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Nitrogen and Plant Density Effects on Sorghum

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Abstract: The aim of this study was to evaluate the effect of nitrogen and plant density on some morphological and agronomic characteristics of grain sorghum in the years 2001-2002. Experimental design was a split-split, randomized complete block with three replications. Three nitrogen levels (0, 75 and 150 kg ha^{-1}) and plant densities (70×10, 70×20 and 70×30 cm) were applied in three grain sorghum cultivars. Generally, nitrogen and plant density had no effect on plant height and stalk length. The effect of nitrogen on grain yield per plant was usually non-significant and increased plant densities tended to increase grain yield per plant. Both nitrogen and plant density have positively affected grain yield per unit area. The effects of cultivar, nitrogen level and plant density on flag leaf area were changeable and dependent on both years and locations. One thousand grain weight was mainly determined by both cultivar and plant density. It may be concluded that increased nitrogen and plant density levels generally give the best results in grain yield and yield components in sorghum.

Key words: Dryland, nitrogen levels, sorghum cultivars, yield, yield components

INTRODUCTION

Sorghum is usually grown in dryland conditions around the world and is used in different ways in many countries. Even though grain sorghum is commonly consumed as foodstuff in developing or less developed countries, it is used as forage and raw material in industry in developed countries. Since sorghum is more tolerant to extreme hot conditions, it has been replaced by corn in most regions of the world. The response of grain sorghum to nitrogen is high and nitrogen fertilization is a major factor determining grain yield in sorghum. It has been reported that increased nitrogen dose positively affected plant height and sugar yield in sweet sorghum (Abbas and Al-Younis, 1989). Baytekin *et al.* (1995) found that the most suitable nitrogen dose for grain sorghum was 200 kg ha^{-1} under irrigated conditions. Inorganic nitrogen application was very important for sorghum and affected positively grain yield, biomass and thousand grain weight (Lehmann *et al.*, 1999). The response of sorghum to nitrogen varied depending on years and locations, however high nitrogen doses generally increased grain yields of sorghum (Khosla *et al.*, 2000).

Cultural practices also determine grain sorghum yields and plant density is one of the major elements required for plant growth and yield. Narrow row spacings or high plant densities affected positively grain sorghum yield in some studies (Foale and French, 1985; Ramshe *et al.*, 1986; Valesco-Lizama and Ramirez-Diaz, 1986; Nema *et al.*, 1987; Huda, 1988; Tsukov and Petkova, 1988; Kizil and Tansi, 1997). In contrary, some studies showed that wide row spacings or low plant densities increased grain yield in sorghum (Muchow *et al.*, 1982; Machado *et al.*, 1986; Rees, 1986; Singh *et al.*, 1986). Ramshe *et al.* (1985), Gupta and Sharma (1986), Gomase *et al.* (1987), Desiderio and Ventura (1992) and Soltero-Diaz (1994) found that plant densities have no effect on grain yield of sorghum. The objective of this study was to determine the effects of nitrogen doses and plant densities on sorghum.

MATERIALS AND METHODS

Field experiments were conducted under dryland conditions in 2001 and 2002 at Ankara, Hatay and Diyarbakır locations, Turkey. Ankara is at 39° 55' N lat and 32° 40' E long and 860 m above mean sea level (Central Anatolian region). The soil was clay loam with a pH of 7.8 and an organic matter content of 1.6%. Hatay is located in the southern part of Turkey (36° 15' N lat and 36° 07' E long and 100 m above mean sea level). The soil of experimental site was clay with a pH of 7.7 and an organic matter content of 2.0%. Diyarbakır is at 37° 55' N lat and 40° 12' E long and 660 m above mean sea level (South-

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Eastern Anatolian region). The soil was clay with a pH of 7.7 and an organic matter content of 1.6%. Annual precipitations in 2001 and 2002 in Ankara were generally higher (437.4 and 387.9 mm, respectively) than the long-term average (377.6 mm). Mean monthly air temperatures for 2001, 2002 and the past years were 13.5, 11.9 and 11.7°C, respectively. Total annual precipitations of Hatay location were higher (1730.3, 1006.1 and 1124.1 mm) than the other two locations. Mean air temperature values were 17.6, 18.6 and 18.2°C (for growing years and long-term). 605.3, 383.7 and 488.6 mm of annual precipitations and 16.1, 15.9 and 15.8°C of mean monthly air temperatures were observed for growing years and long-term in Diyarbakır.

The experiments were conducted in a split-split plot arrangement of treatments in a randomized complete block design with three replications. P_2O_5 of 60 kg ha^{-1} was given prior to planting in whole plots. The main plot treatments included three sorghum cultivars, Beydarı (C_1), Hatay (C_2) and Diyarbakır (C_3). Nitrogen levels of 0 (N_0), 75 (N_1) and 150 (N_2) kg ha^{-1} were applied to the subplots. The sub-subplot treatments were three different plant densities, 70×10 (D_1), 70×20 (D_2) and 70×30 (D_3) cm. Each plot was 5 m in length and consisted of 4 rows. Planting dates were dependent on climatic conditions and were in April, May and June at three locations. Plants were harvested by hand between August and October. Measurements and observations were made from five plants randomly chosen in each plot. In this study, plant characteristics measured were as follows: plant height (cm), flag leaf area (cm^2), stalk length (cm), grain yield per plant (g), 1000 grain weight (g) and grain yield per unit area (kg ha^{-1}). Mstat-C (5.0 Version, 1986, USA) statistical programı was used for statistical analysis in the study.

RESULTS AND DISCUSSION

Plant height: The results of analysis of variance showed that there were significant differences between cultivars in both years at Ankara location (Table 1). Nitrogen and plant densities did not have effect on plant height. In 2001, plant heights of cultivars varied from 74.7 cm to 121.6 cm. The greatest plant heights were obtained at C_2 (121.6 cm) and C_3 (106.8 cm) while C_1 had the lowest plant

Table 1: Effect of different nitrogen levels and plant densities on plant height of grain sorghum

