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Original Article

# The Effects of Nitrogen Source on Nutritive Value of Irrigated Silage Corn

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**Abstract**

Nitrogen is considered one of the most important nutrients affecting yield and quality of maize forage (*Zea mays* L.). A two-year field experiment was carried out to evaluate the effects of broiler litter and mineral fertilizer on dry matter production and silage quality of corn. The applied treatments were: unfertilized (control), 100, 200 and 300 kg $ha^{-1}$ in the form of urea fertilizer (217, 434, and 651 kg urea $ha^{-1}$, respectively) and 100, 200 and 300 kg $ha^{-1}$ in the form of broiler litter (7142, 14284, and 21426 kg broiler litter $ha^{-1}$, respectively). The present findings showed that Fe, Mn, Cu and Zn concentrations in forage corn were not affected by urea application; however, broiler litter application significantly increased Fe, Mn and Cu concentrations of corn stover in a linear trend. The broiler litter and urea fertilizer significantly increased both dry matter and protein content of forage corn but no significant differences on those components were obtained between broiler litter and urea fertilizer at each N application rate. The results suggested that N applied to forage corn by broiler litter, at the recommended rate for inorganic N fertilization, is almost more effective in terms of forage nutritive value response than urea fertilizer. The profitability of forage corn production could be enhanced by replacing chemical fertilizers with broiler litter.

***Keywords:*** *Zea mays* L., acid detergent fiber, broiler litter, micronutrient, protein

## Introduction

Forage corn (*Zea mays* L.) is an excellent feed for dairy cattle due to its high dry matter yield, energy content, and palatability, especially when mixed with other feeds (Hart *et al.*, 2009). Nitrogen is the most important fertilizer for forage corn production (Hart *et al.*, 2009) and the application of this nutrient affects the forage yield of corn while improving its quality, especially its protein content (Amanullah *et al.*, 2009). Moreover, low and high doses of nitrogen have an adverse effect on quality of corn (Stone *et al.*, 1998) and an efficient management of nitrogen fertilizer is critical for the long-term protection of environmental quality (Fallah and Tadayyon, 2010). Thus, it is necessary to determine the optimum dose of N to improve the quality of corn (Li *et al.*, 2010).

Manure produced by poultry industry is capable of causing serious environmental pollution, but agronomic management practices on the use of manure could transform it from a waste to a resource product (Annicchiarico *et al.*, 2011). The expansion of the broiler industry and an increase in the price of anorganic fertilize, especially N, has increased the use of broiler litter as a source of crop nutrients. The poultry manure is recognized as a valuable natural fertilizer because of its high N content (Ma *et al.*, 1999). Among the types of organic manure, poultry manure is used as a soil amendment for agricultural crops and provides appreciable quantities of all important plant nutrients (Schomberg *et al.*, 2009).

Cu, Zn, Fe and Mn in forage affect directly food quality and are closely related to livestock nutrition. In addition, the concentrations of crude protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF), and the digestibility of these nutrient components influence the energy value of feedstuff (Weiss, 1994).

Although most of the nitrogen and phosphorus required by corn is provided through chemical fertilizers (Fallah *et al.*, 2013), broiler litter might increase corn performance with a residual effect on succeeding crops (Fallah *et al.*, 2013). Besides, of its application for increasing of arable land productivity, broiler litter might minimize the risk of the broiler litter accumulation near the poultry farms.

Land application of manures for crop production has increased in recent years due to the concerns related to crop quality and due to the commercial fertilizer cost. Furthermore, forage producers often have insufficient information for application of broiler litter at agronomically and environmentally acceptable rates. In addition comparative information is needed on nutrients efficiency from commercial nitrogen fertilizer, and broiler litter. Studies of broiler litter as a source of nitrogen can help elucidate the value of this manure as

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an alternative source of nutrients for corn production given the economic challenges of the rising cost of commercial fertilizer. The objective of the present study was to evaluate the effect of adding broiler litter and urea fertilizer on dry matter and protein yield, micronutrient concentration, and digestibility of corn. Results provided information for applying broiler litter safely and effectively to silage corn production.

