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ORIGINAL ARTICLE

Plant density and Nitrogen Effects on Quality and Quantity traits of Forage Sorghum

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ABSTRACT
A field experiment was carried out to investigate the efficacy of various plant densities and nitrogen applications on quantitative and qualitative traits of forage sorghum as factorial set of treatments based on randomized complete block design with three replications in 2010. Two factors included plant density at levels of 15, 20, 25 and 30 plants/m² and nitrogen application at levels of full dose of nitrogen without split at sowing date, nitrogen application at two equal splits of 1/2 at planting time+1/2 at the first cutting and nitrogen application at three equal splits of 1/3 at planting time + 1/3 at the tillering stage + 1/3 at the first cutting. The recommended dose of nitrogen (full dose) was 100kg.ha^{-1}. The tillers per plant were decreased as plant density increased, so between two cuttings, maximum tillers per plant were obtained in the second cutting with density of 15 plants/m². The highest fresh forage weight and percentage of crude protein (CP) in the whole of cuttings, were achieved at the density of 15 plants/m², nitrogen application in full dose without split for the first cutting. Also the first cutting had more dry forage weight than the second cutting. The lowest percentage of neutral detergent fiber (NDF) in the whole of cuttings was related to the density of 20 plants/m² in the first cutting and nitrogen application in three splits.
Keywords: *cutting, density, forage sorghum, nitrogen application.*

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INTRODUCTION

Forage sorghum is one of the valuable crops due to it's compatibility to dry conditions and water deficit. Also it has high water use efficiency (because of C_4 photosynthesis system), fresh, dry and silage forage production, diversity in varieties and productive hybrids [1]. Among agronomic factors, plant density plays an important role in the absorption of solar energy via crop canopy that affects yield per plant and unit area [2]. The optimum density ensures proper growth in aerial and underground parts of crops through the different utilization of solar radiation and nutrition [3]. Scheduling of nitrogen application is an important management tool in order to achieve suitable crop yield [4]. Based on nitrogen mobility and leaching, it is recommended that this macro-element be used in several phases [5]. Non-management of this element causes to environmental damages including groundwater contamination [6]. Nitrogen is the essential element in sorghum production [7], and sorghum strongly indicates response to the application of nitrogen, even in low dosage [8]. Kohanmou and Mazaheri [9] suggested three-phase distribution of nitrogen in forage sorghum production. Crop dry matter, as considerable criteria in crop performance assessing is related to the crop density and exploitation of solar source [10]. High densities of crops produce remarkable dry matter, because by adding the crop density, biomass production is relatively increasing in linear mode [11]. Plant density is an impressive factor in the tillering capacity [12]. Tillering and creating the side branches are important compensatory mechanisms in forage sorghum yield [13,14]. By adding plant density, the number of tillers are being significantly reduced, because in compact cropping systems, the amount of assimilates in the bottom of canopy are being decreased [15].

Protein requirements for livestock usually are expressed as Crude Protein (CP) [16], which is the sum of true protein and non-protein nitrogen [17,18]. Neutral Detergent Fiber (NDF) represents all of the structural or cell wall mineral of forage such as lignin, hemi-cellulose and cellulose. The NDF of forage is inversely related to ability of animal to consume of forage, thus the forages with low NDF have higher intakes than those with high NDF [17,18,19]. Therefore, the objectives of this study were to evaluate the forage sorghum quantity and quality traits under split application of nitrogen and various densities.

