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THE EFFECTS OF NITROGEN AND SULPHUR FERTILIZERS ON THE YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.)

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ABSTRACT

This study was conducted to determine the effects of nitrogen and sulphur applications on the yield and quality of fenugreek in Van, Turkey in 2006 and 2007 growing seasons. Field trials were designed in Completely Randomized Block Design with three replications at the experimental fields of Agricultural Faculty of Yüzüncü Yıl University. In the study, plant height (cm), the number of branches (branch plant^{-1}), first pod height (cm), the number of pods (pod plant^{-1}), the number of seeds in the pod (seed pod^{-1}), pod length (cm), thousand-seed weight (g), seed yield (kg ha^{-1}), protein content (%) and protein yield (kg ha^{-1}) were determined. The all growth and yield parameters except for thousand seed weight were significantly affected by nitrogen fertilization. All the parameters except for the number of branches, pod length and thousand seed weight were affected by sulphur fertilization.The highest seed yields (853.0 and 815 kg ha^{-1}) were obtained from 90 kg N ha^{-1} and 20 kg S ha^{-1}applications in 2006 and 2007, respectively. The highest protein content (24.2 %) was obtained from 90 kg N ha^{-1} and 40 kg S ha^{-1} applications in both experimental years.

Key words: Fenugreek, nitrogen, sulphur, yield

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.), belongs to subfamily *Papilionaceae* of the *Leguminous* family, is an erect annual herbaceous plant that grows up to 10-50 cm height. This species is indigenous to western Asia and south-eastern Europe (Sulieman et al., 2008). Because of edible and medicinal values of its seeds, it has long been widely cultivated in Asia, Africa and Mediterranean countries for a long time (Amin et al., 2005).

Nowadays, the number of the plants used for medical purpose is about 35.000 species. The large majority (80 %) of the world population use the plants in treatment. One-fourth of the modern pharmacopies is pure substances that omitted from plants (Anonymous, 2010). Most of the plants used for this aim have been collected from nature and production of them is limited, unfortunately.

Fenugreek *(Trigonella foenum-graecum* L.*)* has a long history of medicinal uses in Ayurveda. It is well-known as traditional medicine for diabetes, indigestion, elevation of lipids and edema (fluid retention) of the legs. Fenugreek is also good source of dietary protein for human and animals. Its seeds have a strong aroma and somewhat bitter in taste. Seeds of fenugreek are used locally as yellow dye in cosmetics and medicinal purposes. Fenugreek is a good soil renevator and is widely used as a green manure (Abdelgani et al., 1999). Fenugreek is used as a spice, vegetable and a medicinal plant. Since antioxidant properties have been linked to health benefits of natural products, such properties were studied in germinated fenugreek seeds which are considered to be more beneficial than dried seeds (Dixit et al., 2005). Fenugreek has a high proportion of protein (approximately 20–30 %) as well as amino acid, 4-hydroxyisoleucine, which has high potential for insulin-stimulating activity.

In Turkey, fenugreek is widely cultivated as a spice crop for a long time. Production area of fenugreek is about 850 hectares and an annual seed production is about 1000 tons. Average seed yield is about 1180 kg ha^{-1} in 2004 (Bayram et al., 2010). It is one of the most important industrial and export crops in Turkey, as well.

Nitrogen fertilization has become the key input in food production. Nitrogen is a common plant nutrition which promotes vegetative developments in plants. This plant nutrient is also important for producing herba, folium and seed yields in medicinal and spice plants (Ceylan, 1995). Sulphur (S) is of the major plant nutrients for grain legumes. Sulphur plays a vital role in plant metabolism. It constitutes the main element of amino acids such as cysteine and methionine, which are of essential nutrients. Sulphur has positive effects on the root growth in plants. In particular, this element positively affects nodulation in legume crops (Kacar, 1984).

The objective of this study was to assess the effects of nitrogen and sulphur levels on the yield and yield components of fenugreek cultivated in Van ecological conditions.

MATERIALS AND METHODS

Fenugreek cv. Gürarslan was used as seed material. The seeds were provided from Department of Field Crops, Faculty of Agriculture of Ankara University. The soil in the experimental area was sandy-clay-loam texture, and the potassium content was 560.1 ppm. Phosphorus content (595.2 ppm) of the soil was adequate; organic matter (% 1.51), nitrogen (% 0.078) and salt (%0.072-0.091) contents were low. Total lime content (19-21.9 %) was high and the soil was light alkalin (pH 7.8).

