

Hossein ZAKER ESFAHANI,

Hashem AMINPANAH, Homayoon DARKHAL GANDOMANI¹

EFFECT OF PLANTING DATE AND NITROGEN RATE ON YIELD AND QUALITY OF FORAGE CORN

SUMMARY

To study the effects of planting date and nitrogen rate on yield and quality of forage corn (*Zea mays* L. cv. SC704), an experiment was conducted in Isfahan, Iran, in 2011. Layout of the experiment was a factorial design with three randomized complete blocks. Factors were N rates (0, 50, 100, 150, and 200 kg ha⁻¹) and planting dates (14 June and 25 June). Result showed that fresh and dry forage yields were significantly increased by 137% and 115%, respectively, as N rate increased from 0 to 200 kg ha⁻¹. Fresh and dry forage yields were significantly higher in planting date of 25 June compared with planting date of 14 June. Regardless of planting date, total aboveground N and P uptake responded linearly to nitrogen rates. Averaged across planting dates, total aboveground N and P uptake were significantly increased by 4.4 and 6.1 times when N fertilization increased from 0 to 200 kg ha⁻¹. A delay in planting date from 14 June to 25 June increased significantly aboveground N and P uptake as averaged across N rates. Based on the results of this experiment, application of 200 kg N ha⁻¹ and planting date of 25 June are recommended for forage corn production in Isfahan.

Keywords: Nitrogen fertilizer, planting date, forage corn, yield

INTRODUCTION

Forage is an essential part of livestock's diet and provides adequate fiber that is utilize as a source of energy for maintenance, growth and performance of livestock. Of the numerous forage crops, forage corn is the most popular forages fed to dairy cows because of its high yield, high energy forage produced with relatively low labor and machinery requirements, and high concentrations of nutrients (Neylon and Kung, 2003).

Factors such as environmental conditions, cultural management, and genotypes could influence corn forage yield and quality. Corn forage producers require more information on how these factors affect dry matter yield and forage quality. Planting date is one of the most important cultural management factors determining the success of corn forage production. Farmers believe that planting

¹ Hossein Zaker Esfahani, Department of Agronomy, Guilan Science and Research Branch, Islamic Azad University, Guilan, Iran, Hashem Aminpanah (corresponding author: aminpanah@iaurasht.ac.ir), Department of Agronomy and Plant Breeding, Rasht Branch, Islamic Azad University, Rasht, Iran, Homayoon Darkhal Gandomani, Isfahan Agricultural and Natural Resources Research Center, Isfahan, Iran

corn for forage could be later than corn for grain because forage harvest does not have to wait until the grain matures fully (Allen *et al.*, 1995). Several studies have reported that planting date had a significant effect on dry matter content of forage corn (Fairey, 1983), dry matter digestibility (Fairey, 1983), fiber content of forage corn (Graybill *et al.*, 1991), and crude protein levels in wheat forage (Lyon *et al.*, 2001). Corn cultivars respond differently to planting dates (Lauer *et al.*, 1999). Hicks *et al.* (1970) reported an interaction between a hybrid's growing season length and optimum planting date, with a full-season hybrid benefiting most from an early planting date and also suffering the most from a delayed planting date. Therefore, it is important to determine the optimum planting date for corn (*Zea mays* L. cv. SC704) in Isfahan, Iran.

Nitrogen (N) is an essential nutrient for plant growth and development. Nitrogen fertilization is an important agronomic practice to obtain high corn forage yield and quality. Corn forage dry matter yield showed positive response to N fertilization. Increasing N rates from 0 to 200 kg ha⁻¹ increased corn forage yield (Sheaffer *et al.*, 2006). O'leary and Rehm (1990) reported that forage dry matter yields of maize responded linearly or quadratically to nitrogen rates depended on environmental conditions. The positive effects of nitrogen on dry matter yield and forage qualities have been reported by other researchers (Cox and Cherney, 2001; Keskin *et al.*, 2005; Sahar *et al.*, 2005). Nitrogen fertilization of corn affects dry matter yield by influencing leaf area index, leaf area duration and photosynthetic efficiency (Muchow, 1988). From a forage quality standpoint, Lawrence *et al.* (2008) reported forage crude protein concentration increased with N fertilization. Moreover, Sheaffer *et al.* (2006) showed nitrogen fertilization increased forage crude protein concentration, but had little effect on other forage quality components.

Very little work is reported on the combined effects of planting date and nitrogen rate on dry matter and quality of forage corn. Therefore, the objective of this research was to study the effects of planting date and N fertilizer and their interactions on forage corn yield and quality.