## Materials and Methods

### *Study site description*

A field experiment was conducted at the Agricultural Research Farm of Shahrekord University in Iran (32°21' N latitude, 50°49' E longitude; elevation = 2050 m). The Emberger and Gossen classification for this area described it as arid with a cold steppe climate. The mean annual rainfall is 334 mm and annual temperature is 10.8 °C. The annual rainfall does not coincide with the corn-growing season and the air temperature is relatively high. The total rainfall during the corn-growing season (June to September) is 5.9 mm.

The site soil was calcareous with more than 30% equivalent calcium carbonate in the surface layer that has developed into limestone. The used soil had never been fertilized with organic manure. Soil samples taken from 0-30 cm in depth were analysed for its characteristics before the experiment (Table 1). Soil texture, pH ($pH_{H2O}$ at 1:2.5 ratio), electrical conductivity, organic carbon (Walkley-Black method), total nitrogen (Kejldahl method), extractable P (Olsen method), available K, and $CaCO_3$ content were determined as described by Carter and Gregorich (2008). DTPA-extractable Cu, Zn, Fe and Mn levels were obtained by combining 10 g of soil (≤2 mm) with 20 ml 0.005 M DTPA + 0.01 M CaCl2 + 0.1 MTEA (triethanolamine) solution. After 2 h of continuous shaking at room temperature, the soil suspension was centrifuged and filtered through a 0.45 µm membrane. Cu, Zn, Fe, and Mn levels in the suspension were determined using an atomic absorption spectrometer (Page *et al.*, 1982).

Broiler litter was obtained from a Poultry Farm at Shahrekord University nearby the experimental site. The litter was made up of the feces mixed with different proportions of sawdust bedding. All litter samples were air-dried and ground to 1 mm for analysis. The manure, EC, OC, total N, P, and K were measured and analysed for their chemical properties (Table 1).

### *Experimental setup*

The experimental setup was a randomized complete block design with four replications. Each replication was divided into seven N treatments (control, 100, 200, and 300 kg N $ha^{-1}$ each of urea fertilizer and broiler litter). Plant-available N was calculated based on the assumption that 50% of organic N in broiler litter mineralizes in the first year of application (Fallah *et al.*, 2013).

The field was ploughed once using a moldboard plow and twice using a disc harrow; ridges were formed every 60 cm. Each experimental plot was designed as 4.2 m wide and 9 m long. After seedbed preparation, the desired broiler litter rates were immediately banded 9 cm below the seed and were covered with soil. In inorganic treatments, one-third of the N fertilizer as urea and all of the super triple superphosphate fertilizer were added to the soil manually on the sides of the ridges before planting the corn. The remaining N was added at the 7-9 leaf stage. Potassium fertilizer was not applied to the soil because the initial level of K in the soil was 344 mg $kg^{-1}$ (Table 1).

Corn seeds (SC 704) were planted in the month of May in 2008 and 2009 at a rate of 140000 plant $ha^{-1}$. Immediately after sowing, all the plots were irrigated every 4-7 day based on environmental conditions to improve the rate of emergence. There were no major pests or diseases that required chemical control.

### *Analysis of corn plants*

At the harvesting stage (progression of milk line in corn kernels), the corn shoots of five plants from the central rows were sampled randomly from each plot. Plant leaf, plant stem, and ear samples to be dried were placed in an oven at 60°C until a constant weight was reached and the dry weights were calculated (Kacar, 1972).

The nitrogen content of the dried samples was determined using the Kjeldahl method and the Gerhardf Vapodest model (Jackson, 1962). Crude protein was calculated by multiplying the total N by 6.25 (Bremner and Breintenbeck, 1983). The Fe, Mn, Zn and Cu concentrations were determined by flame atomic absorption spectrophotometer (FAAS) with suitable matrices after samples were digested by nitric acid and hydrogen peroxide. All results were recalculated on a 105°C oven-dry basis (Carter and Gregorich, 2008).