MATERIALS AND METHODS

The field experiment was conducted at the research station (Lattitude 38° 15´ N, Longitude 46°17´E and Altitude 1360 m) of the of Faculty of Agriculture, University of Tabriz, Tabriz-Iran during of 2010 growing season. The soil was sandy loam with pH 7.96, 0.66% and 0.03% organic matter and total nitrogen in the soil (0-30 depth), respectively. The treatments included plant density at levels of 15, 20, 25 and 30 plants/m^2 and nitrogen application at levels of full dose of nitrogen without split with planting time application (N_1), nitrogen application at two equal splits as 1/2 at planting time+1/2 at first cutting (N_2) and nitrogen application at three equal splits as 1/3 at planting time + 1/3 at tillering stage + 1/3 at first cutting (N_3). The experimental plot size was 5×2.5 m^2. The row spacing was 50 cm. The plots were irrigated as needed. A basal dose of 100 kg N. ha^{-1} was applied in the form of urea. Data on tiller were recorded from 10 randomly selected plants each plot. Fresh biomass of sorghum (*Sorghum bicolor* var. Speed feed) was determined before drying from area 2m^2 for each plot in floral initiation stage. Thereafter, the forage dry matter was measured after drying at 75 ˚C for 48 h. The forage-dried samples were ground in a cyclone mill to pass a 1 mm screen for chemical analysis. The samples were analyzed for CP and NDF. The N concentration was measured using the kjeldahl method and then, the CP was achieved by N multiplied to 6.25. NDF was determined using the Van Soest procedure [20]. Data were subjected to analysis of variance as factorial and factorial-split-plot experiment based on randomized complete block design for first and second cutting of sorghum, individually, and both cutting together, respectively at three replications by MSTAT-C and SAS statistical softwares and means were compared with Duncan's multiple range test at 0.05 probabilities.

Results and Discussion

Quantity traits of forage sorghum

Data analysis indicated that the numbers of tillers per plant in first and second cuttings were significantly affected by plant density (Table 1). In the first and second cuttings, the number of tillers per plant was decreased as plant density increased, so the maximum and minimum tillers per plant were obtained at densities of 15 and 30 plants/m^2, respectively (Fig. 1, 2). Interaction effect of density*cutting was significant ($p<0.01$) for the number of tillers per plant in total cuttings (In this experiment, data based on analysis of variance related to first and second cutting of forage sorghum together or total cutting not shown). Between two cuttings of sorghum, maximum tillers per plant were obtained in second cutting and density of 15 plants/m^2 (Fig.3). Ferraris and Charles [15] showed that suppression the number of tillers per plant in intensive cultivation is led from some physiological effects such as accumulation of assimilates in the above ground of canopy that are used in order to development of aerial parts of plants. Increased competition in intensive cultivation of forage sorghum can reduce the number of tillers per plant [21]. It seems that cross section of stem in forage sorghum causes to increase in tillering ability.

Fresh forage weight in first and second cutting was significantly affected by nitrogen application and plant density, respectively (Table 1). Among nitrogen application levels in the first cutting, full dose of nitrogen without split showed the maximum fresh forage weight, but there was negligible difference between full dose of nitrogen application without split and nitrogen application in three splits (Fig. 4). In the second cutting, the highest and the lowest fresh forage weight of sorghum were sequentially obtained from densities of 15 and 30 plants/m^2. By increasing sorghum density from 15 up to 20 and 25 up to 30 plants/m^2, fresh forage weight was decreased slightly, but the difference between them was insignificant, respectively (Fig. 5).

Data analysis indicated that effects of cutting, nitrogen application and density on fresh forage weight in total cutting were significant ($p<0.01$) (data not shown). According to the mean comparisons, the highest and the lowest fresh forage weight of sorghum in total cutting related to densities of 15 and 30 plants/m^2 (Fig. 6).

Table 1. Analysis of variance of forage sorghum quantity and quality traits.

		Mean squares					
		Number of tillers per plant		Fresh forage weight		Dry forage weight	
Source	df	First cutting	Second cutting	First cutting	Second cutting	First cutting	Second cutting
Rep	2	0.03ns	30.518ns	363837.72ns	17941.29ns	34815.252ns	1731.99**
Density	3	12.28**	1244.73**	340325.518ns	222952.03**	66959.184ns	12702.90**
Nitrogen	2	0.055ns	6.055ns	1182209.91**	5061.65ns	45456.214ns	130.79ns
Density*Nitrogen	6	0.19ns	24.27ns	314428.09ns	7757.74ns	79012.138ns	714.42ns
E	22	0.208	27.415	154132.21	10546.8	36862.12	460.73
CV%	-	13.603	14.58	10.88	12.15	22.42	10.87

		Mean squares			
		Crude Protein percentage (CP%)		Neutral Detergent Fiber percentage (NDF%)	
Source	df	First cutting	Second cutting	First cutting	Second cutting
Rep	2	0.227ns	0.084ns	0.038ns	0.043ns
Density	3	3.166**	0.12ns	1.522**	38.2**
Nitrogen	2	3.575**	3.305**	4.068**	17.336**
Density*Nitrogen	6	0.407**	0.59**	6.269**	10.383**
E	22	0.055	0.086	0.088	0.076
CV%	-	1.942	3.68	0.51	0.41

Ns: non significant at 0.05 probability level. * and ** significant at p<0.05 and p<0.01, respectively.