		Ankara plant density				Hatay plant density				Diyarbakır plant density			
		D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean
2001													
C_1	N_0	77.2±8.1	74.0±3.6	77.7±4.3	76.3±2.9	79.6±2.4	81.7±0.6	82.7±4.6	81.3±1.6	63.2±1.8	62.3±2.1	61.0±1.5	62.2±1.0
	N_1	72.2±4.5	74.3±1.9	73.0±4.2	73.2±1.9	78.5±2.9	76.4±2.7	77.8±2.2	77.6±1.3	50.7±10.9	62.2±3.0	60.7±2.3	57.9±3.8
	N_2	77.6±0.2	71.1±5.5	75.3±4.9	74.6±2.3	80.7±1.4	83.2±2.3	86.2±4.7	83.4±1.8	61.5±1.6	61.3±1.0	63.6±1.0	62.1±0.7
	Mean	75.7±2.8	73.1±2.0	75.3±2.3	74.7±1.4b	79.6±1.2	80.5±1.5	82.2±2.4	80.8±1.0c	58.5±3.8	61.9±1.1	61.8±1.0	60.7±1.3c*
C_2	N_0	109.4±22.2	121.9±16.9	114.0±14.3	115.1±9.2	147.7±6.3	142.2±6.4	137.4±1.8	142.4±3.0	144.3±6.4	145.8±2.5	147.9±8.1	146.0±3.1
	N_1	140.2±0.8	134.9±8.3	127.2±6.9	134.1±1.5	136.2±5.1	146.9±3.0	134.8±2.1	139.3±2.6	154.7±3.6	149.7±2.7	159.3±3.8	154.6±1.2
	N_2	135.0±3.6	92.5±40.5	119.4±12.5	115.6±3.6	144.7±6.1	141.7±6.7	141.5±7.8	142.6±3.5	150.9±3.5	150.3±1.7	149.3±4.5	150.2±2.2
	Mean	128.2±8.1	116.4±14.3	120.2±6.1	121.6±5.7a	142.9±3.4	143.6±2.9	137.9±2.6	141.5±1.7a	150.0±2.8	148.6±1.4	152.2±3.4	150.3±1.5a
C_3	N_0	93.6±16.0	90.1±14.8	106.1±8.7	96.6±7.2	104.6±8.3	100.8±7.6	100.1±3.4	101.8±3.5	126.9±4.3	118.7±6.9	120.3±3.6	121.9±2.9
	N_1	119.9±7.2	115.1±6.5	111.2±5.9	115.4±3.5	100.2±3.2	102.9±5.5	100.7±3.2	101.3±1.2	126.4±9.7	123.1±7.2	122.3±1.2	124.0±3.6
	N_2	106.4±2.8	105.7±4.4	113.5±4.7	108.5±2.4	105.0±2.8	113.4±6.5	101.9±4.1	106.8±2.1	113.5±3.8	134.0±15.8	127.5±4.3	125.0±5.7
	Mean	106.6±6.4	103.6±6.1	110.2±3.5	106.8±3.1a	103.3±2.8	105.7±3.8	100.9±1.8	103.3±1.7b	122.2±3.9	125.3±5.9	123.4±2.0	123.6±2.4b
	Mean	103.5±5.4	97.7±6.2	101.9±4.5		108.6±5.3	109.9±5.3	107.0±4.7		110.2±7.8	111.9±7.4	112.4±7.5	
	N_0	93.4±9.5	95.3±9.6	99.3±7.4	96.0±5.0	110.6±10.4	108.2±9.4	106.7±8.3	108.5±5.2	111.5±12.5	108.9±12.5	109.7±13.1	110.0±7.1
	N_1	110.8±10.4	108.1±9.4	103.8±7.7	107.5±5.3	105.0±8.6	108.7±10.5	104.4±9.6	106.0±5.1	110.6±16.1	111.7±13.2	114.1±11.9	112.1±8.1
	N_2	106.3±8.4	89.8±12.9	102.7±8.0	99.6±5.7	110.2±9.5	112.8±8.9	109.9±8.7	110.9±5.0	108.6±13.1	115.2±14.4	113.5±13.0	112.4±7.5
2002													
C_1	N_0	72.4±1.4	73.9±2.3	73.7±2.2	73.4±1.0	93.3±14.3	97.3±13.8	97.9±11.9	96.2±6.7	106.6±5.6	106.4±1.4	119.8±1.9	110.9±2.8
	N_1	69.3±1.9	74.2±6.1	72.3±1.3	71.9±2.0	97.5±9.7	83.2±4.0	90.0±7.5	90.2±4.3	119.9±1.0	124.3±7.2	107.1±7.9	117.1±4.0
	N_2	74.1±3.1	74.2±2.6	73.7±4.5	74.0±1.7	90.3±6.2	90.5±3.2	83.8±12.0	88.2±4.1	121.1±9.4	119.6±2.6	109.4±3.8	116.7±3.5
	Mean	72.0±1.3	74.1±2.0	73.2±1.5	73.1±0.9 b	93.7±5.4	90.3±4.7	90.6±5.7	91.5±3.0c	115.9±3.9	116.8±3.5	112.1±3.2	114.9±2.0b
C_2	N_0	149.2±15.4	134.5±6.6	133.5±7.4	139.1±5.9	145.1±11.0	147.3±6.2	150.2±4.3	147.5±3.9	187.5±24.2	196.4±9.2	216.7±17.4	200.2±10.0
	N_1	128.3±1.7	139.7±15.3	149.3±12.1	139.1±2.0	148.1±3.5	155.9±14.5	154.3±7.2	152.8±4.9	168.3±11.6	181.2±10.5	182.6±11.5	177.4±4.9
	N_2	146.5±23.5	135.8±7.1	142.0±8.0	141.4±6.4	149.7±6.9	162.1±9.6	140.3±1.8	150.7±4.7	183.5±21.6	194.2±24.5	186.5±13.1	188.1±6.0
	Mean	141.3±8.8	136.7±5.3	141.6±5.2	139.9±3.7a	147.6±3.9	155.1±5.7	148.3±3.2	150.3±2.5a	179.8±10.4	190.6±8.5	195.3±8.9	188.6±5.3a
C_3	N_0	114.5±15.3	115.4±14.4	124.3±11.7	118.1±7.1	121.9±1.2	129.0±12.8	129.6±9.1	126.8±4.7	168.4±8.1	165.3±10.3	169.9±30.1	167.9±9.5
	N_1	111.2±6.1	122.3±9.6	106.7±5.8	113.4±4.4	119.9±2.7	115.5±3.5	113.5±4.2	116.3±3.2	166.5±4.7	155.7±9.5	165.4±12.9	162.6±5.1
	N_2	124.7±15.4	125.2±8.5	121.6±4.1	123.8±5.2	112.3±3.6	126.4±5.7	114.5±2.9	117.7±2.0	163.7±8.3	177.1±19.3	152.9±18.5	164.6±8.8
	Mean	116.8±6.8	121.0±5.8	117.5±4.8	118.4±3.3a	118.1±2.0	123.6±4.7	119.2±4.0	120.3±2.1b	166.2±3.7	166.1±7.5	162.7±11.1	165.0±4.5a
	Mean	110.0±6.7	110.6±5.8	110.8±6.0		119.8±4.9	123.0±5.9	119.4±5.2		154.0±6.6	157.8±7.1	156.7±8.2	
	N_0	112.0±12.8	108.0±10.1	110.5±10.1	110.2±6.1	120.1±9.1	124.5±9.3	125.9±8.8	123.5±5.1	154.2±14.4	156.0±13.8	168.8±17.2	159.7±8.5
	N_1	102.9±9.0	112.1±11.2	109.4±10.7	108.1±6.0	121.8±7.9	118.2±11.4	119.3±8.4	119.8±5.5	151.6±8.7	153.8±9.4	151.7±16.1	152.3±5.8
	N_2	115.1±13.5	111.7±10.1	112.4±10.5	113.1±6.4	117.4±9.1	126.3±10.9	112.9±8.9	118.9±5.5	156.1±11.7	163.6±14.4	149.6±13.0	156.4±7.3

*p<0.05

height (74.7 cm). Nitrogen levels had no significant effect on plant height and N_1 treatment gave the slightly highest plant height (107.5 cm). The lowest plant height was obtained from without nitrogen addition (96.0 cm). The effect of plant density on plant height was non-significant in 2001 and mean values for plant height varied from 97.7 to 103.5 cm. Cultivar effects on plant height were significant in 2002 and C_2 (139.9 cm) and C_3 (118.4 cm) had the highest plant heights. The lowest plant height was obtained from C_1 cultivar (73.1 cm). Increased levels of nitrogen had no effect on plant height. Concerning plant heights, there were no significant differences between plant densities.

Significant differences between cultivars were found for plant height in both years at Hatay location. Among all cultivars, C_2 gave the highest plant height (141.5 cm) whereas C_1 had the lowest plant height (80.8 cm) in 2001. No nitrogen effect was found for plant height and plant height values varied from 106.0 to 110.9 cm. Non-significant differences between plant densities were observed in plant height in 2001. In the second year, there were highly significant differences between cultivars (ranged from 91.5 to 150.3 cm). Both nitrogen and plant densities did not significantly affect plant height in 2002 (Table 1). There were significant differences between cultivars in plant height for both years in Diyarbakır location. The greatest plant height was found for C_2 (150.3 cm) and C_1 had the lowest plant height (60.7 cm) in 2001. Small but non-significant differences were observed between both nitrogen levels and plant densities in plant height. In 2002, the greatest plant heights were obtained from C_2 (188.6 cm) and C_3 (165.0 cm), respectively. C_1 (114.9 cm) had the lowest plant height. The effects of nitrogen and plant densities on plant height were non-significant in the second year (Table 1). As a result, both nitrogen and plant density had no effect on plant height of sorghum for three locations. Present plant height results are not in agreement with the findings of Abbas and Al-Younis (1989).

Stalk length: There were significant differences between cultivars in stalk length at Ankara location in 2001. The greatest stalk length was found for C_2 (22.3 cm) whereas C_3 had the lowest value (14.1 cm). Non-significant differences were observed between nitrogen levels and stalk lengths varied from 17.5 to 18.2 cm. Differences in stalk length between plant densities were not significant. Stalk length results of 2002 were similar to that of previous year. Among all cultivars, the highest and the lowest stalk lengths were obtained from C_2 and C_3, respectively. Small and non-significant differences were observed between nitrogen treatments in stalk length. The effect of plant density on stalk length was not significant (Table 2).

Similarly, significant differences were found between cultivars for stalk length in both years at Hatay location. In 2001, C_2 and C_1 had the greatest stalk length values, respectively. The effects of both nitrogen and plant densities on stalk length were not significant. The responses of cultivars in stalk length were similar to that of previous year in 2002. Neither nitrogen levels nor plant densities had significant effect on stalk length in the second year.

Differences in stalk length between cultivars were significant for Diyarbakır location in the first year. C_2 cultivar had the highest stalk length (22.0 cm). Stalk length of C_3 was rather low (14.4 cm) in comparison with the other cultivars. Small but non-significant differences were found between nitrogen levels. Higher plant densities had positive effect on stalk length and the greatest stalk length (19.5 cm) was obtained from D_3 treatment. In the second year, the three treatments significantly affected stalk length and Cultivar×nitrogen×plant density interaction was significant (Table 2). Generally, the greatest stalk lengths were achieved by different nitrogen levels and plant densities at C_2 cultivar. Also, the higher stalk length values were in the same statistical group. The treatment of C_2 with N_1 and D_3 had the greatest stalk length (23.9 cm) in all treatments. The lowest stalk lengths were observed at the treatments of C_3 applied different nitrogen levels and plant densities (Table 2).

