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RESPONSE OF DIFFERENT LEVEL OF NITROGEN AND SULPHUR DOSES ON OIL YIELD AND SEED NUTRIENTS CONTENT OF SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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ABSTRACT

This research was performed to determine the response of nitrogen (40, 80, 120 kg N ha^{-1}) and sulphur rates (0, 50, 100, 150 kg S ha^{-1}) on oil yield and seed nutrients content of sunflower. The experiment design was in split plots of randomized complete blocks with three replications for two years.

According to the results the lowest oil yield (0.66 t ha^{-1}) was obtained with 40 kg N ha^{-1} and 0 kg S ha^{-1} while the highest oil yield (1.61 t ha^{-1}) was from 80 kg N ha^{-1} and 150 kg S ha^{-1} application. The increase in oil yield parallel with increase the nitrogen doses to 80 N kg ha^{-1} doses without sulphur and after this increase was stopped. But with the addition of sulfur doses, this increase higher and continued to 120 N kg ha^{-1}. The nitrogen and sulfur applications as compared to control increased the nitrogen and protein content of seeds by about 2%. The increase in nitrogen doses had a positive effect on nitrogen and protein content of seeds, though the increase in nitrogen content was become important after 100 kg S ha^{-1} application. Seed phosphorus content varied between 0.44% and 0.545% in practice. The effects of sulfur doses and nitrogen x sulfur interactions on seed potassium content were significant and the seed potassium content varied between 0.574% and 0.960%. The effect of nitrogen and sulfur doses on the seed calcium content in sunflower was significant in both years and the seed calcium ratio was between 0.111% and 0.144%. The effect of sulfur doses on seed sulfur content in sunflower was significant in both years and the seed sulfur ratio was between 0.133% and 0.238%.

KEYWORDS:
Sunflower, Sulphur, oil yield, nutrients content

INTRODUCTION

Food demand increases parallel to the population growth. The demand can be only meet by increasing the production in per unit area due to the lack of opportunity to expand agricultural areas. Since increasing oil demand in Turkey cannot be met by agricultural production, about 3.5 million dollars each year is paid for oilseeds and their derivatives. Turkey imports 70% of the vegetable oils consumed [1-3]. The oil industry, which has sufficient oil seed processing capacity, is dependent on the oilseed to be imported. Sunflower, containing 40-50% oil in seeds is in the first place in Turkey among oilseed crops. The pulp obtained from sunflower with 40-45% rate is a valuable livestock feed due to containing 30-40% of protein. Sunflower with high level of linoleic acid in its oil has an important role in the oil paint industry due to its accelerating properties. It is also used as raw material for the paper, plastic, soap and cosmetic products [4]. Consumption of fertilizers, which is an important input of crop production in agriculture, is increasing, though this does not result in expected increase in crop yield. Improper and excessive use of fertilizers in crop production degrades fertility balances of soils and lead decrease in the quality of yields obtained from crops grown. Fertilizers are usually applied as homogeneously to the entire field. Fertilizer application without soil analysis, leads to accumulation of excess nutrients in the soil and diminishes the fertility of soils. Sulphur plays an important role in the metabolism of all living organisms influencing their proper growth and development[5]. Sulfur is one of the most important nutrients in oilseed plants. Sulfur plays an important role in plants both synthesis of protein and other enzymes. The reduction of atmospheric sulfur gases with the environmental activities in addition to decline in consumption of pesticides containing sulfur have increased the sulfur deficiency[6]. Sulfur deficiencies are observed in soils with the decrease in consumption of sulfur fertilizers. Sulfur deficiency has been reported in about 30% of agricultural lands in China, India, Western Europe and North America [7]. Inal et al. [8] found sulfur deficiency in more than 50% of wheat grains and straws collected from surrounding regions of Ankara province. The sulfur deficiency symptoms may be misidentified because the similar to nitrogen deficiency. The use of sulfur fertilizer has a positive effect on oil quality and yield especially in oilseed plants. The most obvious symptom of sulfur deficiency in sunflower, as in all other plants, is a pale-yellow coloring that is uniformly distributed throughout all the leaves of a plant, sometimes with a mottled appearance but more pronounced in young leaves. Sulfur deficiency is easily corrected by application of sulfated (Ammonium Sulfate, Triple Super Phosphate etc.) fertilizers, other fertilizers with sulfur and gypsum. Sulfur is considered as the fourth major nutrient, but some plants require as much sulfur as phosphorus. Sulfur requirement of oil seed plants is higher than other cultivated plants. Sunflower, which is not very selective in terms of soil requirements, can be grown in different soil types. The often use of nitrogen in sunflower increases the severity of the existing sulfur deficiency. Retardation of sunflower in growth and decrease in grain and oil yield are expected in sulfur deficiency.