MATERIAL AND METHODS

A field experiment was conducted in Isfahan (51° 78' N, 32° 73' E; 1545 m above sea level), Iran, in 2011. The layout of the experiment was a factorial design with three randomized complete blocks. Factors were N rate (0, 50, 100, 150, and 200 kg ha⁻¹) and planting data (14 June and 25 June). Other than nitrogen application rate and planting date treatments, all plots were managed by practices similar to those used by producers in the surrounding area of that location. The previous crop was wheat which was harvested on 25 May 2011. Corn (*Zea mays* L. cv. SC704) seeds were sown in 27 m² plots (six rows × 6 m, with plant spacing 75 cm × 15 cm) at a depth of 5 cm. Out of total chemical N fertilizer, 1/2 of N, total P (25 kg P ha⁻¹ as triple superphosphate) were applied as basal, just before final land preparation. The rest amount of N was topdressed 40 days after planting. The crop was irrigated immediately after sowing and later as

required (irrigation after 75 mm evaporation from class A pan). Atrazine [2-chloro-4-ethylamino-6-isopropylamino-s-triazine] and Alachlor (2-Chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl) acetamide) were applied before sowing at the recommended rates, 1.3 kg ha⁻¹ and 5 l ha⁻¹ respectively, and remaining weeds were controlled manually during the experiment.

Corn was hand-harvested on 4 and 21 October 2011 for planting dates of 14 and 25 June, respectively. At harvesting stage, plant height was measured from the base of the plant to the top of the panicle in four random plants per plot. To measurement fresh and dry forage yields, a 4 m² sample from the center of each plot was randomly chosen, clipped at the ground level, weighed, and then dried at 70 °C for 7 days, and reweighed. Moreover, aboveground tissues were grounded to pass through a 1-mm sieve and N and P concentrations were determined. N concentration was determined using kjeldahl method as described by Horowitz (1970), and P using the spectrophotometric method of Lowry and Murphy and Riley (1962). Finally, aboveground N and P uptake were calculated by multiplying aboveground dry weight by N and P concentrations, respectively. Crude protein concentration was calculated by multiplying N concentration × 6.25, and then crude protein yield was calculated by multiplying crude protein concentration by dry forage yield.

Statistical analysis was conducted using SAS program (SAS Inst., 2004) and means were compared using Fisher's Protected LSD at the 0.05 probability level.

RESULTS AND DISCUSSION

Weekly temperatures (maximum, mean, and minimum) are shown in Figure 1. Soil properties (0-30 cm) of the experimental field was 1.37% organic matter content, 52% clay, 30% silt, 18% sand, 6.8 pH, 45.3 mg kg⁻¹ P₂O₅, and 339 mg kg⁻¹ K₂O.

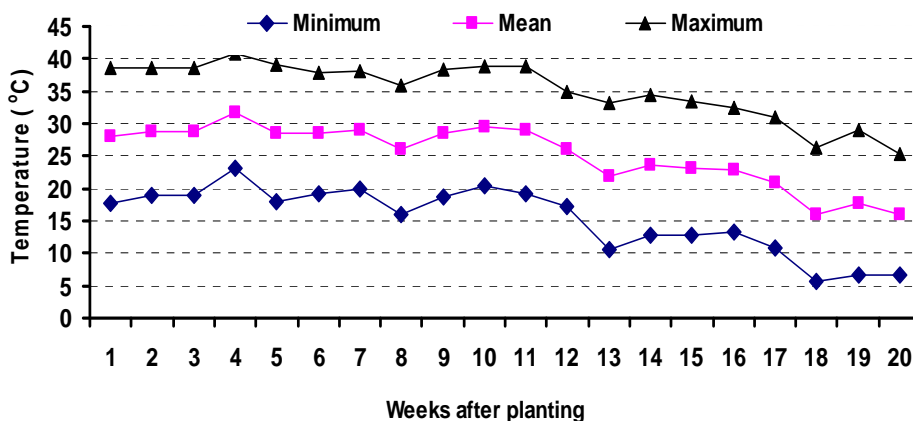


Figure 1. Weekly temperature during corn growing period in 2011 at the experimental site

Plant height

Plant height of corn was significantly affected by N rate, while the main effect of planting date and the interaction of N rate \times planting date were not significant for plant height (Table 1). A linear function provided the best description of plant height response to N fertilizer. Regardless of planting date, plant height increased by 32% for the 200 kg ha⁻¹ N rate over the 0 kg ha⁻¹ N rate (Figure 2). Increase in plant height with nitrogen application has also been reported by Carpici *et al.* (2010), who found a linear relationship between N rate and maize plant height and reported that plant height was 16 % higher at 400 kg N ha⁻¹ than at 0 kg N ha⁻¹. N is an essential nutrient for plant growth and, therefore, increase in plant height with increased N application might be primarily due to enhanced vegetative growth with more nitrogen supply to plant.

