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# Yield and quality of forage corn (*Zea mays* L.) cultivar Single Cross 704 in response to nitrogen fertilization and plant density

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**Abstract**

**Abstract**

The producers of forage corn need more information on agronomic managements such as plant density and nitrogen fertilization. Therefore, a split-plot experiment was carried out to investigate the growth, yield and quality of forage corn (*Zea mays* L.) responses to nitrogen fertilization and plant density. The nitrogen treatment of the main plot included four levels 0, 75, 150 1nd 225 kg and the sub-plot was of plant density at three levels 75000, 100000 and 125000 plant $h^{-1}$. Plants harvested in the soft dough stage and plant height, stem diameter, cab weight, crude protein, protein yield, dry matter content and forage yield were determined. The results showed that plant height significantly affected by nitrogen treatment and nitrogen × plant density interaction. Nitrogen treatment, plant density and their interaction had significantly effect on stem diameter, crude protein, protein yield and forage yield as the highest amount was found in 150 and 225 kg nitrogen treatment with 100000 and 125000 plant $h^{-1}$ densities. Cab weight increased with increasing in amount of nitrogen treatment, whereas increasing of plant density reduced cab weight. Moreover, dry matter content significantly affected by nitrogen treatment and plant density had no affected on dry matter content. Overall, 150 and 225 kg nitrogen treatment with 100000 and 125000 plant $h^{-1}$ densities are recommended to obtaining higher fodder yield and quality of forage corn cultivar Single Cross 704.

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## Introduction

Corn (*Zea mays* L.) is a member of the family Poaceae. Based on area and production, corn is the 3rd most important cereal crop after wheat and rice in world. Corn is a plant that stores varied material such as starch, protein, fat and etc. in different organs. The crop has a wider range of uses including: human food, industrial processed food production of starch and used as forage to feed animals (Amin, 2011).

Corn is a high-yield, high-energy content and considerable protein amount, with lower labor and machinery requirements compared to other cereal forage crops. Corn is palatable, quick growing with a high dry matter production and is primary source of energy in dairy industry, that its high nutritive value is related to digestibility (Cusicanqui and Lauer, 1999).

Corn forage producers require more information on how nitrogen fertilization and plant density practices affect dry matter yield and forage quality. Forage corn responds differently to nitrogen fertilization and plant densities under different environmental and cultural factors which influence corn forage yield and quality (Çarpici *et al.,* 2010).

Among the agronomic factors that may affect the yield and quality of forage in cereal, the application of nitrogen is considered to be the most important (Tofinga, 1990; Amin, 2011). Nitrogen element is the nutrient that most frequently limits yield and plays an important role in quality of forage crops. It improved yield and protein contents of mixed forage (Iqbal *et al.*, 2006 and Ayub and Shoaib, 2009). Similarly Ayub *et al.* (2002a) reported that application of nitrogen to corn increase the nutritive value by increasing crude protein and by reducing ash fiber contents. Higher rates of nitrogen application reduced the number of effective nodules, increased the risk of lodging and encouraged diseases (Nannetti *et al.*, 1990).

Moreover, it was found that application of nitrogen gave a significant additional increase in crude protein contents of forage, grain protein content and protein content in corn straw (Amin, 2011).

On the other hand, plant density is very important parameters in crop production and paves the way for better-use of light, temperature, precipitation and other factors. There is an optimum plant density for each crop (Moosavi *et al.*, 2012). Also, it is possible that under low plant density, although single-plant production increased, yield per unit area decreases (Ghanbari and Taheri Mazandarani, 2003).

Plant deficit per unit area prevents maximum usage of production parameters and on the other hand, excessive density can increase the competition and decrease the yield. Plant density is of particular importance in corn, because it does not have tillering capacity to adjust to variation in plant stand. Cox and Cherney (2001) reported that increasing plant density increased dry matter yield of corn and the difference in dry matter yield between the two plant densities (32000 and 47000 plants/ac) was 13.7%. Maximum forage corn yields have also been reported at 79000 plants $ha^{-1}$ (Graybill *et al.*, 1991) and 100000 plants $ha^{-1}$ (Sparks, 1988).

Bangarwa *et al.* (1988) stated that generally, the yield of a single corn plant decreases with increasing plant population whereas the yield per unit area increases. Furthermore, Karlen *et al.* (1985) reported that total dry matter increases 6 to 40% when plant density increases from about 55000 to 88000 plants $ha^{-1}$.