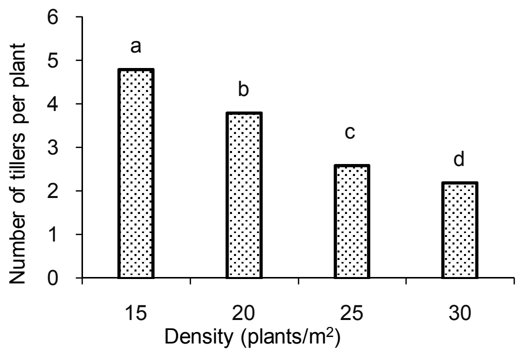

Figure 1: Mean number of tillers per plant at different densities in first cutting. Different letters indicating significant difference at at p≤0.05.

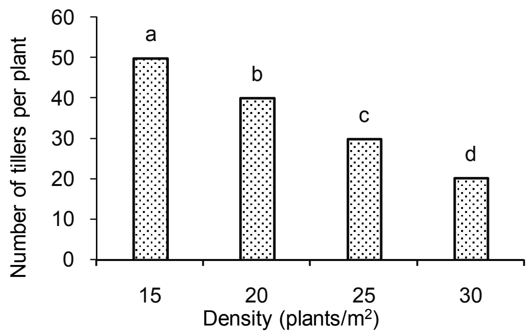

Figure 2: Mean number of tillers per plant at different densities in second cutting. Different letters indicating significant difference at p≤0.05

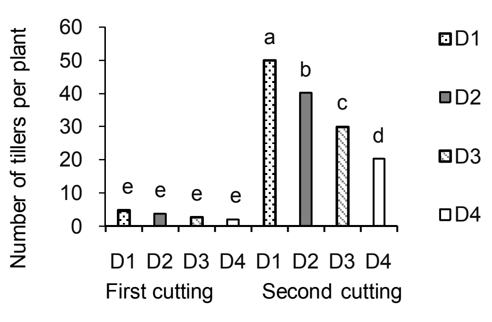

Figure 3: Mean number of tillers per plant at different densities in total of two cutting. D_1, D_2, D_3 and D_4: density of 15, 20, 25 and 30 plants/m^2, respectively. Different letters indicating significant difference at p≤0.05.

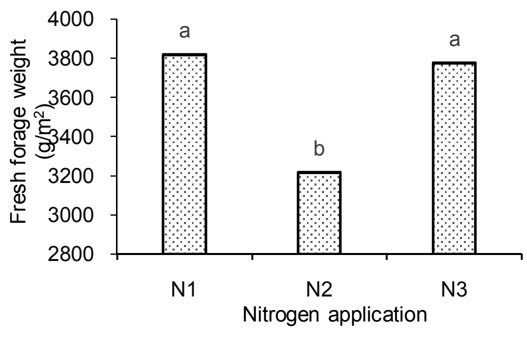

Figure 4: Mean of fresh forage weight at levels of nitrogen application in first cutting. N_1: nitrogen application in full dose without split, N_2: nitrogen application in two splits, N_3: nitrogen application in three splits. Different letters indicating significant difference at p≤0.05.

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In this experiment, among nitrogen treatments in total cutting, nitrogen application in full dose without split had the great fresh forage weight (2340 g/m²), but full dose of nitrogen without split didn't have as much significant difference as the nitrogen application in three splits (2295 g/m²) (Fig. 7). Considerably, based on total cutting comparisons, the first cutting of sorghum caused to significant increasing in fresh forage weight compared to the second cutting (Fig. 8).