Table 1. Main variables of soil and broiler litter for the experiment

| Parameter | Unit | Soil | | Broiler litter | |
|---|---|---|---|---|---|
| | | 2008 | 2009 | 2008 | 2009 |
| Texture | - | Clay loam | Clay loam | - | - |
| pH | - | 8.34 | 7.84 | 8.21 | 6.41 |
| EC | (dS $m^{-1}$) | 0.25 | 0.86 | 1.1 | 12.7 |
| OC | (g $kg^{-1}$) | 3.6 | 3.7 | 368 | 400 |
| N | (g $kg^{-1}$) | 0.22 | 0.03 | 26 | 30 |
| P | (mg $kg^{-1}$) | 18 | 11.5 | 7423 | 10560 |
| K | (mg $kg^{-1}$) | 350 | 344 | 9927 | 11454 |
| C/N | - | 16.4 | 12 | 14.15 | 13.33 |
| Fe | (mg $kg^{-1}$) | 6.5 | 4.98 | 527 | 878 |
| Mn | (mg $kg^{-1}$) | 4.3 | 5.21 | 88 | 142 |
| Zn | (mg $kg^{-1}$) | 0.90 | 0.81 | 448 | 453 |
| Cu | (mg $kg^{-1}$) | 0.55 | 0.56 | 28 | 26 |

EC, and OC represent electrical conductivity and organic carbon content

NDF samples (0.3 g) were analysed by wet chemistry for whole-plant NDF and ADF as recommended by Van Soest *et al.* (1991). Levels of NDF and ADF for calibration sets were determined using the ANKOM filter bag system (ANKOM Technologies, 2003) to include a 120 min reflux and 4 min rinse with a 1.0 g kg$^{-1}$ heat stable α-amylase solution (Mertens, 1991). All compositional data were calculated on a DM basis. Protein yield was determined as a function of biomass yield and biomass protein concentration (Martin *et al.*, 1998).

### *Statistical analyses*

All the analyses were performed based as a randomized complete block design. Data from both years were combined. Each data point was the mean of two years and four replicates (n = 8) and the least significant difference (LSD) option of Statistical Analysis System software (Version 9.1.3; SAS Institute; USA). The data were analysed using one-way and regression analysis ANOVA and mean comparison was performed by Fisher's least significant difference (LSD) test ($p \leq 0.05$).

## Results and Discussion

### *Micronutrients*

There were no significant differences in nutrients concentration, except for Fe and Mn concentrations, between 2008 and 2009 (Table 2). The mean of Fe and Mn concentrations for forage corn were 73% and 23% greater, respectively, in 2009 than in 2008 (Fig. 1). In 2008, there were no significant differences between same nitrogen rates in the form of urea fertilizer and broiler litter, however in 2009 nitrogen levels in the form of broiler litter increased than the nitrogen levels in the form of urea fertilizer (Fig. 1). This might be the results of increased Fe and Mn concentrations in the broiler litter in 2009 (Table 2). It appears that the use of broiler litter with an appropriate concentration of micronutrients is the best strategy for strengthening these nutrients in crops (Adeli *et al.*, 2015). Increased plant growth associated with increased N supply may explain, in part, the increased uptake observed for other nutrients (Nyiraneza and Snapp, 2007).

### *Iron*

The ANOVA analysis shows that Fe concentration was significantly affected by nitrogen amendment (Table 2). Fe concentrations for forage corn were 18% after N amendment than in the unfertilized plots. Also, there were significant increases in Fe concentration for forage corn caused by broiler litter application over chemical fertilizer rates (Fig. 2). The increased Fe concentration was the result of the high rate of these minerals in the litter, particularly in the second-year litter application (Table 2). Similar results has reported that applied poultry manure increased concentration of Zn in tomato and wheat plants (Yaduvanshi and sharma; Demir, *et al.*, 2010), but had no significant effects on the concentrations Fe in tomato plants (Demir, *et al.*, 2010).