Grain yield per plant: There were no significant differences between treatments in both years for Ankara location (Table 3). In 2001, the effect of cultivars on grain yield per plant was not significant and C_3 and C_1 had the highest and the lowest grain yields per plant, respectively. Increased nitrogen levels (N_1 and N_2) had generally the greatest grain yields per plant. Similarly, the highest grain yields were obtained with increased plant densities.

The grain yields per plant of cultivars in 2002 were similar to the previous year's results. The effects of both nitrogen and plant density on grain yield were non-significant and the greatest values were determined with increased nitrogen levels and plant densities. In 2001, differences between plant densities and Cultivar×plant density interaction were significant at Hatay location. Grain yield per plant was dependent on both cultivar and plant density and the greatest values were generally obtained from the cultivars with increased plant densities. The treatment of C_2 with D_3 had the highest grain yield (47.1 g) in all treatments. The cultivars with decreased plant densities had the lowest grain yields. Nitrogen levels had no effect on grain yield per plant and higher nitrogen amounts generally increased grain yields in Hatay. Significant differences between cultivars were

Table 2: Effect of different nitrogen levels and plant densities on stalk length of grain sorghum

		Ankara plant density				Hatay plant density				Diyarbakır plant density			
		D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean
2001													
C_1	N_0	17.8±1.2	17.2±0.5	17.8±1.1	17.6±0.5	16.9±1.1	16.1±1.6	16.9±0.2	16.7±0.6	18.8±0.6	18.6±0.5	18.8±1.0	18.7±0.4
	N_1	16.8±1.6	17.6±0.2	17.0±0.9	17.1±0.5	17.0±0.8	17.3±1.0	17.8±1.0	17.4±0.5	19.0±0.4	18.7±0.6	22.2±0.8	19.9±0.6
	N_2	17.5±0.8	17.1±0.8	17.7±1.7	17.4±0.6	18.2±0.5	17.5±0.4	18.3±0.3	18.0±0.2	16.4±1.1	17.3±0.7	18.4±0.7	17.4±0.5
	Mean	17.4±0.6	17.3±0.3	17.5±0.6	17.4±0.3b	17.4±0.5	17.0±0.6	17.7±0.4	17.3±0.3a	18.1±0.6	18.2±0.4	19.8±0.7	18.7±0.4b*
C_2	N_0	20.4±2.0	22.8±0.6	21.9±1.1	21.7±0.8	17.4±1.7	16.1±1.6	17.0±1.6	16.8±0.8	19.9±0.5	22.0±1.1	23.5±0.7	21.8±0.7
	N_1	23.0±0.8	24.8±1.2	21.9±0.9	23.2±0.3	18.3±1.1	17.6±0.5	19.1±1.0	18.3±0.5	21.0±1.8	20.5±0.7	22.9±0.4	21.5±0.9
	N_2	22.4±0.8	21.9±1.1	21.5±1.9	21.9±0.6	19.2±0.5	20.4±0.8	20.0±0.8	19.9±0.4	22.2±1.1	22.3±0.3	23.6±1.0	22.7±0.7
	Mean	21.9±0.8	23.2±0.7	21.8±0.7	22.3±0.4a	18.3±0.7	18.0±0.8	18.7±0.8	18.4±0.4a	21.0±0.7	21.6±0.5	23.3±0.4	22.0±0.4a
C_3	N_0	13.3±1.2	12.4±1.3	13.9±0.5	13.2±0.6	11.3±0.1	12.6±0.9	11.6±0.7	11.8±0.4	13.6±1.3	14.0±0.8	14.8±0.7	14.2±0.5
	N_1	13.8±0.6	14.8±0.7	13.8±1.1	14.1±0.4	11.6±0.3	12.0±0.4	12.2±0.5	11.9±0.5	14.9±1.6	13.4±0.2	15.9±0.9	14.7±0.6
	N_2	14.7±0.6	14.4±0.2	15.6±0.6	14.9±0.3	11.5±0.4	13.1±0.8	12.5±1.1	12.4±0.2	12.9±0.7	14.7±0.5	15.2±1.0	14.3±0.5
	Mean	13.9±0.5	13.9±0.6	14.5±0.5	14.1±0.3c	11.5±0.2	12.5±0.4	12.1±0.4	12.0±0.2b	13.8±0.7	14.0±0.3	15.3±0.5	14.4±0.3c
	Mean	17.7±0.7	18.1±0.8	17.9±0.7		15.7±0.6	15.8±0.6	16.2±0.6		17.6±0.7b	17.9±0.6b	19.5±0.7a	
	N_0	17.2±1.3	17.5±1.6	17.9±1.3	17.5±0.8	15.2±1.1	14.9±0.9	15.2±1.0	15.1±0.6	17.4±1.1	18.2±1.2	19.0±1.3	18.2±0.7
	N_1	17.9±1.5	19.1±1.5	17.6±1.3	18.2±0.8	15.6±1.1	15.6±1.0	16.4±1.0	15.9±0.6	18.3±1.1	17.5±1.1	20.3±1.4	18.7±0.7
	N_2	18.2±1.2	17.8±1.2	18.3±1.1	18.1±0.6	16.3±1.2	17.0±1.1	16.9±1.2	16.7±0.7	17.2±1.4	18.1±1.2	19.1±1.3	18.1±0.7
2002													
C_1	N_0	16.2±0.2	16.4±0.0	16.4±1.1	16.3±0.3	19.3±1.6	19.4±2.0	19.8±1.4	19.5±0.9	16.5±0.6hi	17.5±0.3fgh	20.6±0.7b-f	18.2±0.7
	N_1	16.5±0.2	17.9±1.7	17.0±0.2	17.1±0.5	16.9±0.1	17.0±1.1	18.3±1.2	17.4±0.5	20.9±0.8a-d	20.7±0.8a-e	18.6±0.6d-h	20.1±0.5
	N_2	16.4±0.2	17.3±0.3	17.2±1.1	17.0±0.4	18.6±2.1	18.9±1.3	17.7±2.1	18.4±1.0	17.4±0.1gh	17.7±1.7e-h	19.2±2.6c-h	18.1±0.9
	Mean	16.4±0.1	17.2±0.5	16.9±0.5	16.8±0.2b	18.3±0.9	18.4±0.8	18.6±0.9	18.4±0.5a	18.3±0.7	18.7±0.7	19.5±0.8	18.8±0.4
C_2	N_0	19.8±0.7	19.2±0.6	19.7±0.8	19.5±0.4	17.5±1.3	21.6±0.9	21.3±0.5	20.1±0.8	21.9±0.5abc	23.0±1.2ab	21.3±0.6a-d	22.0±0.5
	N_1	18.6±0.2	19.5±1.0	20.0±0.8	19.4±0.5	18.7±0.9	19.7±2.1	18.5±0.7	19.0±0.7	22.3±1.1abc	21.4±0.8a-d	23.9±1.3a	22.5±0.6
	N_2	19.0±0.4	18.7±0.2	17.8±3.1	18.5±0.4	18.4±0.9	20.3±1.5	16.4±1.5	18.4±0.9	22.7±0.7ab	19.8±1.2b-g	22.6±1.4ab	21.7±0.7
	Mean	19.1±0.3	19.1±0.4	19.2±1.0	19.1±0.4a	18.2±0.6	20.5±0.8	18.8±0.9	19.2±0.5a	22.3±0.4	21.4±0.7	22.6±0.7	22.1±0.4
C_3	N_0	11.9±0.8	12.3±0.6	13.7±0.6	12.6±0.4	12.1±0.7	12.4±0.8	12.9±1.1	12.5±0.5	13.6±0.7ij	13.9±0.3ij	13.0±0.5j	13.5±0.3
	N_1	13.1±0.9	14.1±1.0	12.5±0.4	13.2±0.5	13.8±1.1	13.0±0.7	13.2±0.1	13.3±0.8	12.9±0.4j	12.9±0.7j	13.1±0.5j	13.0±0.3
	N_2	11.8±0.3	14.3±1.7	12.7±0.8	12.9±0.7	12.4±0.3	12.3±1.5	12.0±0.1	12.2±0.4	13.6±0.4ij	13.9±0.4ij	13.4±1.1j	13.7±0.4
	Mean	12.3±0.4	13.5±0.7	13.0±0.4	12.9±0.3c	12.8±0.5	12.5±0.5	12.7±0.4	12.7±0.3b	13.4±0.3	13.6±0.3	13.2±0.4	13.4±0.2
	Mean	15.9±0.6	16.6±0.5	16.3±0.6		16.4±0.6	17.2±0.8	16.7±0.7		18.0±0.8	17.9±0.7	18.4±0.9	
	N_0	15.9±1.2	15.9±1.0	16.6±1.0	16.2±0.6	16.3±1.2	17.8±1.6	18.0±1.4	17.4±0.8	17.3±1.3	18.1±1.4	18.3±1.4	17.9±0.7
	N_1	16.1±0.8	17.1±1.0	16.5±1.0	16.6±0.6	16.4±0.8	16.6±1.2	16.7±1.4	16.6±0.6	18.7±1.5	18.3±1.4	18.6±1.3	18.5±0.8
	N_2	15.7±1.1	16.8±0.8	15.9±1.3	16.1±0.6	16.5±1.2	17.2±1.4	15.4±1.2	16.3±0.7	17.9±1.3	17.2±1.1	18.4±1.6	17.8±0.8

*$p<0.05$

found for grain yield per plant in second year. The greatest grain yield were obtained with C_2 and C_1 and C_3 cultivars followed it. The effect of both nitrogen and plant density on grain yield per plant were changeable. Different nitrogen levels with increased plant densities had generally the greatest grain yields and the treatment of N_0 with D_3 had the highest value (50.1 g) in all treatments. The lowest grain yield per plant was determined with the treatment of N_2 with D_1 (34.6 g).

