Response of irrigated sunflower (*Helianthus annuus* L.) hybrids to nitrogen fertilization: growth, yield and yield components

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ABSTRACT

N fertilization has a substantial influence on sunflower (*Helianthus annuus* L.) seed yield and quality. It was also well established that high-yielding sunflower hybrids had more N requirement than old cultivars such as open-pollinated ones. However, in Turkey, no sufficient information regarding the response of new developed oilseed sunflower hybrids to nitrogen fertilization under irrigated conditions. Therefore, a 2-year study was conducted to determine the effects of nitrogen application rates on the growth, yield, and yield components of two oilseed sunflower hybrids (AS-508 and Super 25) under irrigated conditions. In this study, all plant parameters were significantly influenced by applied nitrogen fertilizer rates. Yield response to nitrogen rates was positive and linear. Our research data indicated that under irrigated conditions N rate of 120 kg/ha was adequate for sunflower production in this region.

Keywords: sunflower; nitrogen rate; growth; seed yield; yield components

Sunflower (*Helianthus annuus* L.) is the most important oilseed crop in Turkey. Although sunflower production has mainly been performed in Marmara region under non-irrigated conditions, the crop is well adapted to the different climatic zones in Turkey, including eastern Anatolia, where the climate is characterized with a short growing season, cool temperatures and semiarid climate conditions. The sunflower is the only oilseed crop grown commercially in this region. But nearly all sunflower cultivars grown in the region consisted of non-oilseed types. Recently, there has been an interest in oilseed sunflower production, but no information concerning oilseed sunflower management practices including N fertilization was available for this region.

Numerous studies have investigated the effects of N fertilization on sunflower in the various parts of the world (Hussein et al. 1980, Blamey and Chapman 1981, Kandil 1984, Narwal and Malik 1985, Khokani et al. 1993, Legha and Giri 1999, Tomar et al. 1999, Zubillaga et al. 2002). Nitrogen is commonly a limiting factor in sunflower production (Zubriski and Zimmerman 1974, Robinson 1978). Managing N fertilization is of particular importance because many environmental and production factors influence sunflower N demand. Nitrogen deficiency reduces vegetative and generative growth and induces premature senescence, thereby potentially reducing yields (Narwal and Malik 1985, Khokani et al. 1993, Legha and Giri 1999, Tomar et al. 1999). On the other hand, high N availability may shift the balance between vegetative and reproductive growth toward excessive vegetative development, thus delaying crop maturity and reducing seed yield (Farah et al. 1981, Hocking et al. 1987). Excess N application also increases the risk of disease and lodging, with a consequent reduction in oil content, and may aggravate ground- and surface-water pollution.

In eastern Anatolia, sunflowers are grown only under irrigated conditions because of insufficient precipitation. The increased yield response of the crop to N fertilization under irrigated conditions is well known. However, in Turkey, a detailed N fertilization study on oilseed sunflower hybrids in irrigated conditions is very limited, and in this region there is no publicated research data on the effect of N fertilizer applications on the sunflower.

The objective of this study was to determine the effects on growth, yield, and yield components of irrigated sunflower hybrids to N fertilizer rates.

MATERIAL AND METHODS

A 2-year experiment was carried out at the Agricultural Experiment and Research Centre, the Faculty of Agriculture, and Atatürk University in Erzurum (29°55′N and 41°16′E, 1850 m elevation) during the seasons 1998 and 1999. The soil at the experimental site was a loamy, with approximately 14.3 g/kg organic matter. The 0–60 cm soil layers contained respectively 18.7 kg/ha N-NO_3, 128.7 kg/ha available P and 431.2 kg/ha available K.

The previous crop for the plots planted in 1998 and 1999 was barley (*Hordeum vulgare* L.). The plot areas were mouldboard ploughed in the fall and cultivated twice in the spring. Two oilseed sunflower hybrid genotypes, AS-508 and Super 25, were used in this experiment. AS-508 and Super 25 was selected based on the regional yield performance and the differences in their plant heights.

