significant increase in dry biomass and in grain yield and nutrient uptake. These results may be due to the role of nitrogen in stimulating the build of amino acids and growth hormones. This in turn into positively in cell division and enlargement also, nitrogen fertilizer may be to promote change in mineral composition of plant (Mengel & Kirkby, 1982). Similarly, Agbede *et al.* (2008) showed that uptake of N and P significantly increased by each successive increment of nitrogen. These results attributed to that account of the corresponding higher amount of the available N and P fertilizer substantially increased utilization and the productivity, furthermore significantly increased on N, P and K concentration and uptake by grain and yield of maize (Nyiraneza *et al.* 2009). Hati *et al.* (2008) also found increase in total nitrogen content with increasing dairy manure levels and N rates in the uppermost soil layer and soil nitrogen content decreased with soil depth. These results are in line with the Huang *et al.* (2010) who concluded that soil P is sufficiently increased by promoting nitrogen fertilizer levels. Similar findings were reported by Agbede *et al.* (2008) that higher concentration of available P, K, N and organic C was observed in higher dairy manure and nitrogen fertilizer levels compared to controlled treatment in soils.

## CONCLUSION

Dairy manure and nitrogen amendments had exerted variable effects on $NO_3$ leaching, soil physical quality indicators and maize yield. The short-term effects of dairy manure significantly improved field saturated hydraulic conductivity and infiltration rate with an associated decrease in soil strength than control. The $NO_3$ leaching was consistently increased by dairy manure application and it is increasing with increase in nitrogen levels. Nitrogen levels also significantly increased maize yield. Interactions between dairy manure and nitrogen levels significantly affect soil $NO_3$ concentration, soil physical properties and yield of maize. The economic determines the ultimate feasibility and practicability of any agriculture practice. The results revealed that dairy manure @ 0 Mg $ha^{-1}$ along with nitrogen @ 250 kg $ha^{-1}$ was most economical treatment combination.

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