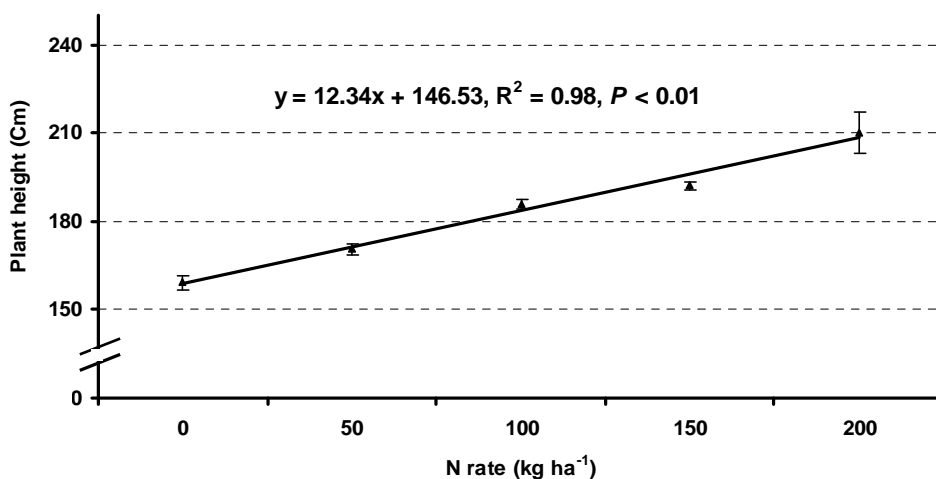


Figure 2. Effect of N rate on plant height as averaged across planting dates

Leaf area index and leaf number per plant

Main effect of N rate was significant for both leaf area index (LAI) and leaf number per plant (Table 1). Averaged across planting dates, LAI was linearly increased from 2.7 to 5.2 as N rate increased from 0 to 200 kg ha⁻¹ (Figure 3). Increase in LAI with increased N application can be due to greater leaf number per plant and leaf size with more nitrogen supply to plant. Cox *et al.* (2001) also reported that leaf area index of corn was increased as N rate increased, however they found that leaf area index of corn had a quadratic-plus-plateau response to N rates. A quadratic equation ($Y = -0.0979X^2 + 0.8681X + 12.7$, $R^2 = 0.88$) provided a good description of the relationship between leaf number per plant and nitrogen rate (Figure 4). Leaf number per plant was significantly increased from 13.3 to 14.2 as N application rate increased from 0 to 50 Kg ha⁻¹, whereas there was only a small rise in leaf number per plant at higher N rates (Figure 4). Main effect of planting date was significant only for

leaf number per plant. The plants were seeded on 25 June had greater leaf number compared with those were seeded on 14 June (Table 2). Bonaparte and Brawn (1976) reported increased leaf number with later planting. The interaction between N rate and planting date was not significant neither for leaf number per plant nor for LAI (Table 1), indicating that for both planting dates, plants showed similar response to N rate in terms of leaf number per plant and LAI.

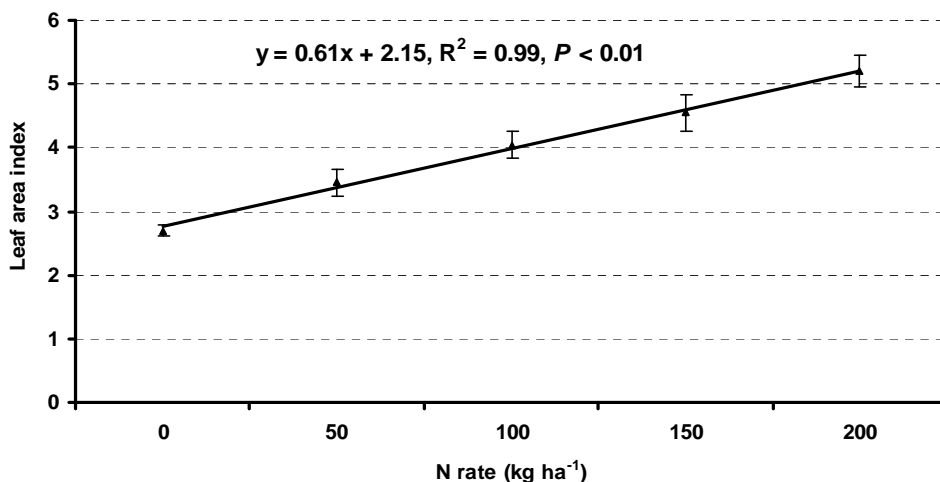


Figure 3. Effect of N rate on leaf area index as averaged across planting dates

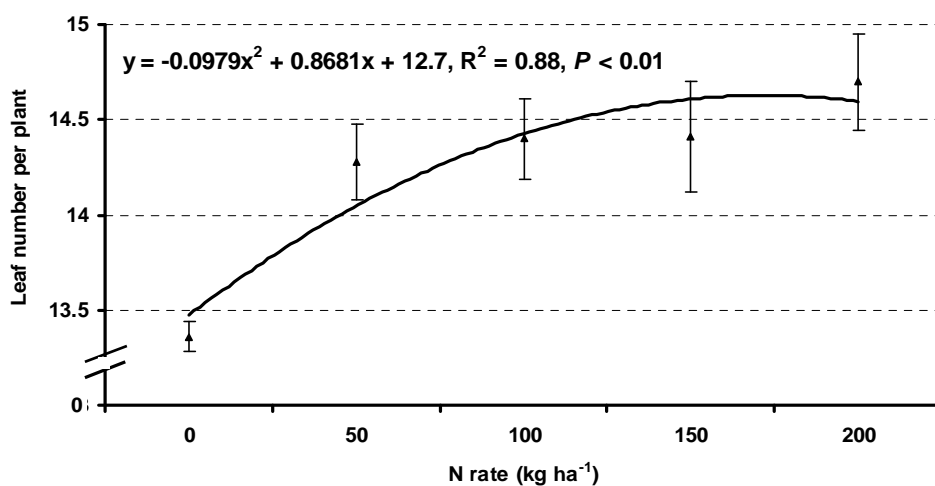


Figure 4. Effect of N rate on leaf number per plant as averaged across planting dates