There were significant differences between cultivars in grain yield per plant in 2001 for Diyarbakır location. The greatest grain yield values were 33.2 g (C_2) and 31.8 g (C_3) and C_1 had the lowest grain yield per plant (15.4 g). The effect of nitrogen on grain yield per plant was non-significant and grain yields varied between 29.1 and 25.3 g. Significant differences in grain yield per plant were observed with plant densities. Increased plant densities had the highest grain yields and lower plant densities decreased grain yields. In 2002, non-significant differences were observed between cultivars. Both nitrogen and plant density had no effect on grain yield per plant in the second year (Table 3). Cultivar and plant density generally affected grain yield per plant for all locations while no nitrogen effect was detected. These results are not similar to the findings of several studies (Baytekin *et al*., 1995; Lehmann *et al*., 1999; Khosla *et al*., 2000).

Grain yield per unit area: Significant differences were observed between treatments in grain yield per unit area in both years for Ankara location (Table 4). The differences between plant densities and Cultivar× nitrogen and nitrogen×plant density interactions were significant in 2001. Though there were the several higher grain yields per unit area in the same statistical group the treatment of C_3 with N_1 had the greatest grain yield per unit area (16.6 kg ha^{-1}) in all treatments. Similarly, the lowest grain yield values were in the other statistical group and the treatment of C_2 with N_2 had the lowest grain yield per unit area (9.6 kg ha^{-1}). The effects of both nitrogen and plant density on grain yield per unit area were significant and the greatest grain yield was obtained

Table 3: Effect of different nitrogen levels and plant densities on grain yield per plant of grain sorghum

		Ankara plant density				Hatay plant density				Diyarbakır plant density			
		D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean
2001													
C_1	N_0	30.0±4.2	26.3±5.5	32.4±6.6	29.6±2.9	30.7±0.2	32.1±2.0	40.0±0.6	34.3±1.6	11.1±0.7	17.1±3.7	16.7±4.2	14.9±1.9
	N_1	26.1±7.3	27.6±1.4	29.2±4.6	27.6±2.6	29.1±0.8	37.7±1.7	44.6±0.9	37.1±2.3	17.0±3.3	18.4±1.6	20.1±5.4	18.5±1.9
	N_2	31.5±1.9	28.0±7.0	33.5±12.0	31.0±4.1	36.4±2.9	40.4±2.0	47.5±2.2	41.4±2.0	9.2±1.5	14.7±1.3	14.2±1.4	12.7±1.1
	Mean	29.2±2.6	27.3±2.6	31.7±4.2	29.4±1.8	32.1±1.4f	36.7±1.5d	44.0±1.3b	37.6±1.2	12.4±1.6	16.7±1.3	17.0±2.2	15.4±1.0 b*
C_2	N_0	27.7±10.0	38.9±4.5	31.5±6.0	32.7±4.0	29.8±0.2	34.7±0.5	42.3±0.7	35.6±1.8	20.5±1.2	32.4±6.9	32.6±3.7	28.5±3.0
	N_1	44.2±5.4	41.2±5.0	43.9±8.0	43.1±1.6	31.8±1.3	40.9±2.1	46.9±0.6	39.8±2.3	26.1±4.7	31.2±7.2	45.4±5.2	34.2±2.4
	N_2	33.6±6.8	26.3±7.6	40.6±13.0	33.5±3.2	37.3±0.5	43.4±1.6	52.2±0.6	44.3±2.2	35.0±3.6	35.4±4.3	40.3±3.7	36.9±4.1
	Mean	35.2±4.5	35.5±3.7	38.7±5.1	36.4±2.5	32.9±1.2f	39.7±1.5c	47.1±1.5a	39.9±1.4	27.2±2.7	33.0±3.2	39.4±2.8	33.2±1.9a
C_3	N_0	35.1±8.7	34.4±8.9	43.3±8.3	37.6±4.6	33.0±1.2	39.6±1.2	43.6±1.4	38.7±1.7	32.2±12.4	37.2±6.5	34.2±3.6	34.5±4.2
	N_1	35.7±6.9	58.2±3.5	35.9±8.3	43.3±5.0	35.1±0.2	38.8±1.3	45.1±0.6	39.6±1.6	33.4±3.9	28.3±4.3	42.1±6.6	34.6±3.2
	N_2	47.1±6.7	43.6±6.2	56.0±6.9	48.9±3.8	35.9±1.3	41.6±1.8	45.6±2.8	41.0±1.5	21.2±3.6	30.2±5.0	27.8±4.6	26.4±2.6
	Mean	39.3±4.2	45.4±4.8	45.1±4.9	43.3±2.6	34.6±0.7e	40.0±0.8c	44.7±1.0b	39.8±0.9	28.9±4.3	31.9±3.0	34.7±3.3	31.8±2.0a
	Mean	34.6±2.3	36.1±2.6	38.5±2.8		33.2±0.7	38.8±0.8	45.3±0.7		22.9±2.3b	27.2±2.1a	30.4±2.5a	
	N_0	30.9±4.2	33.2±3.8	35.7±4.0	33.3±2.2	31.1±0.6	35.5±1.3	42.0±0.7	36.2±1.0	21.2±4.7	28.9±4.2	27.8±3.4	26.0±2.4
	N_1	35.4±4.2	42.3±4.8	36.3±3.9	38.0±2.5	32.0±1.0	39.1±1.0	45.5±1.2	38.9±1.2	25.5±3.1	26.0±3.1	35.9±3.2	29.1±2.3
	N_2	37.4±3.7	32.6±4.4	43.4±6.4	37.8±2.9	36.5±0.9	41.8±1.0	48.4±1.4	42.3±1.1	21.8±4.0	26.8±3.7	27.4±4.2	25.3±2.3
2002													
C_1	N_0	21.3±1.8	27.5±5.2	30.3±4.5	26.4±2.4	35.9±5.6	37.7±5.8	49.8±3.2	41.1±3.3	23.9±1.5	26.9±1.7	33.9±2.4	28.2±1.7
	N_1	21.9±0.8	32.6±9.0	28.0±3.6	27.5±3.2	42.6±2.7	30.3±3.2	32.5±4.5	35.1±2.6	29.9±1.3	31.0±3.9	25.4±1.0	28.8±1.5
	N_2	25.3±4.0	25.8±4.2	32.5±6.1	27.9±2.7	36.2±1.3	44.8±3.3	47.4±1.0	42.8±2.0	27.5±1.8	33.2±3.4	32.2±0.5	31.0±1.4
	Mean	22.8±1.4	28.6±3.4	30.3±2.5	27.2±1.6	38.2±2.1	37.6±3.0	43.2±3.1	39.7±1.6b	27.1±1.2	30.4±1.8	30.5±1.5	29.3±0.9
C_2	N_0	26.3±6.1	25.3±1.4	32.7±6.0	28.1±2.7	45.8±3.8	49.5±7.1	58.6±1.0	51.3±3.0	29.6±3.3	30.0±2.2	30.0±7.6	29.9±2.5
	N_1	23.3±3.5	27.5±2.7	32.0±6.0	27.6±3.2	45.4±6.4	42.6±1.6	43.3±4.1	43.8±2.3	33.7±7.1	37.9±7.8	28.4±2.9	33.3±1.5
	N_2	27.1±3.6	24.8±2.0	29.5±6.9	27.1±2.5	38.8±7.3	48.9±1.7	46.8±4.8	44.8±3.0	42.1±9.7	30.1±1.8	33.6±1.3	35.3±3.4
	Mean	25.6±2.3	25.9±1.1	31.4±3.2	27.6±1.4	43.3±3.2	47.0±2.4	49.6±3.0	46.6±1.7a	35.1±4.0	32.7±2.7	30.6±2.5	32.8±1.8
C_3	N_0	24.5±1.1	28.1±3.0	27.2±6.9	26.6±2.3	30.7±4.6	34.6±1.6	41.8±4.6	35.7±2.5	27.7±3.2	20.3±3.2	21.7±1.8	23.3±1.8
	N_1	30.1±2.2	31.6±7.4	30.4±4.8	30.7±2.6	39.1±2.6	43.0±5.0	40.2±1.0	40.8±1.8	20.5±1.3	22.9±1.7	23.6±5.8	22.3±1.8
	N_2	28.8±6.9	39.5±16.7	30.1±4.6	32.8±5.6	28.9±0.3	37.1±3.9	39.4±2.6	35.1±1.8	20.6±2.4	24.1±6.8	18.4±2.3	21.0±2.3
	Mean	27.8±2.3	33.1±5.6	29.2±2.8	30.0±2.2	32.9±2.2	38.3±2.3	40.5±1.6	37.2±1.3b	22.9±1.7	22.5±2.3	21.2±2.0	22.2±1.1
	Mean	25.4±1.2	29.2±2.2	30.3±1.6		38.2±1.6	40.9±1.7	44.4±1.7		28.4±1.8	28.5±1.5	27.5±1.4	
	N_0	24.1±2.0	27.0±1.8	30.0±3.0	27.0±1.4	37.5±3.2cd	40.6±3.5bcd	50.1±2.9a	42.7±2.1	27.1±1.6	25.8±1.9	28.5±3.0	27.1±1.3
	N_1	25.1±1.8	30.6±3.5	30.1±3.1	28.6±1.6	42.4±2.3bc	38.6±2.7bcd	38.7±2.9bcd	39.9±1.4	28.0±2.9	30.6±3.4	25.8±3.0	28.1±1.6
	N_2	27.0±2.6	30.0±5.5	30.7±3.0	29.3±2.2	34.6±2.6c	43.6±2.3bc	44.5±2.1ab	40.9±1.6	30.1±4.3	29.1±2.6	28.1±2.6	29.1±1.8