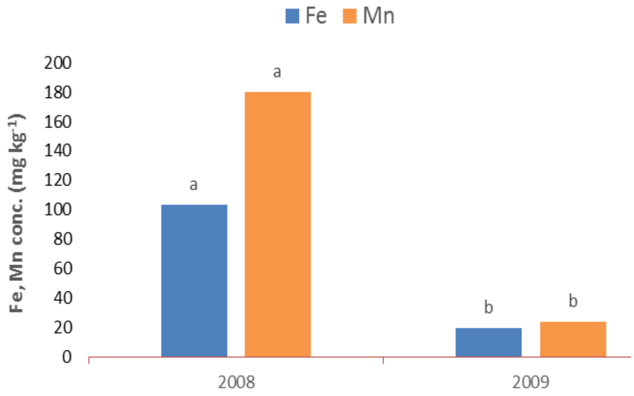


Fig. 1. Fe and Mn concentration of silage corn in 2008 and 2009. Means with the different letters show significant difference (LSD, $P \leq 0.05$)

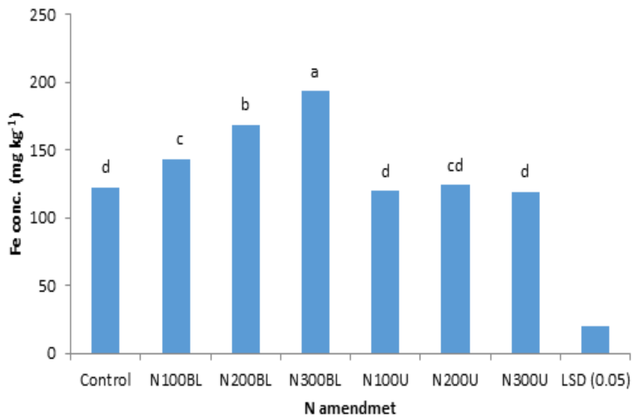


Fig. 2. The effects of N source and rate on Fe concentration of silage corn. Control: without chemical fertilizer and broiler litter; $N_{100U}$, $N_{200U}$, and $N_{300U}$: 100, 200 and 300 kg ha$^{-1}$ of N as urea fertilizer, respectively; $N_{100BL}$, $N_{200BL}$, and $N_{300BL}$: 100, 200 and 300 kg ha$^{-1}$ of N as broiler litter, respectively. Means with the different letters show significant difference (LSD, $P \leq 0.05$)

Table 2. The effects of N source and rate on micro nutrients concentration, and NDF of silage corn

| S.O.V | Fe | Mn | Zn | Cu | NDF† |
|---|---|---|---|---|---|
| Year | ** | ** | NS‡ | NS | NS |
| N amendment | ** | ** | ** | ** | ** |
| Year × N amendment | ** | NS | NS | NS | NS |
| Litter linear | ** | ** | ** | ** | * |
| Litter quadratic | NS | NS | NS | NS | NS |
| Fertilizer linear | NS | NS | NS | NS | NS |
| Fertilizer quadratic | NS | NS | NS | NS | NS |

* Significant at $P \leq 0.05$. ** Significant at $P \leq 0.01$.
† NDF, Nutrient detergent fiber. ‡ NS, not significant

*Manganese*

Effect of nitrogen on Mn concentration in forage corn varied between nitrogen source in 2008 and 2009 and showed an inconsistent trend (Table 2). In broiler treated plots, Mn concentrations were significantly higher than the urea treated plots (Fig. 3) and showed a linear trend (Table 2). With chemical fertilizer in both years, however, no trend due to nitrogen rate was visible and Mn concentration in high nitrogen level (300 kg ha$^{-1}$) stayed always below the corresponding results with broiler litter (Table 2). Khaliq and Abbasi (2010) showed that combination of organic–inorganic amendments increased soil organic matter content by 3–9%, total N 14–29%, available P 5–35% and extractable K 12–39%. The response of micronutrient to organic or organic–inorganic amendments was even higher than that recorded for macronutrients.

*Zinc*

The effect of nitrogen on Zn concentration in forage corn varied between nitrogen sources (Table 2). Zn concentration was bigger in both years in broiler litter compared to urea fertilizer treatments (Fig. 4). Zn concentration was lowest in unfertilized plot and urea fertilizer plots. In broiler treated plots, Zn concentration was significantly higher the urea treated plots (Fig. 4) and showed a linear trend (Table 2). Phosphorus has a vital role in energy storage and root development. According to Mohanty *et al.* (2006), poultry manure had induced more p uptake from soil, and increased root growth associated with increased P supply may explain, in part, the increased uptake observed for other nutrients. Additionally, Shakhawat *et al.* (2016) attributed that chemical fertilizers alone could not provide adequate and balanced nutrition for potential crop yield. But, total N, available P and available Zn improved in treatments that included poultry manure.