The experimental design was a randomised complete block design with the three replicates. The plots were 2.8 m wide and 6 m long and consisted of four rows spaced 0.7 m apart. Three seeds were sown in each hill, and the plots were hand-thinned to one plant per hill when the plants were at the four to six-leaf stage. Nitrogen rates of 0, 40, 80, 120 and 160 kg N/ha were tested. Nitrogen was applied as split into two applications; half with sowing and the remaining half at the beginning of stem elongation ($N_{20+20,}$ N_{40+40}, N_{60+60}, and N_{80+80}). N fertilizer applied as ammonium sulphate [$(NH_4)_2SO_4$] form. A basal dressing of ammonium sulphate was applied and incorporated into the seedbed. Additional ammonium sulphate was broadcast by hand just before the end of floret initiation (Hocking and Steer 1995). All plots received phosphorus at 60 kg P_2O_5/ha as triple superphosphate at sowing in both years. Weeds were controlled mechanically and by hand hoeing. All plots were furrow irrigated regularly to avoid drought stress. A total of 4 irrigation's each year was applied. Each irrigation brought the soil moisture back to near field capacity. A 1-m alley was left around each plot to avoid plot to plot N contamination during irrigation.

The sunflower plants were hand-harvested at the stage of physiological maturation when the back of the head has turned from green to yellow and the bracts are turning brown. At harvest, ten plants from each plot were selected for determining days to maturity, plant height, leaf number, head diameter, 1000 seed weight, test weight, and ratio of dehulled/hulled seed weight. Leaf area (cm^2) was calculated according to Schneiter (1978) at 50% anthesis. At maturity, head samples for yield were harvested from the two center rows of each plot, dried and threshed mechanically. Seed yield was adjusted to a 10.0% moisture basis. Seed oil concentration was determined by the Soxhlet apparatus and seed N concentration by micro-Kjeldahl method.

A combined year analysis of variance was conducted on all data using the SAS package (SAS Inst. 1990). For statistical analyses, cultivar and nitrogen rate effects were considered fixed. When the F-test indicated statistical significance at the P = 0.05 level, the protected least significant difference (Protected *LSD*) was used to separate the means. Regression models were calculated to determine the association of seed yield to nitrogen rates. Treatment comparisons were made using a single degree of freedom contrasts for linear, quadratic, cubic and quartic effects of each nitrogen rate.

RESULTS AND DISCUSSION

Air temperature, rainfall, and relative humidity for the experimental site during the study years are presented in Table 1. Long-term average rainfall for this area during the growing season is 198.9 mm. In general, environmental conditions in 1998 were more favourable for the growth of sunflower than those in 1999. The average rainfall for 1998 (193.7 mm) was higher than that observed (174.8 mm) in 1999 (Table 1). The 1998 growing season received rainfall above normal, but the year 1999 rainfall was below normal. Interestingly, total rainfall for 1999 (286.2 mm) was the lowest rainfall value of the last 50 years, and the total rainfall for 1998 was 465.4 mm. Temperature values were about

Table 1. Monthly and growing season precipitation, temperature, and relative humidity at Erzurum in 1998 and 1999

Months	Precipitation			Temperature			Relative humidity		
	1998	1999	normal*	1998	1999	normal	1998	1999	normal
	mm			°C			%		
May	98.1	35.3	73.1	10.8	10.3	10.8	71.0	56.0	60.9
June	26.4	49.6	53.1	16.4	15.0	15.4	59.4	57.7	56.6
July	32.7	34.2	29.1	19.2	19.2	19.2	52.9	52.9	49.9
August	9.5	6.1	18.9	19.7	20.3	19.5	45.7	68.6	46.7
September	27.0	49.6	24.7	13.4	14.2	14.9	54.5	54.6	49.2
Total/Mean	193.7	174.8	198.9	15.9	15.8	15.9	56.7	57.9	52.7

*normal refers to the long term average, a 70 year average the same for 1998, 1999, and long-term. The relative humidity values of the study were very close to each other and higher than normal (Table 1).

Significant year × cultivar × nitrogen rate interaction (Tables 2) was observed for agronomic traits such as leaf area, 1000 seed weight, test weight, the ratio of dehulled/hulled seed weight, and seed protein concentration. Year × cultivar, year × nitrogen rate interactions usually were insignificant. Furthermore, significant cultivar × nitrogen rate interactions were observed in stem diameter, leaf area, 1000 seed weight, and seed protein concentration (Table 2).