*$p<0.05$

with the treatment of N_1 and D_2 (15.1 kg ha^{-1}) whereas the treatment of N_0 with D_3 had the lowest grain yield value (9.4 kg ha^{-1}) in all treatments. For the second year, cultivars had no effect on grain yield per unit area and grain yields of cultivars varied from 13.7 kg ha^{-1} (C_1) to 11.9 (kg ha^{-1}) (C_3). Differences in grain yield per unit area between nitrogen levels were significant. Higher nitrogen levels considerably increased grain yield per unit area from 10.6 to 15.1 kg ha^{-1}. The effect of plant density on grain yield per unit area was not significant and the highest grain yield was determined with D_2 treatment (13.1 kg ha^{-1}).

Differences between nitrogen levels and plant densities and Nitrogen×plant density interaction were significant at Hatay location in 2001. Cultivar effects on grain yield per unit area were non-significant and the highest and lowest grain yields were obtained with C_3 and C_2, respectively. Both nitrogen and plant density significantly affected grain yield per unit area in the first year. There were considerable differences in grain yields in Hatay location in 2001. The highest grain yield per unit area was found for the N_2 with D_1 treatment (33.2 kg ha^{-1}). The N_0 with D_3 treatment had the lowest grain yield (20.0 kg ha^{-1}) in all treatments. Cultivar×nitrogen and nitrogen×plant density interactions were significant in grain yield per unit area in 2002. The cultivars with increased nitrogen levels generally had the greatest grain yield values and the C_3 with N_2 treatment gave the highest yield (36.4 kg ha^{-1}) whereas the cultivars with no nitrogen addition had the lowest grain yields per unit area. Increased nitrogen levels with different plant densities positively affected grain yields and the greatest grain yield per unit area was obtained from the treatment of N_2 D_1 (37.4 kg ha^{-1}). Non-nitrogen applications with different plant densities commonly had the lowest grain yield values in all treatments.

In 2001, differences between cultivars and Cultivar× nitrogen, cultivar×plant density, nitrogen x plant density and cultivar×nitrogen×plant density interactions in grain yield per unit area were significant at Diyarbakır location. There were considerable differences between the treatments in grain yield per unit area (Table 4). The C_2 cultivar with different nitrogen levels and plant densities generally had highest grain yield values. The treatment of

Table 4: Effect of different nitrogen levels and plant densities on grain yield per unit area of grain sorghum

		Ankara plant density				Hatay plant density				Diyarbakır plant density			
		D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean
2001													
C_1	N_0	15.9±0.4	10.5±3.1	9.3±1.6	11.9±1.4ab	24.9±0.6	22.6±1.7	18.5±0.5	22.0±1.1	12.9±1.6jk	17.5±1.9g-k	14.5±1.5ijk*	15.0±1.1
	N_1	10.3±1.2	11.4±1.4	10.0±1.8	10.6±0.8b	27.0±1.1	27.3±0.9	23.7±2.8	26.0±1.1	18.3±3.7g-k	19.1±0.7g-j	16.5±3.5g-k	18.0±1.5
	N_2	13.8±3.0	11.5±2.8	16.0±3.2	13.7±1.6ab	35.5±1.7	29.2±0.8	25.4±0.6	30.0±1.6	10.5±1.3k	12.6±0.7jk	12.3±1.5jk	11.8±0.7
	Mean	13.3±1.3	11.1±1.3	11.8±1.6	12.1±0.8	29.1±1.7	26.4±1.2	22.5±1.3	26.0±1.0	13.9±1.7	16.4±1.2	14.4±1.3	14.9±0.8
C_2	N_0	11.9±1.8	15.0±2.0	9.8±2.0	12.2±1.2ab	24.8±0.7	23.2±0.8	19.7±1.1	22.6±0.9	22.8±2.0e-h	31.6±4.8cd	29.6±5.4cde	28.0±2.5
	N_1	17.3±1.4	15.2±2.5	10.6±0.7	14.4±1.2ab	26.0±0.4	25.9±2.3	21.2±0.4	24.4±1.0	35.1±6.1cd	32.1±4.7cd	48.3±4.3a	38.5±1.7
	N_2	12.4±1.6	7.3±1.3	9.2±1.3	9.6±1.3b	30.1±1.7	27.8±0.4	24.2±0.8	27.4±1.0	43.3±3.2ab	36.8±5.2bc	34.0±1.3cd	38.1±3.6
	Mean	13.9±1.2	12.5±1.6	9.9±0.8	12.1±0.8	27.0±1.0	25.6±1.0	21.7±0.8	24.8±0.7	33.8±3.6	33.5±2.6	37.3±3.5	34.9±1.8
C_3	N_0	12.8±3.8	10.6±2.4	9.0±1.4	10.8±1.5b	27.4±1.0	27.3±1.2	21.8±1.4	25.5±1.1	28.0±7.5def	21.4±0.8f-i	15.0±1.0h-k	21.5±2.9
	N_1	17.1±3.7	18.9±2.9	13.7±4.2	16.6±2.0a	29.6±1.2	29.0±0.2	21.6±1.2	26.7±2.0	24.1±1.0efg	19.8±1.7g-j	22.1±2.5f-i	22.0±1.1
	N_2	16.1±1.6	11.7±2.2	13.6±2.1	13.8±1.2ab	33.9±2.9	28.2±1.7	24.5±1.3	28.8±1.4	24.3±2.9efg	20.1±2.8g-j	16.5±1.8g-k	20.3±1.7
	Mean	15.3±1.7	13.7±1.8	12.1±1.6	13.7±1.0	30.3±1.3	28.2±0.6	22.6±0.8	27.0±0.8	25.5±2.4	20.5±1.0	17.9±1.4	21.3±1.1
	Mean	14.2±0.8	12.5±0.9	11.2±0.8		28.8±0.8	26.7±0.6	22.3±0.6		24.4±2.2	23.5±1.7	23.2±2.4	
	N_0	13.5±1.4abc	12.0±1.5b-e	9.4±0.9e	11.6±0.8	25.7±0.6cd	24.4±1.0d	20.0±0.7f	23.4±0.6	21.2±3.2	23.5±2.6	19.7±3.0	21.5±1.7
	N_1	14.9±1.7ab	15.1±1.6a	11.5±1.1cde	13.8±0.9	27.6±0.7bc	27.4±0.8bc	22.2±1.3e	25.7±0.7	25.8±3.2	23.7±2.6	28.9±2.8	26.1±2.2
	N_2	14.1±1.2abc	10.2±1.3de	12.9±1.5a-d	12.4±0.8	33.2±1.4a	28.4±0.6b	24.7±0.5d	28.8±0.8	26.0±4.9	23.2±4.0	20.9±3.4	23.4±2.3
2002													
C_1	N_0	10.0±1.4	11.9±0.3	11.6±0.5	11.2±0.5	25.0±0.8	26.7±2.8	19.1±0.8	23.6±1.5d	32.7±2.1d-j	43.4±4.4a-g	55.9±12.2ab	44.0±5.1
	N_1	14.2±1.1	15.6±0.9	12.8±1.4	14.2±0.7	29.3±1.0	32.1±1.8	26.9±1.3	29.4±1.0bc	46.2±2.8a-d	33.8±1.4c-j	31.8±2.0d-j	37.3±2.5
	N_2	16.3±1.3	15.0±0.1	15.9±0.6	15.7±0.5	39.1±1.3	35.5±1.3	32.2±2.0	35.6±1.3a	39.5±3.4b-c	59.3±5.4a	55.3±2.8ab	51.4±3.6
	Mean	13.5±1.1	14.1±0.6	13.5±0.8	13.7±0.5	31.1±2.2	31.4±1.7	26.1±2.1	29.5±1.2	39.5±2.4	45.5±4.2	47.7±5.4	44.2±2.4
C_2	N_0	11.5±1.2	10.8±0.4	8.2±0.8	10.2±0.7	24.9±0.8	24.4±3.1	21.4±0.8	23.6±1.1d	40.9±5.1b-i	41.9±1.6b-h	44.7±13.3a-e	42.5±4.2
	N_1	12.5±0.7	13.0±2.9	14.9±1.7	13.4±0.8	30.3±1.0	33.9±0.7	27.4±1.4	30.6±1.1b	44.2±8.1a-f	51.6±12.5ab	43.7±8.1a-f	46.5±1.7
	N_2	15.4±2.3	16.7±1.7	13.5±1.4	15.2±1.1	33.7±2.2	31.0±0.6	29.4±0.9	31.4±0.9b	50.4±10.8abc	39.1±1.2 b-j	46.3±2.0 a-d	45.3±5.1
	Mean	13.1±1.0	13.5±1.3	12.2±1.2	12.9±0.7	29.6±1.5	29.8±1.7	26.1±1.3	28.5±0.9	45.2±4.4	44.2±4.1	44.9±4.6	44.8±2.4
C_3	N_0	11.4±1.6	10.2±2.3	9.7±1.0	10.4±0.9	26.2±0.9	22.3±1.3	21.7±0.6	23.4±0.9d	27.4±3.3f-j	24.4±4.6ij	25.6±3.1hij	25.8±1.9
	N_1	10.0±1.7	11.0±1.5	12.0±0.5	11.0±0.7	28.2±0.4	30.0±1.5	23.6±0.9	27.3±1.9c	23.8±2.7j	29.2±2.6e-j	23.1±6.4j	25.4±2.3
	N_2	14.1±0.9	13.6±1.3	15.4±1.0	14.3±0.6	39.3±0.6	37.1±2.2	32.7±2.4	36.4±1.1a	28.1±4.2e-j	26.6±3.4g-j	24.2±2.0ij	26.3±1.7
	Mean	11.8±0.9	11.6±1.0	12.3±0.9	11.9±0.5	31.2±2.1	29.8±2.3	26.0±1.9	29.0±1.2	26.4±1.9	26.8±1.9	24.3±2.1	25.8±1.1
	Mean	12.8±0.6	13.1±0.6	12.7±0.6		30.7±1.1	30.3±1.1	26.0±1.0		37.0±2.3	38.8±2.6	39.0±3.1	
	N_0	11.0±0.7	11.0±0.7	9.8±0.6	10.6±0.4c	25.4±0.5e	24.5±1.4e	20.7±0.6f	23.5±0.6	33.7±2.7	36.5±3.6	42.0±6.9	37.4±2.7
	N_1	12.2±0.9	13.2±1.2	13.2±0.7	12.9±0.5b	29.3±0.5d	32.0±0.9c	26.0±1.2e	29.1±0.6	38.1±4.4	38.2±5.0	32.9±7.1	36.4±2.6
	N_2	15.3±0.9	15.1±0.8	14.9±0.7	15.1±0.4a	37.4±1.2a	34.5±1.2b	31.4±1.1cd	34.4±0.8	39.3±4.8	41.7±5.1	42.0±4.8	41.0±2.7