*Copper*

Copper (Fig. 5) in the forage corn increased with increasing rate of nitrogen from broiler litter but decreased with increasing rate of nitrogen from urea fertilizer. In both years, plots fertilized with urea fertilizer showed the same effect for Cu concentration of forage corn and there were no clear trend among nitrogen levels (Fig. 5). Cu concentration in forage corn was higher at 300 kg N $^{-1}$ha form broiler litter than urea fertilizer (Fig. 5).

The use of organic manure increased the Fe, Mn, and Cu concentrations as the application rate increased, but the Zn concentration remained unchanged. Mineral supplementation of livestock feeds often enriches their manure and the soil to which they are applied with Cu and Zn (Mikkelsen, 2000). In urea fertilized plots, nutrient removal values for Cu and Zn are relatively low compared with the amounts of these nutrients that could be present in a typical manure application. In semi-arid conditions, low organic matter and high pH of soil decreased micronutrients uptake by plant (Fallah *et al.*, 2013).

To use broiler litter as an illustration, a single application at a rate of 11.2 Mg ha$^{-1}$ could potentially add the following nutrient amounts: Fe = 7.3; Mn = 3.8; Zn = 3.5; and Cu = 2.5 kg ha$^{-1}$ (Heckman *et al.*, 2003). The application of appropriate rates of nitrogen fertilizer can increase soil Cu, Zn, and Mn availability and the concentrations of Cu, Zn, Fe, and Mn in corn. Similar results regarding increased micronutrient uptake

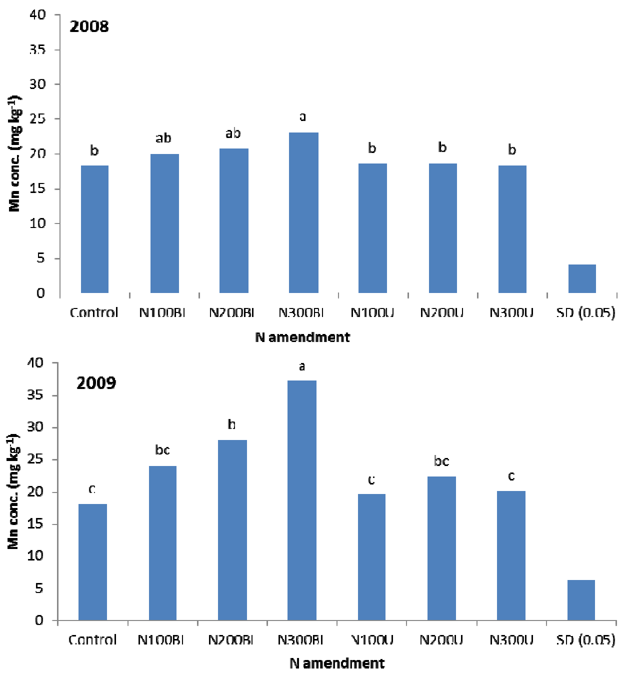


Fig. 3. The effects of N source and rate on Mn concentration of silage corn in 2008 and 2009. Control: without chemical fertilizer and broiler litter; $N_{100U}$, $N_{200U}$, and $N_{300U}$: 100, 200 and 300 kg ha$^{-1}$ of N as urea fertilizer, respectively; $N_{100BL}$, $N_{200BL}$, and $N_{300BL}$: 100, 200 and 300 kg ha$^{-1}$ of N as broiler litter, respectively. Means with the different letters show significant difference (LSD, P ≤ 0.05)

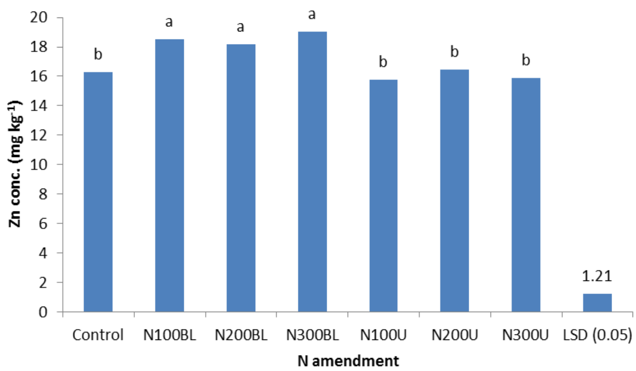


Fig. 4. The effects of N source and rate on Zn concentration of silage corn. Means with the different letters show significant difference (LSD, P ≤ 0.05). See Fig. 2 for abbreviations