MATERIALS AND METHODS

The research was carried out in the research and application field of Field Crops Department of the Faculty of Agriculture, Ankara University in 2006 and 2007. Sanbro oil sunflower variety was used as plant material. The experiment was conducted according to split plots in randomized blocks design for two-year with three replications. Nitrogen doses (40, 80, 120 kg N ha^{-1}) were placed in the main plots of the experiment. Ammonium nitrate (33% N) fertilizer was used as a nitrogen source, and half of nitrogen was applied at planting, while the remaining half was placed with hoeing when plants had 6-8 leaves. Sulfur doses (0, 50, 100, 150 kg S ha^{-1}) to the sub plots were applied at planting in the form of gypsum ($CaSO_42H_2O$) containing 17% sulfur (S). 60 kg P_2O_5 ha^{-1} DAP (18-46) fertilizer was broadcasted to all experimental plots during planting. The N was balanced by N from NH_4NO_3 fertilizer and DAP fertilizer applied at planting.

The crude oil ratio was determined by using Soxhlet method. Three to four g seed from each plot was ground, placed into cartridges and analyzed for 6 hours in anhydrous ether extraction (Akyıldız, 1968). For the analysis of seeds, the husks of 3-4 g seed from each plot were removed and seeds were ground. The nitrogen-protein content was determined by Kjeldahl method and phosphorus, potassium, calcium and sulfur contents were analyzed by using ICP-OES device.

The soils in experimental site were loamy in texture with moderately alkaline reaction and non-saline (Table 1).

According to the climatic data (as can be seen in Table 2), the relative humidity and precipitation in 2006 and 2007 between April and September (the period the study was conducted) were below the long-term annual average. Temperature values during the cultivation period were above the long-term average for the region. All plots were furrow irrigated regularly and uniformly to avoid drought stress. Each irrigation brought the soil moisture back to near field capacity.

The data obtained in two-year were subjected to analysis of variance according to split plots in randomized blocks experimental design. The significance of difference among treatments were determined by using The Least Significant Differences (LSD) test. All statistical evaluations were performed using the MSTAT-C statistical program [9].

TABLE 1
Physical and chemical properties of soils in trial areas

Texture	pH	EC (dS/m)	$CaCo_3$ (%)	Total N (%)	Available P (ppm)	Available K (ppm)	OM (%)
Loamy	8.20	0.19	5.92	0.19	12.3	430	3.8

TABLE 2
Meteorological data in Ankara Province during the period of 1975-2007

Month	Temperature (°C)			Precipitation (mm)			Relative Humidity (%)		
	1975-2006	2006	2007	1975-2006	2006	2007	1975-2006	2006	2007
January	0.3	-1.5	1.2	40.6	35.5	39	73	76	76
February	1.8	0.4	2.5	33.4	67.2	16.4	70	81.1	68.5
March	6	7.6	7.2	35.4	40.4	37.5	63	62.2	59.5
April	11.3	13.3	9.1	53.1	29.4	23.8	60	50.4	53.7
May	15.9	16.4	20.4	50.5	29.5	17.9	58	53.9	41.1
June	20	21.5	22.6	33.6	31.8	31.7	53	47.5	45
July	23.4	23.2	26.7	15.2	2.2	3.9	47	42.2	29.8
August	23.1	27.6	26.3	12.7	0.1	9.8	47	34	37.1
September	18.5	18.4	20.9	17	78.3	0	51	56	35
October	12.9	14.1	16.7	30.8	37.1	14.1	62	69.6	49.4
November	6.6	5.8	6.7	36.5	19	66.7	70	72.2	66.6
December	2.3	1.3	2	41.4	1.3	44.4	76	67.6	75.7
Total	-	-	-	400.2	371.8	305.2	-	-	-
Mean	11.8	12.3	13.5	-	-	-	60.8	61.5	52.9