Table 1. Mean squares for plant height (H), leaf area index (LAI), leaf number (LN), fresh forage yield (FFY), dry forage weight (DFY), aboveground N concentration (ANC), aboveground N uptake (ANU), aboveground P concentration (APC), aboveground P uptake (APU), protein concentration (PC), and protein yield (PY) as affected by N rate (N) and planting date (P).

Sources of variation	df	H	LAI	LN	FFY	DFY	ANC	ANU	APC	APU	PC	PY
Block (R)	2	943 ^{ns}	1.46 ^{**}	0.2 ^{ns}	0.2 ^{ns}	1.3 ^{ns}	0.0833 ^{**}	3240 ^{**}	0.020 ^{**}	671 ^{**}	2.67 ^{**}	107145 ^{**}
Nitrogen rate (N)	4	4611 ^{**}	5.60 ^{**}	1.5 ^{**}	480 ^{**}	128 ^{**}	0.5949 ^{**}	60516 ^{**}	0.043 ^{**}	3479 ^{**}	19.61 ^{**}	2000836 ^{**}
Planting date (P)	1	1851 ^{ns}	0.02 ^{ns}	2.7 ^{**}	125 ^{**}	12 ^{**}	0.0001 ^{ns}	1454 ^{**}	0.001 ^{ns}	200 [*]	0.001 ^{ns}	48069 ^{**}
N × P	4	706 ^{ns}	0.09 ^{ns}	0.3 ^{ns}	0.7 ^{ns}	0.7 ^{ns}	0.0006 ^{ns}	104 ^{ns}	0.0002 ^{ns}	12 ^{ns}	0.020 ^{ns}	3446 ^{ns}
Error	18	710	0.21	0.3	0.5	0.4	0.0076	190	0.001	35	0.247	6285
CV (%)	-	14.8	11.6	3.7	10.6	4.2	8.2	7.5	15.4	14.2	8.1	7.5

* and ** represent significance at 0.05 and 0.01 probability levels, respectively.

ns represent non-significance.

Table 2. Effect of planting date on plant height (H), leaf area index (LAI), leaf number per plant (LN), fresh forage weight (FFW), dry forage weight (DFW), aboveground N concentration (ANC), aboveground N uptake (ANU), aboveground P concentration (APC), aboveground P uptake (APU), protein concentration (PC), and protein yield (PY) as averaged across N rates

Planting dates	Traits	H (cm)	LAI	LN (No. plant ⁻¹)	FFW (kg ha ⁻¹)	DFW (kg ha ⁻¹)	ANC (%)	ANU (kg ha ⁻¹)	APC (%)	APU (kg ha ⁻¹)	PC (%)	PY (kg ha ⁻¹)
14 June		180	3.96	13.9	65653	15385	1.07	175.7	0.23	39.1	6.15	1010.5
25 June		185	4.01	14.5	69740	16669	1.06	189.6	0.24	44.2	6.14	1090.6
LSD (0.05)		20	0.35	0.4	552	520	0.06	10.5	0.02	4.5	0.38	60.8

Fresh and dry forage yields

Main effects of N rate and planting date were significant for fresh and dry forage yields, but the interaction of N rate \times planting date was not significant (Table 1). Fresh and dry forage yields responded linearly to nitrogen rate and increased by 137% and 115%, respectively, as N rate increased from 0 to 200 kg ha⁻¹ (Figures 5 and 6).

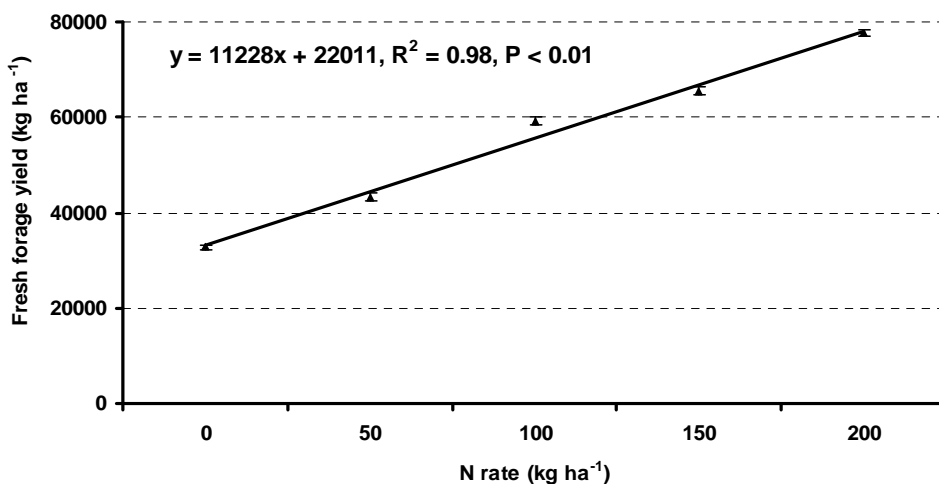


Figure 5. Effect of N rate on fresh forage yield as averaged across planting dates