*$p<0.05$

C_2 with N_1 and D_3 gave the greatest grain yield per unit area in all treatments (48.3 kg ha^{-1}). The treatments of C_1 with different nitrogen levels and plant densities generally had lowest grain yields per unit area. Similarly, Cultivar× nitrogen×plant density interaction was significant in grain yield per unit area in second year. C_1 and C_2 cultivars treated with different nitrogen levels and plant densities generally had highest grain yields per unit area whereas C_3 cultivar with different nitrogen levels and plant densities had lowest grain yield per unit area in all treatments.

Increased nitrogen levels and plant densities positively affected grain yield per unit area for locations. Our grain yield results are similar to the reports of several authors (Baytekin *et al*., 1995; Lehmann *et al*., 1999; Khosla *et al*., 2000; Foale and French, 1985; Ramshe *et al*., 1986; Valesco-Lizama and Ramirez-Diaz, 1986; Nema *et al*., 1987; Huda, 1988; Tsukov and Petkova, 1988; Kizil and Tansi, 1997), while the results of some studies (Ramshe *et al*., 1985; Gupta and Sharma, 1986; Gomase *et al*., 1987; Desiderio and Ventura; 1992; Soltero-Diaz, 1994) differed from our findings.

Flag leaf area: There were no significant differences between cultivars in flag leaf area in 2001 at Ankara location (Table 5). Flag leaf areas of cultivars varied from 78.8 to 113.9 cm^2 and the highest flag leaf area was obtained from C_2. The effect of nitrogen on flag leaf area was non-significant and the N_1 treatment gave the best result concerning flag leaf area. Significant differences were found between plant densities for flag leaf area in 2001 in Ankara. The treatment of D_2 had the highest flag leaf area (110.0 cm^2). Significant differences between cultivars were found for flag leaf area in 2002. Of all cultivars. C_2 had the greatest flag leaf area (113.5 cm^2). The effects of both nitrogen and plant density were non-significant in second year.

Significant differences between cultivars were found for flag leaf area in 2001 in Hatay location. C_1 had the highest flag leaf area (209.9 cm^2) whereas the lowest flag leaf areas were determined by C_3 (131.4 cm^2) and C_2 (124.7 cm^2) cultivars respectively. Both nitrogen and plant density had no effect on flag leaf area in Hatay location. The effects of both cultivar and nitrogen on flag leaf area were significant in 2002. C_1 gave the best result in flag leaf

Table 5: Effect of different nitrogen levels and plant densities on flag leaf area of grain sorghum