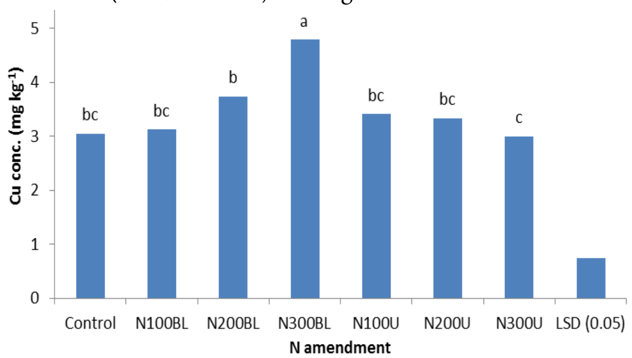


Fig. 5. The effects of N source and rate on Cu concentration of silage corn. Means with the different letters show significant difference (LSD, P≤0.05). See Fig. 2 for abbreviations

with manure application have been reported for wheat by Zhang *et al.* (2015). Several authors have reported Cu, Zn, Fe, Mn, Mg, and Ca concentrations in rice and cotton initially increased and then decreased as the N dose applied continued to increase ( Hao *et al.,* 2007*;* Adeli *et al.,* 2015*).*

*Neutral detergent fiber*

ANOVA showed that the difference in NDF concentration between 2008 and 2009 was not significant (Table 2). Nitrogen treatments significantly decreased NDF concentration of forage corn as the broiler litter increased. No significant difference in NDF concentration was observed for different levels application of urea fertilizer (Fig. 6). In the regression analysis, NDF showed a decreasing trend with increasing rate of nitrogen from broiler litter, but the NDF urea treated plots, generally remained unchanged (Table 2).

Stover NDF and ADF concentrations were significantly greater for unfertilized control treatment than for soil amendment by N treatments (Fig. 6), suggesting that a larger portion of the nitrogen and other nutrients taken up by the crop were derived from the fertilizer and broiler litter, as has been demonstrated elsewhere (Cao *et al.*, 2000; Mahala *et al.*, 2007). The decreased lignin concentration is associated with greater digestibility of the cell wall (Beck *et al.*, 2007; Miron *et al.*, 2007).

*Acid detergent fiber*

In the present study the ADF of forage corn was significantly affected by nitrogen treatments. No significant difference in ADF concentration was observed for different levels application of urea fertilizer (Fig. 7). However, forage ADF ($p \leq 0.05$) decreased linearly as broiler litter increased (Table 3).

Higher nitrogen rates appeared to delay plant maturity for later harvests and increased plant digestibility (Coleman *et al.,* 2004). The results of the current study are agreement with other researches that suggested the linear effect of broiler litter on digestibility and on fiber concentration. The application of N in broiler litter increased nutritive value and fiber digestibility (Adeli *et al.*, 2005).

*Crude protein*

There was no difference between years for crude protein (Table 3). Compared with the unfertilized treatment, both fertilizer and broiler litter application increased the concentration and yield of crude protein (Fig. 8). The plants receiving lower values of nitrogen fertilizer had a lower crude protein concentration when compared with the other levels of nitrogen, which is similar to the results observed by Eghball and Power (1999).

Protein forage concentration showed a linear response to nitrogen levels. An increase in nitrogen in the form of broiler litter or urea fertilizer linearly improved the protein content (Table 3). The average crude protein concentration and protein yield were approximately 5% and 12% greater, respectively, for broiler litter than for commercial fertilizer application (Fig. 8 and 9). The nitrogen uptake from manure treatments increased the crude protein compared with chemical fertilizer. Broiler litter contains most of the secondary nutrients and micronutrients required for crop growth (Adeli *et al.*, 2015) and increase protein yield compare to commercial fertilizer and has a good availability of macro- and micro-nutrients along with N and by contrast, Abbasi *et al.* (2010) reported similar results when comparing poultry litter and urea fertilizer.