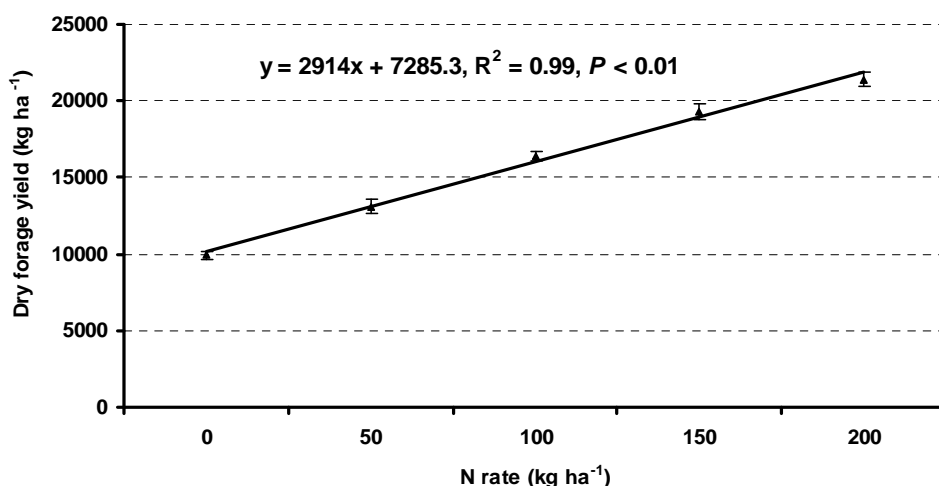


Figure 6. Effect of N rate on dry forage yield as averaged across planting dates

The highest fresh and dry forage yields (77750 and 32747 kg ha⁻¹, respectively) were recorded when nitrogen was applied at the rate of 200 kg ha⁻¹, while the lowest ones (54800 and 9923 kg ha⁻¹, respectively) were recorded when

nitrogen was not applied. This result is consistent with the finding of Sheaffer *et al.* (2006) who reported that N fertilization increased significantly corn dry matter yield, however they found a quadratic relationship between corn dry matter and N rate. A significant positive correlation was observed between dry yield and leaf area index (Figure 7). N fertilization results in increased crop leaf area and light interception, which in turn increased plant photosynthesis and dry matter accumulation. At the same time, the response of leaf photosynthesis to irradiance is largely dependent on the leaf N content. Photosynthetic proteins (Rubisco and light harvesting complex proteins) represent a large proportion of total leaf N. It has been reported that leaf photosynthesis rate increases either linearly, or asymptotically, with leaf N content (Evans, 1989). Therefore, increased crop leaf area and leaf N content due to N fertilization may enhance dry matter accumulation. Fresh and dry forage yields increased by 6 and 8%, respectively, as planting date went from 14 to 25 June (Table 2). Darby and Lauer (2002) found a positive or negative linear relationship between dry matter yield and planting date depend on production zones. Higher night temperatures during final growth stage of corn in planting date of 15 June compared with the planting date of 25 June may cause a significant increase in respiration rates, which result in a reduction in leaf and stem carbohydrate content. As carbohydrates are considered to be the basic building components for the majority of crops, it seems that detrimental effect of high night temperatures on the consumption of carbohydrates will have a significantly negative effect on yield.

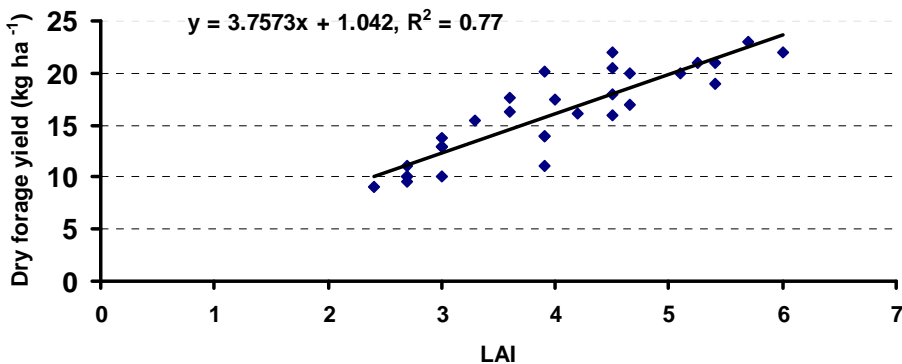


Figure 7. Relationship between leaf area index and dry forage yield. Data correspond to five N rates and two planting dates