		Ankara plant density				Hatay plant density				Diyarbakır plant density			
		D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean
2001													
C_1	N_0	82.1±8.6	72.9±4.7	88.4±6.0	81.1±4.0	192.6±17.7	193.9±16.9	218.9±14.5	201.8±9.3	30.6±0.7	29.9±1.3	31.9±1.8	30.8±0.7
	N_1	82.9±14.6	84.2±1.2	72.8±7.2	80.0±5.0	195.7±27.9	205.2±12.5	222.6±5.7	207.8±9.8	30.4±1.4	31.2±1.3	30.1±1.6	30.6±0.7
	N_2	67.0±4.8	73.8±2.4	84.8±17.0	75.2±5.8	221.0±32.5	215.3±11.7	224.4±12.8	220.2±10.7	31.3±0.9	29.2±1.0	32.3±1.3	30.9±0.7
	Mean	77.3±5.7	77.0±2.4	82.0±6.1	78.8±2.8	203.1±14.1	204.8±7.6	222.0±5.9	209.9±5.7a	30.8±0.5	30.1±0.7	31.4±0.8	30.8±0.4b*
C_2	N_0	92.5±11.9	132.1±18.2	98.7±11.7	107.8±9.4	105.6±5.1	116.3±8.3	113.9±16.0	111.9±5.6	95.8±11.5	77.4±8.3	102.1±13.9	91.8±6.8
	N_1	120.9±4.4	145.1±29.9	104.4±9.1	123.5±3.6	115.7±3.9	140.8±12.1	124.1±14.7	126.9±6.7	116.9±15.0	108.7±5.3	115.0±26.4	113.5±0.7
	N_2	107.9±6.6	121.5±13.5	102.4±17.1	110.6±10.9	132.8±4.4	121.2±5.3	151.5±6.2	135.2±5.2	104.5±8.2	107.0±8.8	115.5±11.5	109.0±9.0
	Mean	107.1±5.8	132.9±11.4	101.8±6.6	113.9±5.3	118.0±4.6	126.1±5.9	129.8±8.6	124.7±3.8b	105.7±6.7	97.7±6.3	110.9±9.5	104.8±4.4a
C_3	N_0	91.3±29.1	93.2±18.0	101.5±16.6	95.3±11.1	128.8±16.1	128.2±4.6	137.0±4.5	131.3±5.2	102.9±15.4	115.4±19.2	95.1±13.9	104.5±8.7
	N_1	125.4±17.8	156.8±17.6	113.0±13.5	131.7±10.5	133.0±15.0	124.5±10.5	113.8±5.3	123.8±10.6	111.7±9.5	97.3±12.0	119.6±10.4	109.5±6.3
	N_2	108.1±10.4	110.4±9.9	119.2±14.4	112.6±6.1	152.7±3.3	133.6±16.2	130.6±10.6	139.0±6.2	85.3±23.7	86.1±9.0	81.4±18.3	84.3±9.1
	Mean	108.3±11.4	120.1±12.3	111.2±7.9	113.2±6.0	138.2±7.4	128.8±5.9	127.1±5.0	131.4±3.6b	100.0±9.5	99.6±8.2	98.7±9.2	99.4±5.0a
	Mean	97.5±5.3b	110.0±7.2a	98.3±4.5b		153.1±8.9	153.2±8.0	159.6±9.4		78.8±7.6	75.8±7.2	80.3±8.1	
	N_0	88.6±9.5	99.4±11.5	96.2±6.4	94.7±5.3	142.3±14.8	146.1±13.3	156.6±17.2	148.4±8.5	76.4±12.8	74.2±13.8	76.4±12.5	75.7±7.2
	N_1	109.7±9.6	128.7±15.1	96.7±6.8	111.7±6.8	148.1±15.2	156.8±13.6	153.5±18.3	152.8±8.7	86.3±14.9	79.0±12.7	88.2±12.6	84.5±8.3
	N_2	94.3±7.8	101.9±8.7	102.1±9.5	99.4±4.9	168.8±16.4	156.7±15.9	168.8±15.1	164.8±8.8	73.7±13.1	74.1±12.2	76.4±13.6	74.7±7.2
2002													
C_1	N_0	82.8±2.4	75.0±7.0	80.5±1.9	79.4±2.5	177.5±9.2	197.3±7.3	200.9±5.6	191.9±5.2	232.8±39.7	223.1±7.3	256.0±10.2	237.3±13.0
	N_1	56.9±3.5	107.3±31.7	83.1±11.4	82.4±12.2	191.9±17.7	205.9±11.7	211.9±7.3	203.2±7.1	259.4±4.0	254.9±16.0	284.0±29.2	266.1±10.7
	N_2	68.6±12.9	87.8±20.0	78.5±11.1	78.3±8.1	211.1±11.3	204.5±3.3	210.8±19.7	208.8±6.7	293.9±19.8	267.9±38.6	252.0±18.8	271.3±15.0
	Mean	69.4±5.4	90.0±12.0	80.7±4.7	80.1±4.8b	193.5±8.2	202.6±4.3	207.9±6.5	201.3±3.8a	262.0±15.6	248.7±13.9	264.0±11.6	258.2±7.8b
C_2	N_0	97.0±14.4	120.5±7.0	126.0±24.1	114.5±9.5	114.6±3.4	116.0±2.1	127.1±11.3	119.3±4.0	256.3±28.3	232.7±24.9	260.8±49.9	249.9±18.6
	N_1	123.8±19.7	109.1±13.0	132.6±14.2	121.8±11.8	118.5±6.3	148.6±11.6	139.2±14.7	135.4±7.2	313.0±28.4	267.8±31.1	286.7±35.7	289.2±12.6
	N_2	95.0±6.0	113.7±10.0	104.0±23.0	104.2±8.7	144.1±2.8	129.4±5.7	158.9±8.0	144.1±5.2	283.8±13.3	286.3±15.0	302.0±42.1	290.7±17.2
	Mean	105.3±8.6	114.5±5.4	120.9±11.3	113.5±5.0a	125.7±5.1	131.3±6.0	141.7±7.4	132.9±3.7b	284.4±14.7	262.2±14.6	283.1±22.3	276.6±9.9a
C_3	N_0	61.6±7.5	62.7±7.4	107.7±2.6	77.3±8.2	132.3±12.9	126.0±5.3	138.6±2.0	132.3±4.5	234.6±2.1	230.6±11.1	184.8±27.4	216.7±11.7
	N_1	66.8±6.0	87.8±8.6	82.5±11.7	79.0±5.5	131.4±5.6	122.1±6.8	125.3±5.5	126.2±5.2	223.6±27.7	228.8±48.7	209.7±6.7	220.7±16.5
	N_2	76.3±12.4	85.7±2.9	76.1±8.5	79.4±4.7	149.1±4.7	141.1±4.8	133.7±1.5	141.3±3.3	219.5±31.9	200.8±33.1	212.9±10.4	211.1±13.9
	Mean	68.2±5.0	78.7±5.3	88.8±6.4	78.6±3.5b	137.6±5.2	129.7±4.1	132.5±2.6	133.3±2.4b	225.9±12.4	220.1±18.0	202.5±9.7	216.2±7.9c
	Mean	81.0±5.0	94.4±5.4	96.8±5.6		152.3±6.8	154.5±7.2	160.7±7.4		257.4±9.2	243.7±9.3	249.9±11.0	
	N_0	80.5±7.0	86.1±9.5	104.7±9.6	90.4±5.3	141.5±10.5	146.4±13.1	155.6±12.0	147.8±6.7b	241.2±14.6	228.8±8.3	233.9±20.7	234.6±8.6
	N_1	82.5±12.0	101.4±10.8	99.4±11.2	94.4±6.4	147.2±12.6	158.9±13.4	158.8±13.4	155.0±7.6b	265.3±17.4	250.5±18.2	260.1±19.9	258.7±10.1
	N_2	80.0±6.7	95.7±7.9	86.2±9.0	87.3±4.6	168.1±11.4	158.3±11.9	167.8±12.9	164.7±6.8a	265.7±16.4	251.7±20.1	255.6±18.8	257.7±10.3

*$p<0.05$

area (201.3 cm^2). Higher nitrogen levels increased flag leaf area in grain sorghum and the highest flag leaf area was obtained from N_2 treatment (164.7 cm^2). Plant density had no effect on the flag leaf area.

Differences in flag leaf area between cultivars were significant for Diyarbakır location in the first year. The greatest flag leaf areas were determined by C_2 (104.8 cm^2) and C_3 (99.4 cm^2) cultivars, respectively. The effects of nitrogen and plant density on flag leaf area were non-significant. Similarly, there were significant differences between cultivars in flag leaf area in 2002. C_2 gave the highest flag leaf area (276.6 cm^2) and C_3 had the lowest flag leaf area (216.2 cm^2). Non-significant differences between nitrogen and plant densities were observed in flag leaf area in 2002.

1000 grain weight: There were significant differences between only cultivars in 1000 grain weight for 2001 in Ankara location (Table 6). C_3 had the highest 1000 grain weight and the lowest one was determined with C_1 cultivar (22.1 g) in all cultivars. The effects of nitrogen and plant density on 1000 grain weight were non-significant. In 2002, no cultivar effect was found for 1000 grain weight and the values varied from 22.9 to 23.8 g. Nitrogen levels had no effect on 1000 grain weight. Also, there were small but non-significant differences between plant densities in 1000 grain weight.

Differences between cultivars and Nitrogen×plant density interaction were significant for 1000 grain weight at Hatay location in 2001. Of all cultivars, C_3 and C_2 cultivars gave the highest 1000 grain weights, respectively. Even though nitrogen×plant density interaction was significant there were small but significant differences between treatments in 1000 grain weight. The treatment of N_2 and D_2 had the greatest 1000 grain weight (22.8 g) whereas the lowest value (19.5 g) was obtained from N_1 D_1 in all treatments. Differences in 1000 grain weight between cultivars and Cultivar×plant density were significant for Hatay location in second year. 1000 grain weight was mainly dependent on both cultivar and plant density and the greatest values were generally obtained from the cultivars with increased plant densities. The treatment of C_3 and D_2 had the best result for 1000 grain weight in all treatments. Small but non-significant differences were observed between nitrogen levels in 1000 grain weight.