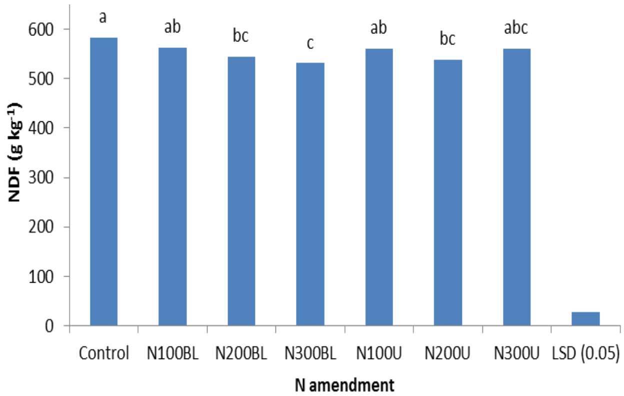


Fig. 6. The effects of N source and rate on NDF concentration of silage corn. Means with the different letters show significant difference (LSD, P ≤ 0.05). See Fig. 2 for abbreviations

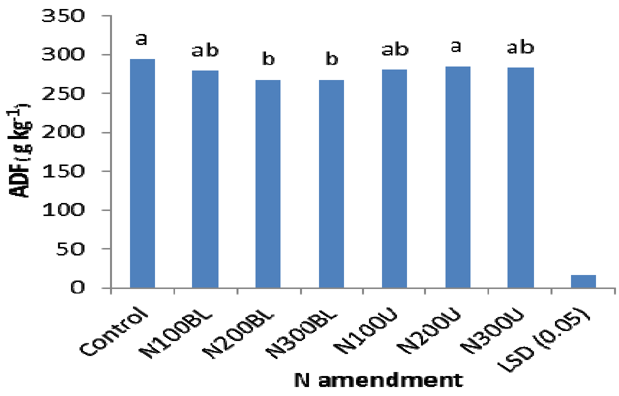


Fig. 7. The effects of N source and rate on ADF concentration of silage corn. Means with the different letters show significant difference (LSD, P ≤ 0.05). See Fig. 2 for abbreviations

Table 3. The effects of N source and rate on ADF, protein concentration, protein yield and aboveground dry matter of silage corn

| S.O.V | ADF† | Protein conc. | Protein yield | Aboveground dry matter |
|---|---|---|---|---|
| Year | NS‡ | NS | NS | NS |
| N amendment | ** | ** | ** | ** |
| Year × N amendment | NS | NS | NS | NS |
| Litter linear | ** | ** | ** | ** |
| Litter quadratic | NS | NS | NS | NS |
| Fertilizer linear | NS | ** | ** | ** |
| Fertilizer quadratic | NS | NS | NS | NS |

* Significant at P≤0.05. ** Significant at P≤0.01 probability level.
† ADF, Acide detergent fiber.
‡ NS, not significant

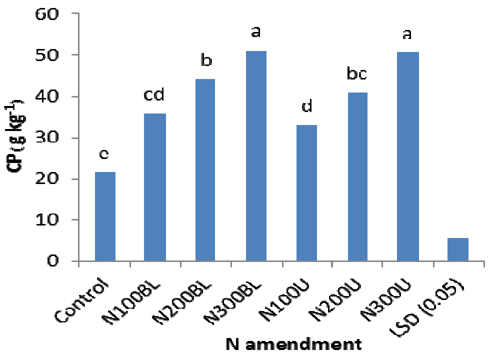


Fig. 8. The effects of N source and rate on crude protein (CP) concentration of silage corn. Means with the different letters show significant difference (LSD, P ≤ 0.05). See Fig. 2 for abbreviations