Plant growth

The results of the analysis of variance showed that plant height was strongly influenced by year and cultivar (Table 2). Averaged across cultivars, plant heights in 1998 were higher than in those in 1999. This can be explained by the fact that in the first year cultivars had more suitable growing conditions due to high rainfall. In general, there was also significant differences in plant height between the genotypes and AS-508 produced taller plants than Super 25 (Table 2). Applying nitrogen tended to increase plant heights of sunflower cultivars and the effect of N application was statistically significant (Table 2). Our research data concur with the literature reporting that increasing N rates increased markedly increased plant height (Hussein et al. 1980, Mahal et al. 1998, Poonia 2000). In sunflower production, increased plant height with excessive nitrogen application may cause lodging problems (Kasem and El-Mesilhy 1992). However, in this study such a problem was not encountered.

As seen in Table 2, the stem diameters of sunflower plants varied with each year and these differences were found to be significant (Table 2). In 1998, average stem diameters were greater than those of the second year of the study. There were insignificant differences between the cultivars. Stem diameters of AS-508 and Super 25 were very close each other. Stem diameter was consistently influenced by nitrogen applications, and increased with increasing N rates (Table 2), as reported by Kasem and El-Mesilhy (1992) and Mahal et al. (1998). A differential response also occurred between cultivars at the increasing N levels. This caused significant cultivar × nitrogen rate interaction (Table 2).

Significant genotypic differences in leaf area occurred between the cultivars. Mean leaf area of AS-508 was greater than that of Super 25 (Table 2). The greater leaf areas were observed in 1998 due to favourable weather conditions. N applications significantly influenced the leaf area (Table 2), although this was not consistent across N treatments (Table 2). The highest leaf area was produced when sunflower plants received nitrogen at the rate of 80 kg/ha. The results are in general agreement with those of Hocking et al. (1987), which reported that leaf area increased as the N rate, was increased. The response of genotypes to N fertilizer applications differed. This resulted in a significant cultivar × nitrogen rate interaction (Table 2).

Yield components

Head diameter is one of the most important yield components in sunflower plant. The head diameters measured for cultivars in the study were not significantly influenced by year (Table 2). A similar trend was also observed for the cultivars. In contrast to the year and cultivar, the effect of the nitrogen levels was significant (Table 2). As N fertilizer rate increased, the head diameter of sunflower plants increased. Indeed, this effect was expected because of positive contribution of nitrogen on plant growth. Head diameter was 20.7 and 20.6 cm for the N rates of 120 and 160 kg N/ha, respectively, while it was 18.48 cm for the check treatment. Some research data (Massey 1970, Hussein et al. 1980) have also shown that fertilizer nitrogen increased head diameter of the sunflower.

1000 seed weight is commonly a major determinant of sunflower yield. The characteristic significantly differed with the study years. Seed weight differs to various growing season and conditions. In 1998 when rainfall was higher (Table 1), 1000 seed weight was higher than in 1999. Nitrogen applications had a significant effect on seed weight. The highest 1000 seed weight (65.02 g) was determined at the rate of 160 kg N/ha. It has been well documented that increasing N rates produced sunflower plants with higher seed weight (Hocking et al. 1987, Mahal et al. 1998). In our study, a progressive and consistent increases in 1000 seed weights were observed with each increment in applied nitrogen rates up to 160 kg N/ha, suggesting the role of nitrogen for seed formation in sunflower. It was concluded that the development of florets and seeds of the sunflower is supported by N taken up by the plant between the end of floret initiation and anthesis (Hocking and Steer 1995).

Table 2 shows the average test weights of the sunflower plants grown in Erzurum in 1998 and 1999 growing season. In general, sunflower genotypes tended to produce higher test weights in 1998 than in 1999. The higher test weight of the first year was partly due to more favourable environmental conditions, particularly total rainfall. Cultivars did not have any effect on test weight (Table 2). In contrast to the genotypes, the effect of applied nitrogen rates on test weight was significant (Table 2). The highest

Table 2. Influence of year, cultivar, and nitrogen rate on yield and some agronomic characters of two oilseed sunflower hybrids grown at Erzurum in 1998 and 1999