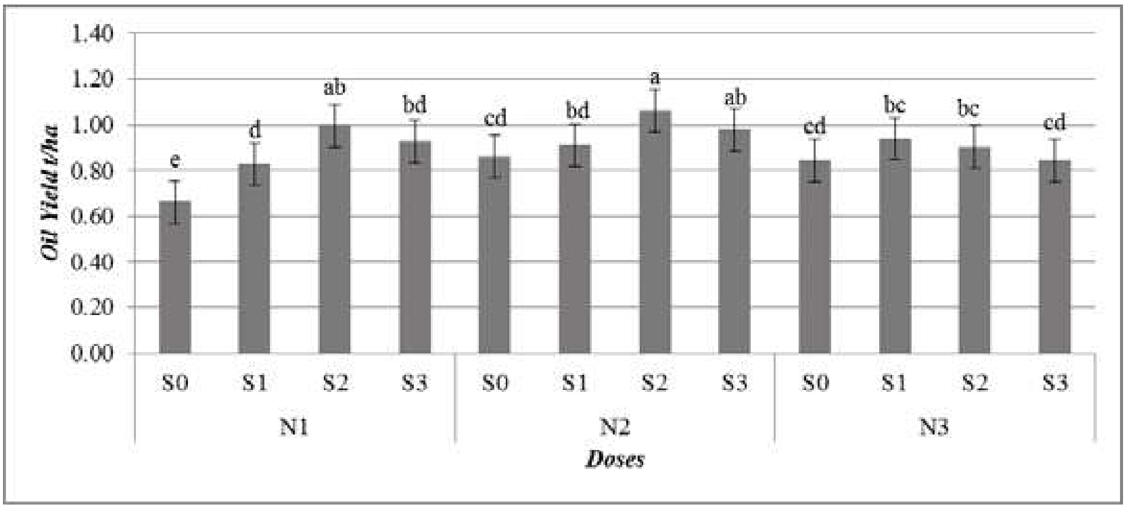

FIGURE 1
The effect of nitrogen and sulphur doses on sunflower oil yields (t ha^{-1}) in 2006

TABLE 3
Effects of nitrogen and sulphur doses on oil yield and nutrients content of oilseed sunflower seed.

Analysis of Variance	*Df*	*Oil Yield*		*Seed N Content*		*Protein Content*	
		2006	*2007*	*2006*	*2007*	*2006*	*2007*
Replication	2	ns	ns	ns	ns	ns	ns
N Doses	2	ns	*	**	**	**	**
Eror	4						
S Doses	3	**	**	*	**	*	**
NxS	6	**	ns	*	**	*	**
Eror	18						
CV		6.60	7.18	8.79	4.67	8.79	4.76
Nitrogen Doses							
N1		***0.853***	***1.255b***	***3.99 b***	***4.27 b***	***24.95 b***	***26.72 b***
N2		***0.953***	***1.417a***	***4.62 a***	***4.76 a***	***28.89 a***	***29.73 a***
N3		***0.883***	***1.543a***	***4.85 a***	***4.98 a***	***30.33 a***	***31.10 a***
LSD			***0.152***	***0,364***	***0,238***	***2,271***	***1,491***
Sulphur Doses							
S0		***0.788b***	***1.244b***	***4.20 b***	***4.22 b***	***26.24 b***	***26.34 c***
S1		***0.891ab***	***1.332b***	***4.33 b***	***4.66 ab***	***27.04 b***	***29.14 b***
S2		***0.987a***	***1.482a***	***4.59 ab***	***4.80 a***	***28.68 ab***	***30.00 ab***
S3		***0.917b***	***1.560a***	***4.84 a***	***5.00 a***	***30.28 a***	***31.24 a***
Mean		***0.896***	***1.405***	***4.489***	***4.669***	***28.059***	***29.181***
LSD		***0.172***	***0.099***	***0.391***	***0,444***	***2,441***	***1,349***

*, ** significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. ns, nonsignificant.