Aboveground N concentration and uptake

N rate had significant effect ($P < 0.01$) on aboveground N concentration and uptake, while planting date effect was significant only for aboveground N uptake (Table 1). Moreover, N rate \times planting date interaction was significant neither for aboveground N concentration nor for aboveground N uptake (Table 1). Aboveground N concentration and uptake of corn responded linearly to

nitrogen rates (Figure 8 and 9). Averaged across N rates, aboveground N concentration increased from 0.72 to 1.49% when N rate increased from 0 to 200 kg ha⁻¹ (Figure 8). Regardless of planting date, increasing N rates from 0 to 200 kg ha⁻¹ increased linearly aboveground N uptake from 72.2 to 318.6 kg ha⁻¹ (Figure 9). Cox *et al.* (2001) reported that N accumulation at harvesting stage had linear or quadratic response to N rates depending on row spacing. Corn plants seeded on 25 July had greater aboveground N uptake compared with those seeded on 14 July (Table 2), primarily due to greater dry matter production in planting date of 25 June rather than of 14 June.

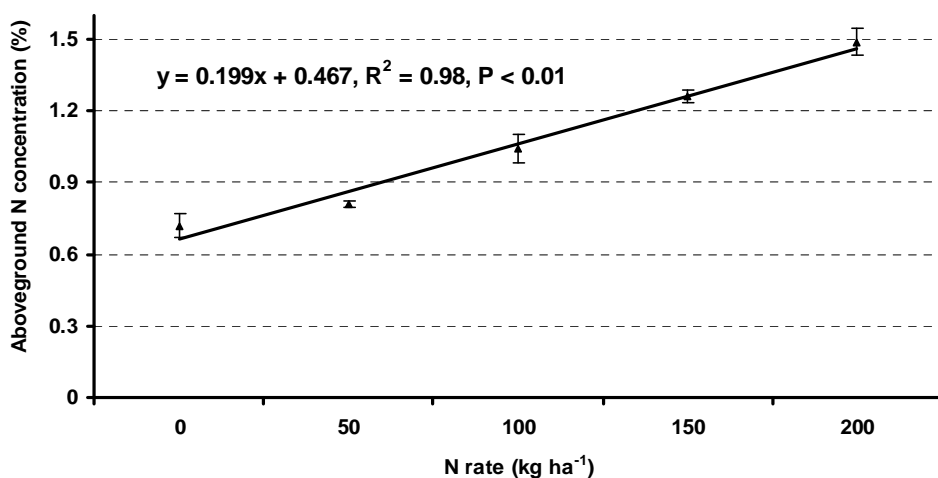


Figure 8. Effect of N rate on aboveground N concentration as averaged across planting dates

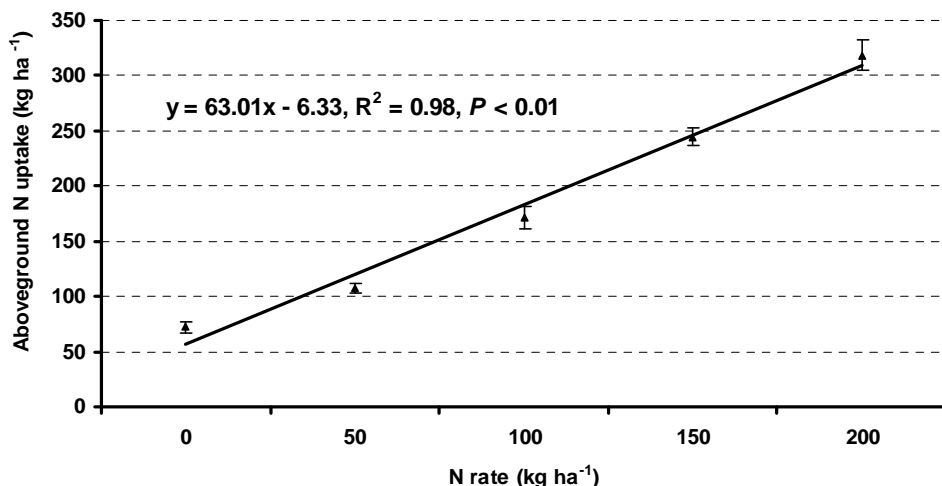


Figure 9. Effect of N rate on aboveground N uptake as averaged across planting dates

Aboveground P concentration and uptake

Aboveground P concentration and uptake were significantly affected by N rate ($P < 0.01$), while Planting date effect was significant ($P < 0.01$) only for aboveground P uptake (Table 1). Also, the interaction between N rate and planting date was significant neither for aboveground P concentration nor for aboveground P uptake (Table 1). There was a significant quadratic increase in aboveground P concentration in response to N fertilization, while a linear function provided the best description of aboveground P uptake response to N fertilizer. Regardless of planting date, aboveground P concentration was significantly increased from 0.12 to 0.29% as N rate increased from 0 to 150 kg ha⁻¹, but thereafter remained constant (Figure 10).