Figure 5: Mean of fresh forage weight at different densities in second cutting. Different letters indicating significant difference at p≤0.05.

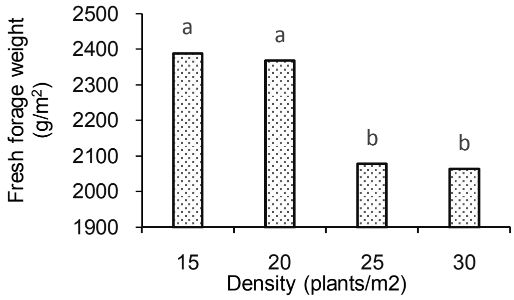

Figure 6: Mean of fresh forage weight at different densities in total of two cutting. Different letters indicating significant difference at p≤0.05.

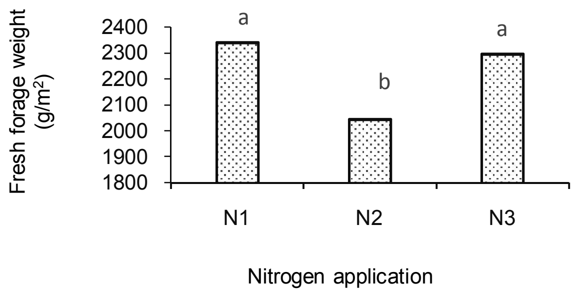

Figure 7: Mean of fresh forage weight at levels of nitrogen application in two cutting. N_1: nitrogen application in full dose without split, N_2: nitrogen application in two splits, N_3: nitrogen application in three splits. Different letters indicating significant difference at p≤0.05.

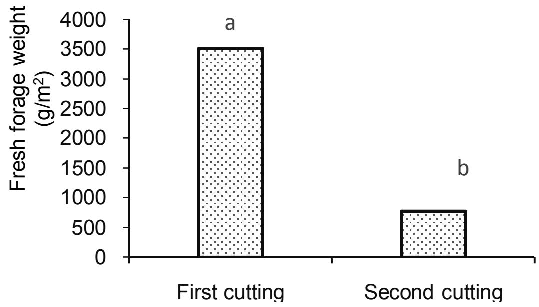

Figure 8: Mean of fresh forage weight in two cutting. Different letters indicating significant difference at p≤0.05.

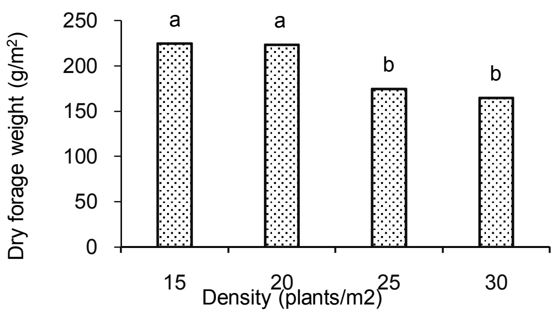

Figure 9: Mean of dry forage weight at different densities in second cutting. Different letters indicating significant difference at p≤0.05.

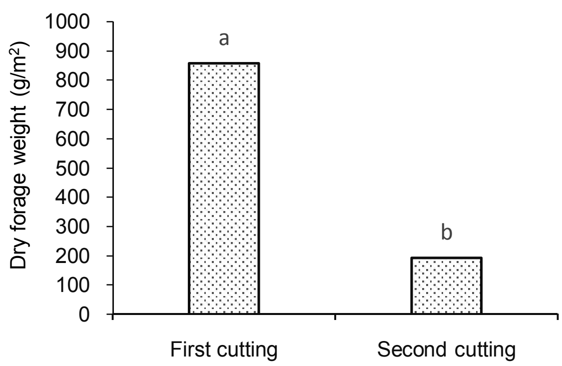

Figure 10: Mean of dry forage weight at different densities in two cutting. Different letters indicating significant difference at p≤0.05.

Motiee [22] and Kohanmou and Mazaheri [9] suggested three splits of nitrogen application for the forage sorghum. Mascadni and Helmz [23] stated that full dose of nitrogen without split can produce the maximum sorghum forage yield.