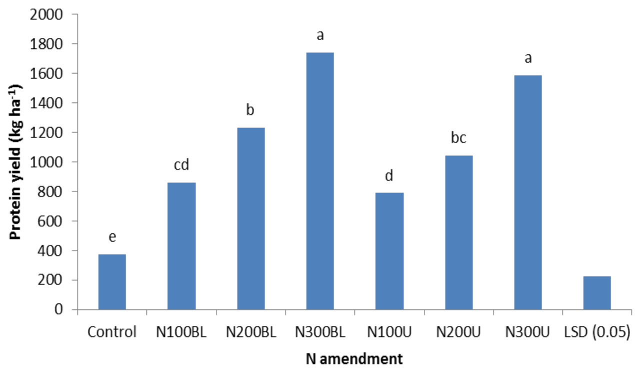


Fig. 9. The effects of N source and rate on protein yield concentration of silage corn. Means with the different letters show significant difference (LSD, P ≤ 0.05). See Fig. 2 for abbreviations

Corn crude protein concentration and yield increased significantly as broiler litter and commercial fertilizer applications increased (Table 3). The increase in crude protein concentration with increased nitrogen levels (Fig. 10) could be due to nitrogen application, which enhances amino acid formation.

Ruttunde *et al.* (2001) found that the nitrogen content of corn stover is an indicator of stover feed quality. The increase in nitrogen uptake of the stover with manure application means an improvement in the nutritive value of the stover, which in turn would have major implications for resource-poor farmers to whom corn is a major feed source for their animals. Montemurro *et al.* (2006) reported that the postanthesis N uptake was higher than N uptake during vegetative stages in maize (59.1 and 40.9% of the total N uptake, respectively). Conversely, continuous of manure N mineralization during the last phenological stages (Alizadeh *et al.*, 2012) strongly affected the process of N uptake and translocation.

*Dry matter*

The dry matter was significantly affected by soil nitrogen amendment. Both soil nitrogen amendment and nitrogen source significantly affected dry matter (Table 3). Average aboveground dry matter was approximately 11.4 and 1.5 Mg ha$^{-1}$ greater for broiler litter than unfertilized treatment and commercial fertilizer application, respectively (Fig. 10).

Although nitrogen supplied either as urea fertilizer or broiler litter significantly increased forage corn yield, the increased corn forage yield in broiler treatments could be the result of better utilization of nutrients by the crop. Subedi *et al.* (2006) indicated that forage yield increased exponentially with nitrogen rate and highest yield was obtained with 225 kg N ha$^{-1}$. In agreement with the results of this study, the remarkable effect of broiler litter application on corn yield could be associated to its favourable effect on soil physical and biological properties (Hati *et al.*, 2001; Sistani *et al.*, 2008). Broiler litter application as a soil amendment for corn provided appreciable forage with high dry matter. Similar results were found by Eghball and Power (1999), who observed that compost or manure application resulted in similar maize grain yield of mineral fertilizer and by Alizadeh *et al.* (2012), who reported that poultry manure could be used to sustain plant production in a calcareous soil.

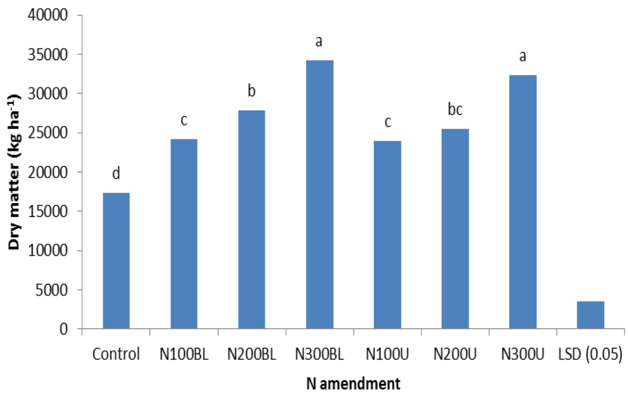


Fig. 10. The effects of N source and rate on dry matter concentration of silage corn. Means with the different letters show significant difference (LSD, P ≤ 0.05). See Fig. 2 for abbreviations

## Conclusions

The results suggested that nitrogen applied to forage corn through broiler litter at the recommended rate for inorganic N fertilization is almost as effective in terms of forage corn micronutrients as urea fertilizer. It can be concluded that the corn properties (micronutrients, protein, NDF, ADF) and forage yield of corn were affected by broiler litter application and the response was better at higher rates of broiler litter. Thus, broiler litter should be applied as an organic fertilizer to provide suitable corn production of suitable quality. The profitability of forage corn production might be increase by replacing chemical fertilizers with organic manure.

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