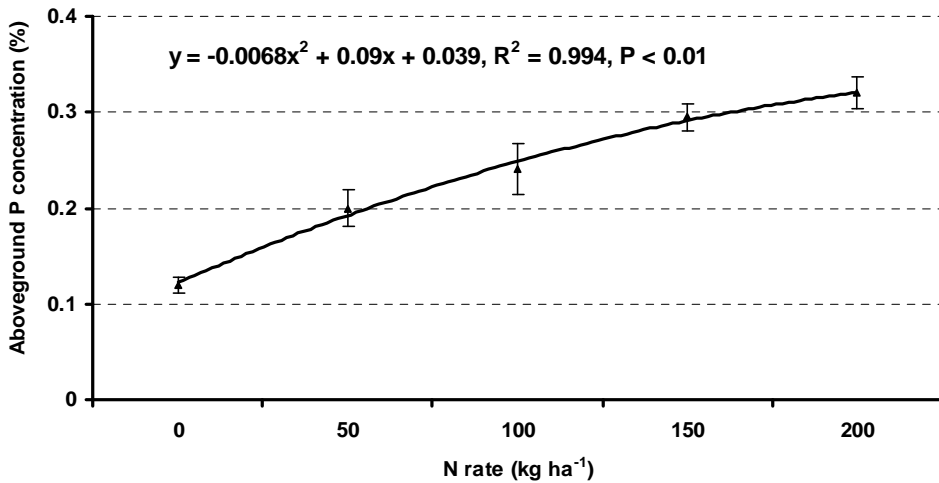


Figure 10. Effect of N rate on aboveground P concentration as averaged across planting dates

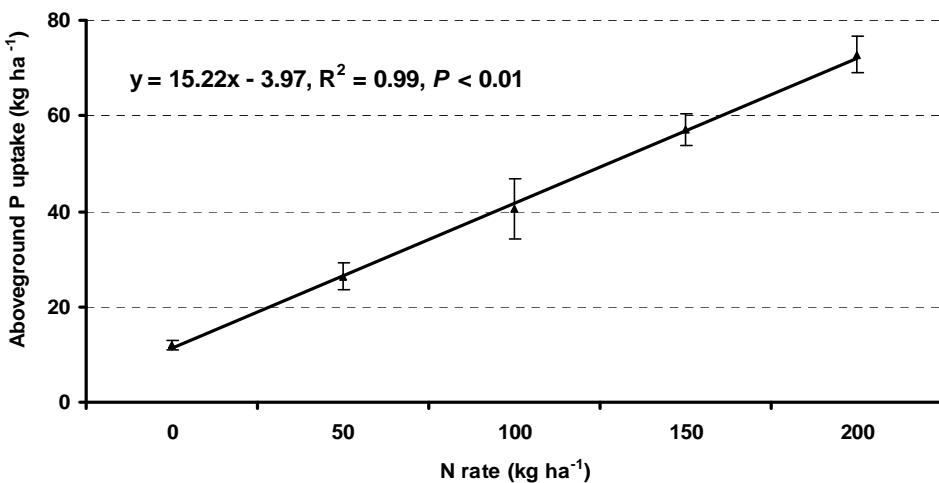


Figure 11. Effect of N rate on aboveground P uptake as averaged across planting dates

At the same time, aboveground P uptake was significantly increased from 11.9 to 72.7 kg ha⁻¹ when N fertilization increased from 0 to 200 kg ha⁻¹ as averaged across planting dates (Figure 11). A delay in planting time from 14 June to 25 Jun increased significantly aboveground P uptake by 5.1 kg ha⁻¹ when averaged across N rates (Table 2). The greater aboveground P uptake in planting date of 25 June is mainly attributed to greater dry matter production in planting date of 25 June compared with 14 June.

Aboveground protein concentration and Protein yield

Main effect of N rate was significant for both aboveground protein concentration and protein yield, while planting date main effects was statistically significant only for protein yield (Table 1). Moreover, the interaction effect between N rate and planting date was statistically significant neither for aboveground protein concentration nor for protein yield (Table 1). Regardless of planting date, aboveground protein concentration was linearly increased from 4.19 to 8.56% as N rate increased from 0 to 200 kg ha⁻¹ (Figure 12). Similarly, protein yield was significantly increased from 415.5 to 1832.4 kg ha⁻¹ with increasing N rate from 0 to 200 kg ha⁻¹ when averaged across planting dates (Figure 13).

This result is consistent with that obtained by Sheaffer *et al.* (2006) who found a significant linear increase in forage protein concentration in response to N fertilization. At the same time, Cox *et al.* (2001) declared that forage protein concentration had a quadratic-plus-plateau response to N fertilization. Regardless of N rate, planting date of 25 June provided greater protein yield compared with 14 June (Table 2), which is mainly contributed to greater dry matter accumulation at later planting date (25 June).