	Treatments	*df*	Plant height (cm)	Stem diameter (cm)	Leaf area (cm^2 per plant)	Head diameter (cm)	1000 seed weight (g)	Test weight (kg/hl)	The ratio of dehulled/hulled seed weight (%)	Seed yield (kg/ha)	Oil yield (kg/ha)	Seed oil concentration (g/kg)	Seed protein concentration (g/kg)
Year (Y)	1998		154.47 a	2.76 a	6116.6 a	20.23	63.63 a	38.56 a	43.43	2497.0 a	1029.4 a	413.2 a	195.9 a
	1999		118.26 b	2.52 b	4875.5 a	19.63	60.23 b	36.91 b	42.28	2409.2 b	964.6 b	401.8 b	189.2 b
Cultivar (C)	AS-508		145.49 a	2.66	5742.1 a	20.14	61.98	38.13	43.42	2586.9 a	1042.5 a	410.8	195.0 a
	Super 25		126.24 b	2.63	5250.0 b	19.72	61.87	37.73	43.29	2319.3 b	951.5 b	404.2	190.1 b
Nitrogen rate (N)	0		131.53 b	2.38 b	5019.4 b	18.48 b	59.13 c	37.22 c	42.80 b	2077.3 d	867.1 c	417.9 a	187.7 bc
	40		136.08 a	2.63 a	5070.7 b	19.88 a	60.29 bc	37.46 bc	42.82 b	2309.1 c	957.3 b	414.3 a	185.7 c
	80		137.87 a	2.68 a	5826.6 a	20.00 a	61.11 b	37.45 bc	44.48 a	2523.6 b	1040.5 a	412.7 ab	192.3 bc
	120		137.01 a	2.74 a	5739.1 a	20.73 a	64.11 a	38.10 ab	42.95 b	2651.3 a	1053.3 a	397.6 bc	193.6 b
	160		136.82 a	2.78 a	5824.6 a	20.57 a	65.02 a	38.44 a	43.74 ab	2704.2 a	1066.8 a	395.0 c	203.5 a
CV (%)			3.16	7.66	11.05	7.55	3.78	2.29	3.97	5.11	6.77	4.59	4.65
Analysis of variance	Y	1	**	**	**	ns	ns	**	ns	**	**	*	**
	C	1	**	ns	**	ns	ns	*	ns	**	**	ns	*
	N	4	**	**	**	**	**	**	ns	**	**	*	**
	linear	1	ns	**	*	**	**	*	ns	**	**	*	**
	quadratic	1	ns	ns	ns	ns	ns	ns	ns	ns	**	*	ns
	cubic	1	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
	quartic	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Y × C	1	ns	ns	ns	ns	ns	ns	ns	**	**	ns	ns
	Y × N	4	ns	ns	**	ns	ns	**	**	ns	ns	ns	**
	C × N	4	ns	*	*	ns	**	ns	ns	ns	ns	ns	**
	Y × C × N	4	ns	ns	**	ns	*	*	*	ns	ns	ns	**

*, **significant at the 0.05 and 0.01 level, respectively; for each main effect, values within columns followed by the same letter are not significantly at $P = 0.05$

CV = coefficient of variation, ns = nonsignificant test weight (38.44 kg/hI) was observed at the rate of 160 kg N/ha of nitrogen fertilizer. This agrees with Poonia (2000) who suggested that N application significantly increased test weight.

The ratio of dehulled/hulled seed weight was not affected by year and cultivar. Increased nitrogen rates had a significant effect on kernel content and but this effect was not consistent (Table 2). In contrast to our research data, Baldini and Vannozzi (1996) have found that an increased supply of nitrogen improves hullability.

Seed yield

The seed yields of sunflower cultivars grown in Erzurum are presented in Table 2. As seen in Table 2, there were significant differences between the growing seasons. The yields (2640.6 kg/ha) of the first year were superior to those (2506.9 kg/ha) of the second year. The higher sunflower yields in 1998 may have resulted from higher N mineralization due to increased rainfall. Similarly, the differences between the cultivars was observed and found to be statistically significant (Table 2). Increased nitrogen rates resulted in higher seed yields up to 160 kg N/ha. Compared to the plots that not received nitrogen, the highest N rate produced about 30% more seed yield, which clearly suggest the importance of nitrogen for higher seed production in the sunflower. Yield increased in a linear fashion in this study. This indicates a close relationship between seed yield and nitrogen rates. The effect of increased N fertilizer rates was expected since fertilizer N requirements of the sunflower for maximum yield tended to be greater than under irrigated conditions. The yield response of the sunflower to increased N levels was not surprising. Rahmatullah et al. (1995), Tenebe et al. (1997) and Legha and Giri (1999) also reported similar results for the sunflower. The increases in yield with N applications can be explained partly by very low available N (N-NO_3) of the experiment soil and by probably increased nitrogen use efficiency due to split applications of nitrogen. On the other hand, this response can also be accounted for the positive response of agronomic characteristics associated with yield such as head diameter and 1000 seed weight to nitrogen. Fertilizer N treatment effects on sunflower yield were inconsistent across the 2 year since the year × N interaction was significant (Table 2).