RESULTS AND DISCUSSION

The effect of sulfur doses on oil yield was significant in both years, while the nitrogen*sulfur interaction was only significant ($P< 0.01$) in 2006 and nitrogen doses significant ($P<0.05$) only in 2007 (Table 3). The results of two year-experiment indicated that the lowest oil yield (0.66 t ha^{-1}) was obtained with 40 kg N ha^{-1} and 0 kg S ha^{-1} in 2006 while the highest oil yield (1.61 t ha^{-1}) was from 80 kg N ha^{-1} and 150 kg S ha^{-1} application rate in 2007 (Figure 1). The effect of nitrogen doses on oil yield increased with the increasing sulfur application rates.

Similarly, Ramu and Reddy [10] reported increased oil content of sunflower with the sulfur application. The increase in oil content has also resulted an increase in the oil yield. This increase in oil yield may be attributed to the increase in fatty acid synthesis due to the increase in sulfur application dose. The increase in oil yield might be resulted from increased activity of thiokinase enzyme, which is effective in the synthesis of fatty acids due sulfur supply [11].

The nitrogen and sulfur doses along with nitrogen x sulfur interaction had significant effect on nitrogen content of seeds (Table 3). The highest seed nitrogen content in both years of the experiment (5.67% in 2006 and 5.58% in 2007) was recorded with 120 kg N ha^{-1} and 150 kg S ha^{-1} (N_3S_3) dose while the lowest seed nitrogen content (3.72% in 2006 and 3.99% in 2007) was with 40 kg N ha^{-1} and 0 kg S ha^{-1} (N_1S_0) dose (Table 4). The nitrogen content of seeds in two-year experiment varied between 3.72 and 5.67%. The nitrogen and sulfur applications as compared to control increased the nitrogen content of seeds by about 2%. The increase in nitrogen doses had a positive effect on nitrogen content of seeds, though the increase in nitrogen content was become important after 100 kg S ha^{-1} application. Studies on different plants revealed that nitrogen and sulfur application improved the nitrogen uptake and nitrogen content in plants [12-15].

The effects of nitrogen and sulfur applications and nitrogen x sulfur interaction on the protein content of sunflower seeds were found to be important (Table 3). The highest seed protein content (35.46% in 2006 and 34.84% in 2007) in both years of the experiment was obtained by the application of 120 kg N ha^{-1} and 150 kg S ha^{-1} (N_3S_3), and the lowest seed protein content (23.25% in 2006 and 2007 24.96%) was obtained by the application of 40 kg N ha^{-1} and 0 kg S ha^{-1} (N_1S_0) application rates (Table 4).

The increase in nitrogen and sulfur application rates significantly increased the protein content of seeds. The seed protein ratio was 23-24% in the control plots with 40 kg ha^{-1} nitrogen and no sulfur, whereas seed protein content was 34-35% with the application of 120 kg ha^{-1} nitrogen and 150 kg ha^{-1} sulfur. The protein ratio was 26% on average with 120 kg N ha^{-1} nitrogen and no sulfur application while protein rate increased to 31% with 150 kg ha^{-1} sulfur application (Table 3,4). Similar results were obtained in studies conducted to determine the effect of nitrogen and sulfur application on protein contents of on different plants [16].

Nitrogen doses had a significant effect ($P<0.05$) on phosphorus content of sunflower seeds only in the second year (2007) of the experiment. The phosphorus content of seeds in 2006 ranged from 0.440 to 0.545%. The highest phosphorus content (0.526%) of seeds in the second year of the experiment (2007) was obtained with 80 kg N ha^{-1} (N_2) while the lowest phosphorus content (0.475%) of seeds was recorded

TABLE 4
Response of different levels of nitrogen and sulphur doses on seed nutrients content of sunflower