Lucas (1986) reported that with increasing density, dry weight per unit area increases, where the highest density of dry matter yield significantly more than other densities and the highest yield was obtained at the highest plant density and plant density of 18000 plants per hectare would produce a minimum yield.
However, Widdicombe and Thelen (2002) reported that crude protein content of forage corn was negatively associated with plant densities, but some of the researchers found no statistical relation between crude protein content and plant densities (Patricio

Soto *et al.*, 2002).

In order to obtain higher forage yield in corn, it is important that recommendation for nitrogen fertilizer and appropriate plant density. So the present experiment is therefore designed to study the forage yield and quality of corn, growing in different nitrogen levels and plant densities.

## Materials and methods

*Description of experiments*

The field experiment was conducted during the 2013 growing season in Kermanshah province, Iran, at latitude of 34°16'24" N, longitude of 46°46'54" E and 1,374 m altitude. Textural analysis showed that the medium-textured soil contains pH of 7.8 and electrical conductivity of 0.7 mmos.

*Agronomic practices*

The experiment was arranged in a split-plot design where nitrogen treatment (75, 150 and 225 kg) was the main plot and plant density (750000, 100000 and 125000 plant $h^{-1}$) was randomized in each subplot. The plots were 42 $m^2$ with 4 rows as ridge and furrow with inter-row spacing of 75 cm and on-row inter-plant spacing of 20 cm. To decrease the marginal effects, the plots were separated by one 75-cm planting row and they were spaced 1.5 m apart.

During the growing season, nitrogen fertilization was applied at the planting time (50%) and when the plants reached the seven-to-nine true-leaf stage (50%). The plants were regularly irrigated during the season, water was supplied based on evaporative demand; meteorological data were recorded throughout the study.

Measurements were taken from plants harvested in the soft dough stage. Immediately after harvest, plant height (m), forage yield (ton $h^{-1}$), stem diameter (cm) and cab weight were determined. Samples were weighed (fresh weight) immediately; percentage of dry matter (%DM) was determined after 72 h drying (60 °C) using a ventilated oven. The protein content was determined by Kjeldahl's method.

*Statistical analysis*

Two-factorial field experiment established according to randomized split-plot design with three replications. Data were analyzed as a combined experiment model by PROC ANOVA procedure by SAS software (Ver. 9.1 2002–2003, SAS Institute, Cary, NC, USA). Before analysis of variance, data were tested for normality and homoscedasticity using the Kolmogorov–Smirnov and Cochran tests, respectively. Variance analysis and least significant difference (LSD) tests were performed at $P \leq 0.01$ to compare differences between means when F values were significant.

## Results

*Plant height*

As the table 1 illustrates, plant height significantly affected by nitrogen treatment and nitrogen × plant density interaction, but plant density had no significantly effect on plant height. It was obtained that along with increasing plant density, plant height decreased. Moreover, 150 and 225 kg nitrogen treatment had the highest plant height.

*Stem diameter*

Nitrogen treatment, plan density and their interaction had significantly ($P \leq 0.001$) effect on corn stem diameter (table 1). Generally, the highest stem diameter was found in 150 and 225 kg nitrogen treatment.

*Cab weight*

The results showed that cab weight significantly affected by nitrogen treatment, plan density and their interaction (table 1). It was revealed that cab weight increased along with increasing in amount of nitrogen treatment, also increasing of plant density reduced cab weight.

*Protein content*

Table 1 showed that nitrogen treatment, plan density and nitrogen × plant density interaction significantly affect crude protein content in corn. The highest crude protein content was obtained in 225 kg of nitrogen treatment.

*Protein yield*

Nitrogen treatment, plan density and their interaction had significantly effect on protein yield (figure 1). The highest protein yield was obtained in 150 and 225 kg nitrogen treatment with 100000 and 125000 plant $h^{-1}$ densities.

**Table 1.** Main effects *P*-values and means for plant height, stem diameter, cab weight and crude protein content of forage corn (*Zea mays* L.) cultivar Single Cross 704 growing in different nitrogen amounts and planting densities.