In the first cutting, none of the factors had significant effect on dry forage weight, but in the second cutting it was significantly affected by plant density (Table 1). Generally, the major and the minor dry forage weight of sorghum were observed at densities of 15 and 30 plants/m^2, respectively (Fig. 9). A significant positive influence on forage yield in sorghum was observed at low densities of sorghum in comparison with high densities, because low densities of sorghum significantly increased the number of tillers per plant that can compensate the fewer number of plants per unit area. The effect of cutting in total cutting analysis on dry forage weight was significant ($p<0.01$) (data not shown). The obtained Results from mean comparisons in total cutting revealed that first cutting (860 g/m^2) had more dry forage weight than second cutting (185g/m^2) (Fig. 10). Due to short growing season, unfavorable weather conditions, poor regrowth and weakness of sorghum in second cutting, the forage yield of sorghum was lower than that of first cutting.

Quality traits of forage sorghum

Forage quality is a function of its digestibility [24] and CP content [25]. Protein is positively related to the forage quality [16] and this relationship is highly depended to the amount of nitrogen fertilizer [26]. Increased the cell wall concentration causes to addition in NDF content and reduction in digestibility [16]. A severe negative correlation between NDF and CP has been observed [27].

It is obvious from the Table 1 that both of the CP and NDF percentage were affected by interaction effect of density* nitrogen in first and second cutting. Comparisons of density* nitrogen in first cutting revealed that the maximum (13.46) and the minimum (11.2) of CP% were achieved by density of 15 plants/m^2 + full dose of nitrogen without split and density of 30 plants/m^2 + nitrogen application in three splits, respectively (Table 2). It can be concluded that by decreasing sorghum density per unit area and reducing competition between plants, the space, soil nutrients and nitrogen sources were being available to the sorghum and then CP% was increased.

Table 2: Means quality traits of forage sorghum at different densities and nitrogen treatments in first and second cutting.

	Crude Protein percentage (CP%)		Neutral Detergent Fiber percentage (NDF%)	
Density*Nitrogen	First cutting	Second cutting	First cutting	Second cutting
D_1N_1	13.46 ^{a}	7.4 ^{c}	58.56 ^{c}	63.66 ^{f}
D_1N_2	12.46 ^{b}	8.63 ^{a}	57.23 ^{d}	63.8 ^{f}
D_1N_3	12.56 ^{b}	8.23 ^{ab}	59.43 ^{ab}	64.36 ^{e}
D_2N_1	13.4 ^{a}	7.4 ^{c}	57.53 ^{d}	62.5 ^{g}
D_2N_2	11.8 ^{c}	8.36 ^{a}	58.46 ^{c}	62.26 ^{g}
D_2N_3	11.63 ^{cd}	7.73 ^{bc}	56.3 ^{e}	68.43 ^{b}
D_3N_1	12.56 ^{b}	7.23 ^{c}	57.3 ^{d}	67.36 ^{c}
D_3N_2	11.7 ^{c}	8.4 ^{a}	59.3 ^{b}	68.76 ^{b}
D_3N_3	11.53 ^{cd}	8.2 ^{ab}	59.16 ^{b}	66.6 ^{d}
D_4N_1	11.53 ^{cd}	7.53 ^{c}	59.9 ^{a}	66.43 ^{d}
D_4N_2	11.51 ^{cd}	8.3 ^{a}	56.8 ^{e}	67.46 ^{c}
D_4N_3	11.2 ^{d}	8.26 ^{ab}	59.36 ^{b}	69.63 ^{a}

Different letters indicate significant differences at $p<0.05$. D_1, D_2, D_3 and D_4: density of 15, 20, 25 and 30 plants/m^2, respectively. N_1: nitrogen application in full dose without split, N_2: nitrogen application in two splits, N_3: nitrogen application in three splits.