Table 6: Effect of different nitrogen levels and plant densities on 1000 grain weight of grain sorghum

		Ankara plant density				Hatay plant density				Diyarbakır plant density			
		D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean	D_1 (70×10)	D_2 (70×20)	D_3 (70×30)	Mean
2001													
C_1	N_0	24.9±2.1	21.8±1.6	23.3±1.5	23.3±1.0	19.1±1.7	17.5±0.4	18.1±1.1	18.2±0.7	17.5±0.4	20.4±1.5	18.3±0.7	18.7±0.6
	N_1	22.2±1.2	21.4±1.1	21.7±0.6	21.8±0.5	17.4±0.6	18.4±1.6	19.4±1.0	18.4±0.6	18.3±1.0	19.3±0.9	20.1±1.2	19.2±0.6
	N_2	21.4±1.1	20.6±1.4	21.4±1.2	21.1±0.6	17.8±0.7	19.0±1.0	19.7±0.5	18.8±0.5	18.0±1.3	19.1±0.4	18.4±0.3	18.5±0.4
	Mean	22.8±0.9	21.2±0.7	22.1±0.7	22.1±0.5b	18.1±0.6	18.3±0.6	19.0±0.5	18.5±0.3b	17.9±0.5	19.6±0.6	18.9±0.5	18.8±0.3c*
C_2	N_0	24.7±2.6	24.3±1.1	25.3±1.2	24.8±0.9	24.7±1.2	24.4±1.6	24.8±1.7	24.6±0.7	21.2±0.4	20.3±1.0	22.7±0.6	21.4±0.5
	N_1	22.1±1.3	24.2±0.9	27.6±1.2	24.6±0.5	19.9±0.8	24.1±0.9	23.7±0.9	22.6±0.8	20.8±0.7	21.5±0.4	22.2±1.0	21.5±0.6
	N_2	25.7±3.7	22.0±0.9	25.3±1.3	24.3±1.0	23.0±0.4	23.1±0.7	22.8±2.4	23.0±0.7	21.8±1.0	21.6±1.4	22.3±0.3	21.9±0.4
	Mean	24.2±1.5	23.5±0.6	26.0±0.7	24.6±0.6ab	22.5±0.8	23.9±0.6	23.7±0.9	23.4±0.5a	21.2±0.4	21.1±0.5	22.4±0.4	21.6±0.3b
C_3	N_0	24.0±1.8	24.4±1.9	24.8±2.6	24.4±1.1	24.3±2.0	21.7±2.2	21.8±2.1	22.6±1.1	24.9±1.3	25.5±1.9	25.9±1.2	25.4±0.8
	N_1	25.1±1.6	31.8±1.2	26.3±1.1	27.7±1.2	21.1±2.0	24.1±2.9	23.2±1.5	22.8±0.6	25.1±0.4	26.8±1.5	29.3±0.5	27.1±0.8
	N_2	27.8±3.5	26.7±0.9	32.4±2.6	28.9±1.6	24.6±1.3	26.3±0.5	24.7±1.0	25.2±1.2	26.6±1.4	27.8±0.7	28.3±0.6	27.6±0.6
	Mean	25.6±1.3	27.6±1.3	27.8±1.6	27.0±0.8a	23.3±1.1	24.0±1.2	23.2±0.9	23.5±0.6a	25.5±0.6	26.7±0.8	27.8±0.7	26.7±0.4a
	Mean	24.2±0.7	24.1±0.7	25.3±0.8		21.3±0.7	22.1±0.7	22.0±0.6		21.6±0.7b	22.5±0.7a	23.0±0.8a	
	N_0	24.5±1.1	23.5±0.9	24.5±1.0	24.2±0.6	22.7±1.2a	21.2±1.3ab	21.6±1.3a	21.8±0.7	21.2±1.1	22.1±1.1	22.3±1.2	21.8±0.7
	N_1	23.2±0.8	25.8±1.6	25.2±1.1	24.7±0.7	19.5±0.8b	22.2±1.4a	22.1±1.4a	21.2±0.6	21.4±1.1	22.5±1.2	23.8±1.2	22.6±0.7
	N_2	25.0±1.8	23.1±1.1	26.4±1.8	24.8±0.9	21.8±1.1a	22.8±1.1a	22.4±1.1a	22.3±0.6	22.1±1.4	22.8±1.4	23.0±1.4	22.6±0.8
2002													
C_1	N_0	22.7±1.1	21.4±1.0	21.9±0.2	22.0±0.5	26.0±2.6	23.9±0.9	23.1±1.6	24.4±1.0	23.2±0.5	21.7±0.5	20.8±0.9	21.9±0.5
	N_1	22.3±0.8	25.0±0.8	22.8±1.2	23.3±0.6	21.4±1.2	21.6±0.8	21.3±0.6	21.4±0.4	20.0±0.3	20.1±0.6	21.3±0.1	20.4±0.3
	N_2	22.5±1.5	23.8±1.0	23.7±1.4	23.3±0.7	25.1±2.4	22.3±0.8	22.2±0.5	23.2±0.9	22.3±0.6	20.2±0.5	21.3±0.7	21.2±0.4
	Mean	22.5±0.6	23.4±0.7	22.8±0.6	22.9±0.4	24.2±1.3de	22.6±0.5e	22.2±0.6e	23.0±0.5	21.8±0.5	20.6±0.4	21.1±0.3	21.2±0.3c
C_2	N_0	24.9±0.4	21.5±1.5	23.9±2.0	23.5±0.9	26.1±1.6	23.9±0.9	25.6±0.6	25.2±0.6	23.3±0.2	24.9±2.4	25.3±1.4	24.5±0.9
	N_1	24.2±2.7	25.8±1.1	24.6±0.4	24.9±0.7	28.4±1.0	29.0±0.8	25.8±0.9	27.7±0.7	26.2±1.3	26.3±2.3	24.2±3.2	25.5±0.4
	N_2	22.0±1.6	23.3±1.8	24.3±3.3	23.2±0.9	26.0±2.3	28.2±1.7	28.1±1.0	27.4±0.9	26.8±4.1	25.3±1.3	25.5±0.6	25.9±1.2
	Mean	23.7±1.0	23.5±1.0	24.3±1.1	23.8±0.6	26.8±0.9bc	27.0±1.0abc	26.5±0.6c	26.8±0.5	25.4±1.4	25.5±1.0	25.0±1.0	25.3±0.6b
C_3	N_0	19.3±1.4	23.8±3.1	23.9±1.7	22.4±1.3	26.9±2.2	28.5±2.0	29.3±1.3	28.2±1.0	32.1±1.2	30.8±2.2	30.3±2.8	31.1±1.1
	N_1	28.5±1.0	25.2±2.6	23.6±1.8	25.8±1.2	23.6±0.4	28.6±1.8	27.8±0.7	26.7±1.0	28.2±1.2	27.9±0.7	30.4±1.7	28.8±0.8
	N_2	22.1±2.0	23.7±3.4	22.8±4.2	22.9±1.7	25.5±0.7	30.0±0.7	29.6±1.1	28.4±1.0	31.2±1.7	27.0±0.3	30.4±0.4	29.5±0.8
	Mean	23.3±1.6	24.2±1.5	23.5±1.4	23.7±0.8	25.3±0.8cd	29.0±0.8a	28.9±0.6ab	27.8±0.5	30.5±0.9	28.6±0.9	30.4±1.0	29.8±0.5a
	Mean	23.2±0.6	23.7±0.6	23.5±0.6		25.4±0.6	26.2±0.7	25.9±0.6		25.9±0.9	24.9±0.8	25.5±0.9	
	N_0	22.3±1.0	22.2±1.1	23.3±0.8	22.6±0.5	26.4±1.1	25.4±1.0	26.0±1.1	25.9±0.6	26.2±1.5	25.8±1.6	25.4±1.7	25.8±0.9
	N_1	25.0±1.3	25.3±0.9	23.7±1.0	24.7±0.6	24.5±1.1	26.4±1.3	25.0±1.2	25.3±0.7	24.8±1.3	24.8±1.4	25.3±1.5	24.9±0.8
	N_2	22.2±0.9	23.6±1.1	23.6±1.6	23.1±0.7	25.5±1.0	26.8±1.3	26.6±1.2	26.3±0.7	26.7±1.8	24.2±1.1	25.7±1.4	25.5±0.8

*p<0.05

Significant differences between cultivars and plant densities were found for 1000 grain weight in 2001 in Diyarbakır location. 1000 grain weights of cultivars varied from 18.8 to 26.7 g and the greatest 1000 grain weight was obtained at C_3. No nitrogen effect was found for 1000 grain weight. Plant density effect on 1000 grain weight was significant and increased plant densities positively affected 1000 grain weight. Similarly, there were significant differences between cultivars in 1000 grain weight and C_3 had the greatest 1000 grain weight (29.8 g) in all cultivars in 2002. Nitrogen and plant density had no effect on 1000 grain weight in second year (Table 6). Present findings related to nitrogen effect are not in agreement with those of Lehmann *et al*. (1999).

CONCLUSION

Different nitrogen and plant density treatments affected grain yield and some yield components in grain sorghum and there were significant differences among cultivars, nitrogen levels and plant densities in most characteristics in this study. Generally, increased nitrogen levels positively affected grain yield and some grain yield components and the greatest grain yields were obtained under 75 and 150 kg ha^{-1} N application. Similarly, higher plant densities increased grain yields and D_2 (70×20 cm) and D_3 (70×30 cm) gave the best results in almost characteristics The response of cultivars to grain yield and yield components were changeable and dependent on year and location. In addition, the results of first year differed from second ones due to different climate conditions in locations. Therefore, higher nitrogen levels and plant densities could be used for high grain yield in sorghum and also high quality cultivars should be recommended in sorghum cultivation.

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