| | Nitrogen treatment (kg) | Planting densities (plant $h^{-1}$) | Plant height (m) | Stem diameter (cm) | Cab weight (g) | Crude protein (%) |
|---|---|---|---|---|---|---|
| Nitrogen (N) | | | 0.275 $^{**}$ | 1.67 $^{**}$ | 246 $^{**}$ | 5.17 $^{**}$ |
| Density (D) | | | 0.009 $^{ns}$ | 3.50 $^{**}$ | 355 $^{**}$ | 0.82 $^{*}$ |
| N × D | | | 0.020 $^{**}$ | 2.02 $^{**}$ | 30 $^{*}$ | 0.99 $^{**}$ |
| | 0 | 75000 | 1.92 d | 4.58 c | 44.33 e | 10.88 f |
| | | 100000 | 1.76 e | 6.55 b | 42.66 e | 11.20 ef |
| | | 125000 | 1.70 e | 7.50 ab | 41.93 e | 12.23 cd |
| | 75 | 75000 | 1.94 d | 6.60 b | 55.70 b | 12.48 bcd |
| | | 100000 | 2.09 abc | 7.26 ab | 45.93 de | 12.84 abc |
| | | 125000 | 2.02 cd | 7.37 ab | 42.00 e | 11.82 de |
| | 150 | 75000 | 2.07 bc | 7.64 a | 56.44 b | 11.90 ed |
| | | 100000 | 2.21 a | 7.53 ab | 45.08 de | 12.22 cd |
| | | 125000 | 2.18 a | 7.39 ab | 44.24 e | 13.24 ab |
| | 225 | 75000 | 2.17 ab | 7.56 a | 63.74 a | 13.34 a |
| | | 100000 | 2.20 a | 7.54 ab | 50.07 cd | 13.16 ab |
| | | 125000 | 2.15 ab | 7.34 ab | 53.26 bc | 13.38 a |

† ns, *, or ** indicates non-significant or significant at $P \leq 0.05$, or 0.01 respectively.

‡ Means within each column followed by the same letter are not different based on LSD test.

*Dry matter content*

Dry matter content significantly affected by nitrogen treatment, but plan density and nitrogen × plant density interaction had no significantly effect on dry matter content (figure 2). It was found that dry matter content increased with increasing in amount of nitrogen treatment, as the highest dry matter content was obtained in 150 and 225 kg nitrogen treatment.

*Forage yield*

As the figure 3 illustrates, nitrogen treatment, plan density and nitrogen × plant density interaction had significantly effect on forage yield. It was revealed that forage yield increased with increasing in amount of nitrogen treatment and plant density. The highest forage yield was found in 150 and 225 kg nitrogen treatment with 100000 and 125000 plant $h^{-1}$ densities.

**Discussion**

Among the various inputs that improve the efficiency of a cultivar in realizing its potential, fertilizers (nitrogen in particular) play a crucial role. To achieve economically viable returns, efficient use of available resources, like nitrogen, is necessary to maximize yields in all seasons (Usofzadeh *et al.*, 2013).

Nitrogen is an integral component of many compounds, including chlorophyll and enzymes, essential for plant growth processes. It is an essential component of amino acids and related proteins. Nitrogen is essential for carbohydrate use within plants and stimulates root growth and development as well as the uptake of other nutrients. This element encourages above ground vegetative growth and gives a deep green color to the leaves (Brady, 1990).

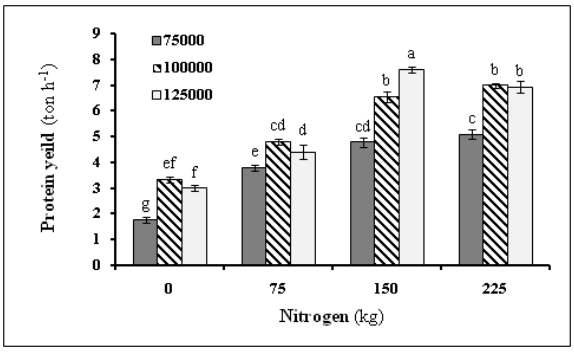


**Fig. 1.** Changes in protein yield of forage corn (*Zea mays* L.) cultivar Single Cross 704 growing in different nitrogen amount and planting densities.

Nitrogen application causes more photosynthetic area and leaves active growth and increases assimilate absorption and transmission due to leaf area improvement. The results for plan height and diameter are quite in line with those of Almodares *et al.* (2008) who showed that nitrogen fertilizer increased plant height and diameter. Nitrogen may affect plant growth through cell division and cell enlargement which consequently increase stem height and diameter (Stals and Inze, 2001).