Nitrogen Doses	*Sulphur doses*	*Oil Yield (t ha^{-1})*		*Nitrogen content (%)*		*Potasium content (%)*		*Protein Content (%)*	
		2006	*2007*	*2006*	*2007*	*2006*	*2007*	*2006*	*2007*
N1 (40 kg ha^{-1})	***S0 (0 kg ha^{-1})***	0.66e	1.06	3.72 e	3.99 f	0.77 d	0.57 f	23.25 e	24.96 e
	S1 (50 kg ha^{-1})	0.83d	1.18	4.31 ce	4.33 ef	0.81 bd	0.68 ce	26.91 ce	27.04 de
	S2 (100 kg ha^{-1})	0.99ab	1.31	4.03 de	4.20 ef	0.81 bd	0.67 de	25.21 de	26.26 de
	S3 (150 kg ha^{-1})	0.93bd	1.48	3.91 de	4.58 de	0.86 b	0.74 a	24.43 de	28.60 de
N2 (80 kg ha^{-1})	***S0 (0 kg ha^{-1})***	0.86cd	1.20	4.39 be	4.10 f	0.79 cd	0.64 de	27.45 be	25.65 e
	S1 (50 kg ha^{-1})	0.91bd	1.33	4.49 be	4.90 bd	0.80 bd	0.69 bd	28.08 bd	30.61 bc
	S2 (100 kg ha^{-1})	1.06a	1.54	4.66 bd	5.18 b	0.96 a	0.73 ab	29.10 bd	32.37 b
	S3 (150 kg ha^{-1})	0.98ab	1.59	4.95 bc	4.85 bd	0.80 bd	0.66 de	30.93 bc	30.29 bc
N3 (120 kg ha^{-1})	***S0 (0 kg ha^{-1})***	0.84cd	1.47	4.48 be	4.55 de	0.77 d	0.63 e	28.02 be	28.42 cd
	S1 (50 kg ha^{-1})	0.94bc	1.49	4.18 de	4.76 cd	0.80 bd	0.66 de	26.12 de	29.76 c
	S2 (100 kg ha^{-1})	0.90bd	1.60	5.08 ab	5.02 bc	0.87 b	0.74 a	31.74 ab	31.36 b
	S3 (150 kg ha^{-1})	0.84cd	1.61	5.67 a	5.57 a	0.85 bc	0.72 ac	35.46 a	34.84 a
LSD (0.05)		0.112		0.677	0.372	0.077	0.054	4.232	2.334

For each main effect, values within columns followed by the same letter are not significant.

TABLE 5
Effects of nitrogen and sulphur doses on oil yield and nutrients content of oilseed sunflower seed.

Analysis of Variance	*Df*	*Seed P Content*		*Seed K Content*		*Seed Ca Content*		*Seed S Content*	
		2006	*2007*	*2006*	*2007*	*2006*	*2007*	*2006*	*2007*
Replication	2	ns	ns	ns	ns	ns	ns	ns	ns
N Doses	2	ns	*	ns	ns	*	*	ns	ns
Eror	4								
S Doses	3	ns	ns	**	**	*	*	**	**
NxS	6	ns	ns	*	*	ns	ns	ns	ns
Eror	18								
CV		7.99	5.82	5.4	5.26	6.27	4.24	4.81	5.1
Nitrogen Doses									
N1		*0.485*	*0.475 b*	*0.814*	*0.665*	*0.132 b*	*0.111 b*	*0.225*	*0.148*
N2		*0.495*	*0.526 a*	*0.837*	*0.68*	*0.137 ab*	*0.120 a*	*0.228*	*0.156*
N3		*0.477*	*0.512 a*	*0.822*	*0.689*	*0.146 a*	*0.119 a*	*0.227*	*0.157*
			0.036			*0.007*	*0.007*		
Sulphur Doses									
S0		*0.488*	*0.48*	*0.774 c*	*0.615 b*	*0.130 b*	*0.113 b*	*0.208 b*	*0.133 c*
S1		*0.482*	*0.503*	*0.817 bc*	*0.676 a*	*0.137 ab*	*0.116 ab*	*0.226 a*	*0.149 b*
S2		*0.505*	*0.521*	*0.881 a*	*0.715 a*	*0.144 a*	*0.118 ab*	*0.238 a*	*0.165 a*
S3		*0.468*	*0.512*	*0.839 ab*	*0.708 a*	*0.142 a*	*0.119 a*	*0.235 a*	*0.166 a*
Mean		*0.486*	*0.504*	*0.824*	*0.678*	*0.138*	*0.117*	*0.227*	*0.153*
LSD				*0.044*	*0.031*	*0,010*	*0,005*	*0,010*	*0,010*

*, ** significant at the 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. ns, nonsignificant.