Also the highest (8.63) and the lowest (7.23) CP% of forage sorghum in second cutting were observed in density of 15 plants/m^2 + two splits of nitrogen application and density of 30 plants/m^2 + sole presence of nitrogen without split, respectively (Table 2). Due to the long growing period of sorghum, application of fertilizer such as nitrogen in several splits resulted in appropriative absorption of nitrogen and to increase the protein percentage, in second cutting. These results about forage sorghum are similar to Kohanmou and Mazaheri [9] and Mascadni and Helmz [23]. Data analysis indicated that sorghum CP content in total cutting was significantly ($p<0.01$) affected by the interaction effect of density* nitrogen *cutting (data not shown). The results represent the dominance of full dose of nitrogen without split + density of 15 plants/m^2 in first cutting (13.46%) (Table 3).

The NDF content is very important in ration formulation because it reflects the amount of forage that can be consumed by animals [28,29]. By increasing the NDF percentage, in taking of forage dry matter will generally be decreased by livestock [30].

Table 3: Means quality traits of forage sorghum at different densities, nitrogen and cutting treatments in total cutting (first and second cutting together).

Density*Nitrogen*Cutting	Crude Protein percentage (CP%)	Neutral Detergent Fiber percentage (NDF%)
$D_1N_1C_1$	13.46 a	58.56 j
$D_1N_2C_1$	12.46 b	57.23 k
$D_1N_3C_1$	12.56 b	59.43 hi
$D_2N_1C_1$	13.4 a	57.53 k
$D_2N_2C_1$	11.8 c	58.46 j
$D_2N_3C_1$	11.63 c	56.3 l
$D_3N_1C_1$	12.56 b	57.3 k
$D_3N_2C_1$	11.7 c	59.3 i
$D_3N_3C_1$	11.53 c	59.16 i
$D_4N_1C_1$	11.53 c	59.9 h
$D_4N_2C_1$	11.53 c	56.5 l
$D_4N_3C_1$	11.2 d	59.36 i
$D_1N_1C_2$	7.43 hi	63.66 f
$D_1N_2C_2$	8.63 e	63.8 f
$D_1N_3C_2$	8.23 f	64.36 e
$D_2N_1C_2$	7.4 hi	62.5 g
$D_2N_2C_2$	8.36 ef	62.26 g
$D_2N_3C_2$	7.73 g	68.43 b
$D_3N_1C_2$	7.23 i	67.36 c
$D_3N_2C_2$	8.4 ef	68.76 b
$D_3N_3C_2$	8.2 f	66.66 d
$D_4N_1C_2$	7.53 gh	66.43 d
$D_4N_2C_2$	8.3 f	67.46 c
$D_4N_3C_2$	8.26 f	69.63 a

Different letters indicate significant differences at $p<0.05$. D_1, D_2, D_3 and D_4: density of 15, 20, 25 and 30 plants/m^2, respectively. N_1: nitrogen application in full dose without split, N_2: nitrogen application in two splits, N_3: nitrogen application in three splits, C_1 and C_2: first and second cutting, respectively.

Data of interaction effect of density* nitrogen on NDF showed that in first and second cutting of sorghum, individually, the highest and the lowest amount of NDF were related to the density of 30 and 20 plants/m^2, respectively (Table 2). Application of nitrogen without split had the maximum value and in three splits had the minimum NDF content in first cutting. But in second cutting, nitrogen application in three and two splits produced the high and the low amount of NDF, respectively (Table 2).

Interaction effect of density* nitrogen *cutting based on total cutting analysis indicated that as plant density increased, the NDF content was increased, so that density of 20 plants/m^2+ nitrogen application in three splits in first cutting and density of 30 plants/m^2 + nitrogen application in three splits in second cutting produced the lowest and the highest NDF content, respectively (Table 3). In the first cutting, application of nitrogen in several phases, especially in low densities led to better consumption of soil resources such as nitrogen, thereupon an enhancement in vegetative growth and a diminution in NDF content of sorghum were occurred. These results are in agreement with Javadi et al [31] who stated that application of nitrogen fertilizer in several stages caused to reduction in NDF content.

Forage quality, quantity and digestibility are influenced by environmental factors such as soil nutrients, climate and harvest management [16]. Generally, reduction the sorghum density in total cutting promoted the number of tillers per plant, forage yield and CP%, and because of negative correlation between CP and NDF content, minimum amount of NDF was recorded by the density of 20 plants/m^2. Also full dose of nitrogen application without split in total cutting caused to the maximum fresh forage weight and CP%.

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