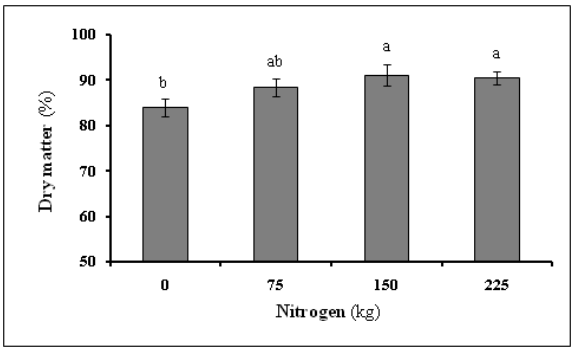


**Fig. 2.** Changes in dry matter content of forage corn (*Zea mays* L.) cultivar Single Cross 704 growing in different nitrogen amounts.

Positive response of nitrogen fertilizers has been reported by Omer (1998), Gasim (2001) and Sawi (1993). They observed that addition of nitrogen fertilizer increased plant height. Increase in plant height resulted in an increase in leaf number per plant as reported by Akintoye (1996). Gasim (2001) indicated that the increase in plant height with nitrogen fertilizer is due to the fact that nitrogen promotes plant growth, increases the number of internodes and length of the internodes which results in progressive increase in plant height.

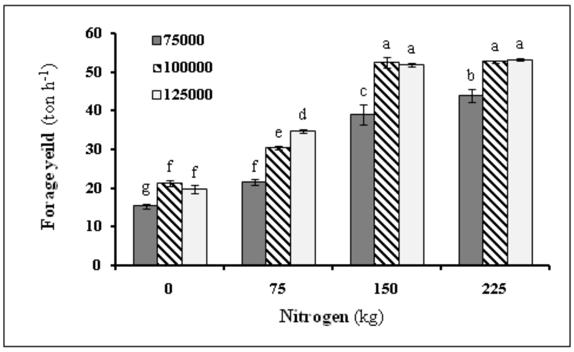


**Fig. 3.** Changes in forage yield of forage corn (*Zea mays* L.) cultivar Single Cross 704 growing in different nitrogen amount and planting densities.

These results are in agree with Koul (1997) who reported that nitrogen application resulted in greater values of plant height, leaf area, number of leaves and stem diameter of fodder maize. The improvement of vegetative characteristics (plant height, stem diameter and number of leaves) with increase in nitrogen fertilizer rate could be attributed to increased uptake of nitrogen and its associated role in chlorophyll synthesis and hence the process of photosynthesis and carbon dioxide assimilation leading to enhanced growth. In addition, nitrogen stimulates vegetative growth resulting in large stems and leaves (Jasso-chaverria *et al.*, 2005).

Nitrogen is a major element essential for synthesis of amino acids, nucleic acids and some organic acids. It is necessary for plant growth and development and its shortage reduces yield (Zhao *et al.*, 2005). Mahmud *et al.* (2003) reported that application of nitrogen increased crude protein, fodder and dry matter yield in forage sorghum. They also mentioned that plant nutrition may not only affect the forage production but also improve the quality of forage from view point of its protein contents. Also, Mullins *et al.* (1998) reported that, nitrogen fertilizer increased forge protein content in corn. The increase in protein contents with increasing in fertilizer levels may be the result of enhancement in amino acid formation due to fertilization.

Dry weight content by manure fertilization in all three years had the lowest value compared to other fertilizer treatments probably because of the small quantities of active substances (mineral elements) which are essential for the synthesis of organic compounds (Brandt and Molgaard, 2001).

The optimum density for optimal plant competition, plant with maximum use of light, water and nutrients, especially nitrogen, will produce higher dry matter with increasing plant density decreased tuber dry matter (Tahmorespour *et al.*, 2013). Plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants (Sangakkara *et al.*, 2004).

Because light is a directional and pre-emptable resource (Schwinning and Weiner 1998), plant height plays an important role in determining light interception and, hence, height may become a primary determinant of individual success in dense plant stands (Weiner and Fishman 1994). The phytochrome system of plants undergoes changes from red to far-red light ratios caused by shade and a plant's proximity to its neighbors (Ballaré 1999; Smith 2000), to which plants respond with increased height growth and decreased branching (Hutchings and de Kroon 1994; Whitelam *et al.*, 1992).

Several studies have shown that biomass yield decreases progressively as the number of plants increases in a given area because the production of the individual plant is reduced (Hamidia *et al.*, 2010). Edwards *et al.* (2005) reported dry matter accumulation increase for corn hybrids at high than at low density due to light interception. Leaf area index is major factor determining photosynthesis and dry matter accumulation (Moosavi *et al.*, 2012). Also, Al-Suhaibani (2011) stated that fresh and dry weights were increased at high plant density of Pearl Millet (*Pennisetum glaucum* L.) and high plant density produced the highest leaf area index.

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