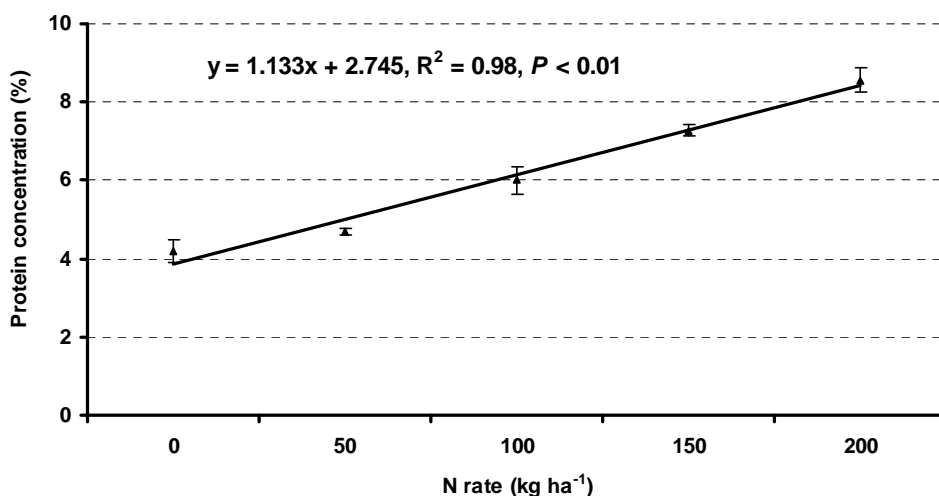


Figure 12. Effect of N rate on protein percent as averaged across planting dates

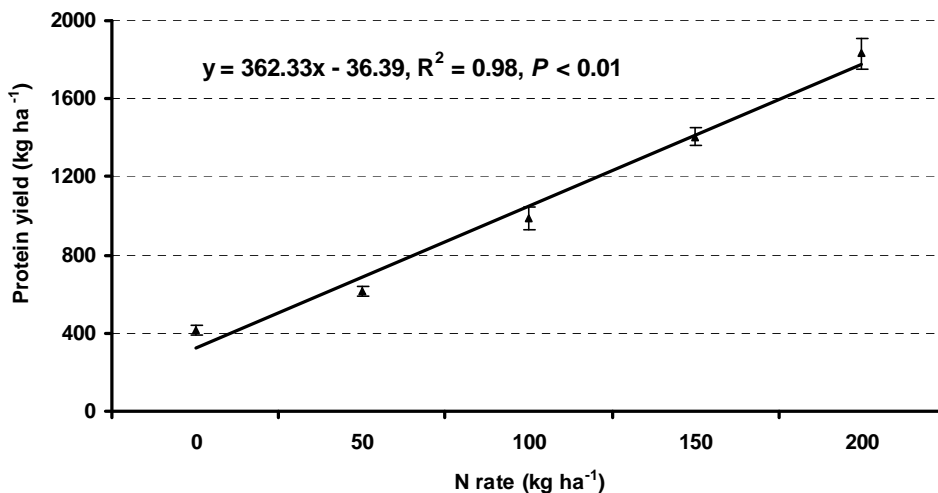


Figure 13. Effect of N rate on protein yield as averaged across planting dates

CONCLUSIONS

Forage corn yield, total aboveground N and P uptake, and protein yield were significantly affected by N rate and Planting date. Regardless of planting date, forage yield, total aboveground N and P uptake, and protein yield responded linearly to nitrogen rates. Regardless of N rate, planting date of 25 June provided greater forage yield total, aboveground N and P uptake, and protein yield compared with planting date of 14 June. To obtain the highest quantity and quality of forage corn, application of 200 kg N ha⁻¹ and planting date of 25 June are suggested to produce forage corn in Isfahan.

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***Hossein ZAKER ESFAHANI ,
Hashem AMINPANAHI , Homayoon DARKHAL GANDOMAN***

**UTICAJ DATUMA SADNJE I NIVOAA AZOTA
NA PRINOS I KVALITET STOČNOG KUKURUZA**

SAŽETAK

U cilju proučavanja uticaja datuma sadnje i nivoa azota na prinos i kvalitet stočnog kukuruza (*Zea mays* L. cv. SC704), tokom 2011. godine postavljen je ogled u Isfahanu, u Iranu kao faktorski sa tri slučajna bloka. Faktori su obuhvatili nivoe N (0, 50, 100, 150, i 200 kg ha⁻¹) i datume sadnje (14. jun i 25. jun). Rezultati su pokazali da je svjež i suvi prinos stočne hrane je značajno porastao za 137%, odnosno, 115%, kako se nivo N povećavao sa 0 do 200 kg ha⁻¹. Prinos svježe i suve stočne hrane bio je značajno veći kod datuma sadnje 25. Juna u odnosu na datum sadnje 14. Juna. Bez obzira na datum sadnje, ukupan unos N i P sa površine značajno je povećan 4,4, odnosno 6,1 puta kada je prihrana zemljišta sa N povećana sa 0 na 200 kg ha⁻¹. Odlaganje datuma sadnje od 14. juna za 25. jun značajno je povećala unos N i P sa površine kao uprosječene vrijednosti N. Na osnovu rezultata ovog ogleda, za proizvodnju stočnog kukuruza u Isfahanu preporučuje se primjena 200 kg N ha⁻¹ i sadnja od 25. juna.

Ključne riječi: azotno đubrivo, datum sadnje, stočni kukuruz, prinos