at 40 kg N ha^{-1} (N_1) application (Table 5). The phosphorus content of sunflower seeds in 2007 ranged from 0.456 to 0.558%. The results of two-year study revealed that the effect of sulfur doses on phosphorus content of sunflower was not significant. The seed phosphorus content at 100 kg S ha^{-1} (S_2) application rate was significantly higher than the other sulfur application rates. In the second year of experiment, the highest potassium content was 0.743% obtained from 40 kg N ha^{-1} and 150 kg S ha^{-1} (N_1S_3) and 120 kg N ha^{-1} and 100 kg S ha^{-1} (N_3S_2) application rates (Table 4).

The effect of sulfur doses on seed potassium content in both years was significant at 1% level of importance, however the effect of nitrogen x sulfur interaction was significant at 5% (Table 4). The highest seed potassium content (0.960%) in 2006 was recorded with 80 kg N ha^{-1} and 100 kg S ha^{-1} (N_2S_2), whereas the lowest potassium content (0.768%) of seeds was obtained with 120 kg N ha^{-1} and 0 kg S ha^{-1}. The lowest potassium rate (0.574%) in sunflower seeds was occurred at 40 kg N ha^{-1} and 0 kg S ha^{-1} (N_1S_0) (Figure 4).

Nitrogen and sulfur application rates in both years had significant ($P<0.05$) effect on calcium content of sunflower seeds. The highest calcium content (0.146%), according to the average nitrogen application rates in 2006, was obtained with 120 kg N ha^{-1} (N_3) dose. Similarly, 100 kg S ha^{-1} (S_2) and 150 kg S ha^{-1} (S_3) among sulfur application rates in 2006 resulted in the highest calcium content as 0.144% and 0.142%, respectively. The highest calcium content (0.12%) of sunflower seeds in 2007 was recorded at 80 kg ha^{-1} (N_2) treatment while the lowest calcium (0.111%) was obtained with 40 kg N ha^{-1} (N_1). The highest seed calcium content (0.119%) among sulfur applications was obtained from 150 kg S ha^{-1} (S_3) dose (Table 5).

The effects of sulfur application on sulfur content of sunflower seeds was significant ($P<0.01$) both in 2006 and 2007. The highest sulfur contents of seeds, according to average sulfur doses, were 0.238% (2006) and 0.166% (2007) and obtained with 100 kg of S ha^{-1} and 150 kg of S ha^{-1} application rates, respectively. The control treatments, zero sulfur resulted in the lowest seed sulfur contents both in 2006 (0.208%) and 2007 (0.133%). Sulfur content of the seeds has also increased with the increase in sulfur application rates. The seed sulfur content in the two-year experiment ranged from 0.125 to 0.243%. Application rates of 100 (S_2) and 150 kg S ha^{-1} (S_3) which resulted in the highest sulfur content were statistically placed in the same group that means seed sulfur contents between S_2 and S_3 were not significantly different (Table 5). Therefore, 100 kg S ha^{-1} is recommended as the optimum application rate. Many researchers have indicated that application of nitrogen alone especially in sulfur-deficient soils negatively impacts nitrogen uptake and yield whereas sulfur addition increases nitrogen uptake, yield and plant sulfur content [17, 18].

CONCLUSION

The effects of different nitrogen (40, 80, 120 kg N ha^{-1}) and sulfur application doses (0, 50, 100, 150 kg S ha^{-1}) on sunflower oil yield (t ha^{-1}), and nitrogen, phosphorus, potassium and calcium contents of seeds were investigated. The increase in nitrogen rate had a positive impact on seed oil yield and seed nutrients content. Sulfur doses, in addition to the nitrogen have further strengthen the positive effect. Sulfur application up to 100 kg S ha^{-1} in addition to nitrogen resulted in about 10-12% increase in oil yield. The results indicated that the highest seed and oil yields and nutrient concentration of seeds can be obtained with 80 kg N ha^{-1} and 100 kg S ha^{-1} application. The increase in oil yield with the use of sulfur fertilizer is important both to meet the vegetable oil demand and decrease the cost of vegetable oil. The increase in the nutrient concentration of seeds will increase the nutritional value of the pulp used in the livestock feed.

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