Management of fertilizer nitrogen is one of the most important components in producing maximum yield and profits in sunflower. Our study data show that up to 160 kg N/ha fertilizer applications increased linearly seed yields. However, significant yield increases with application of nitrogen up to only 120 kg/ha were observed (Table 2). In this study, a rate of 120 kg N/ha has been shown to be adequate for sunflower production under the region conditions. The information provided by this experiment might be helpful for recommending the optimum N rate in sunflower production in similar climatic and soil conditions. However, this N rate can not be generalized for oilseed sunflower since the optimum amount of fertilizer N depends on the soil mineral N concentrations and the amount of N mineralised from soil organic sources during the growth period.

Oil yield

The oil yield obtained from sunflower plants in this study was substantially altered by year, cultivar and nitrogen rates (Table 2). As in seed yield, cultivars produced more oil yield in 1998 than in 1999. The oil yield of AS-508 was more than that of Super 25. Irrespective of sunflower genotypes, increasing the N rate from 0 to 160 kg N/ha consistently increased oil yields. In fact, the response was associated directly with the response of seed yield to applied N rates. Steer et al. (1986) also reported that oil yields in irrigated sunflower were increased by increasing N application.

Seed oil concentration

Seed oil concentration was significantly affected by year and cultivar. In the first year oil concentration was higher (413.3 g/kg) than the second year (401.8 g/kg) (Table 2). The reduced oil concentration was probably caused by the very low total annual rainfall. Talha and Osman (1975) also found that water stress during the vegetative stage as well as the reproductive growth periods decreased the seed oil content from 31.9 to 24.7%. There was no significant effect of cultivars on seed oil concentration. N fertilization caused a consistent decline in the seed oil concentration of sunflower cultivars. Averaged over years and cultivars, the highest oil concentration was detected in the control plants. Increased N rates led to declines in oil concentrations of the sunflower plants. Similar responses have been reported in other studies (Steer et al. 1986, Geleta et al. 1997, Scheiner et al. 2002). There were no significant cultivar × year, year × nitrogen rate, and year × cultivar × nitrogen rate interactions for seed oil concentration (Table 2).

Seed protein concentration

Seed protein concentration was significantly influenced by year, cultivar, nitrogen, year ×

cultivar, cultivar × nitrogen rate, and year × cultivar × nitrogen rate interactions. Differences in protein concentrations of cultivars were higher in 1998 than in 1999. AS-508 tended to produce higher protein concentration than super 25. N applications to sunflower resulted in increased seed protein concentrations (Table 2). It is noteworthy that compared to the control the highest N rate produces in a 9% increase in protein concentration. Previous research has indicated that nitrogen fertilization tends to increase seed protein content at the expense of oil (Blamey and Chapman 1981, Steer et al. 1986).

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ABSTRAKT

Vliv dusíkatého hnojení na zavlažované hybridy slunečnice: růst, výnos a výnosotvorné prvky

Dusíkaté hnojení má významný vliv na výnos a kvalitu nažek slunečnice (*Helianthus annuus* L.). Je také známo, že vysoce výnosné hybridy slunečnice mají větší nároky na dusíkatou výživu než staré liniové odrůdy. Nicméně v Turecku nebyla dosud ověřena reakce nově vyšlechtěných hybridů slunečnice na hnojení dusíkem v podmínkách závlah. Proto proběhlo dvouleté sledování k určení vlivu různých dávek dusíku na růst, výnos a výnosotvorné prvky dvou hybridů slunečnice (AS-508 a Super 25) v podmínkách závlah. Všechny sledované znaky byly průkazně ovlivněny použitými dávkami dusíkatých hnojiv. Výnosová reakce na tyto dávky byla pozitivní a lineární. Výsledky pokusu ukázaly, že ve sledovaném regionu byla pro produkci slunečnice pod závlahami optimální dávka 120 kg N/ha.

Klíčová slova: slunečnice; dávky dusíku; růst; výnos nažek; výnosotvorné prvky

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