In the experimental years, the amount of rainfall in the second year (349.4 mm) was lower than the first year (424.1 mm). Average rainfall for long years was 385.7 mm. Average temperature values were about 10.0 °C, 9.5 ^{0}C and 9.0 °C for 2006, 2007 and long years, respectively. It was 109.0 mm in 2007 trial year, while average rainfall amount was 99.9 mm in summer growing season (April-August) of 2006 trial year. Also, rainfall distribution to months was irregular in both years. Relative humidity was higher than the long years' average (57 %) in both years (59.6 -60.9 %) (Anonymous, 2008).

Field trials were conducted in the fields of Yüzüncü Yıl University according to Completely Randomized Block Design with three replications in the growing seasons of 2006 and 2007. In the study, four different nitrogen (Ammonium sulphate 21 %) doses (N_o= 0, N_3 = 30, N_6= 60 and N_9 =90 kg N ha^{-1}) and three different sulphur doses (So= 0, S_2= 20 and S_4= 40 kg S ha^{-1}) were applied. Sowing dates were 4th April in 2006 and 7th April in 2007. Seeds were sown by hand with 25 cm apart in eight lines per plot. Seed rate was 30 kg ha $^{-1}$. In this research, plot sizes were 3 m in length, 2 m in wide and total plot area was 6 m^2. Triple super phosphate (TSP) fertilizer (46 % TSP) was applied to plots as 60 kg ha $^{-1}$ at sowing. In this study, irrigation was made 7 times in 2006, and 8 times in 2007. Weed control was made a few times during both years.

Before harvesting, two edge rows and 50 cm from each plot heads were discarded as side effects. All the plots were evaluated on 3 m^2 area. In the trial plant height, the number of branches, first pod height, the number of pods, the number of seeds per pod and pod length in 10 plants randomly chosen were measured. Harvest was carried out at end of July in both years. Harvested plants were dried in shade throughout 3-4 days on the field. They were threshed, and seed yields were calculated for plots.

The data obtained from the trials were subjected to statistical analyses in Completely Randomized Block Design. Average values were compared by LSD % 5 (Düzgüneş et al., 1987).

RESULTS AND DISCUSSION

All the growth and yield parameters were significantly affected by different nitrogen doses in both years, except for the number of seeds per pod and pod length in first experimental year. Plant height, the number of branches, first pod height, the number of pods, pod length, the number of seeds in per pod, thousand-seed weight, seed yield, seed protein content and protein yield increased with increasing nitrogen levels.

The effects of different sulphur doses applications on the seed and protein yield in fenugreek were found significant statistically except for the number of branches in both years. Plant height, the number of pods and the number of seeds per pod in 2006, and first pod height, pod length, thousand-seed weight and protein content in 2007 were found statistically significant (Table 1).

Plant Height

Plant height of fenugreek was affected significantly ($P<0.05$) by the experimental years (Table 1). Plant heights were 40.5 and 38.9 cm in 2006 and 2007, respectively (Table 2). Different nitrogen doses affected the plant height significantly ($P<0.01$) in both years (Table1). The highest plant height (42.2 cm) was obtained from 90 kg N ha^{-1} application in both experimental years. The lowest plant height was obtained from the control plots as 38.5-36.3 cm for 2006 and 2007, respectively (Table 2). Plant height increased with increasing nitrogen doses. In previous studies related to fenugreek; Data et al. (2005), Rathore and Manohar (1990), Selverajan and Chezhiyan (2001), Thapa and Maity (2004) and Sharma (2000) reported that plant height increased by increasing nitrogen doses.

Table 1. The significant F values of the treatments and their interactions for the yield and yield components in Fenugreek

	Years	Plant height	Number of branches	First pod height	Number of pods	Number of seeds in pod	Pod lenght	Thousand-seed weight	Seed yield	Protein content	Protein yield
Nitrogen (N)	2006	**	**	**	*			*	**	**	**
	2007	**	**	**	**	**	**	*	**	**	**
	Means	**	**	**	**	**	**		**	**	**
Sulphur (S)	2006			*			*	*	**	*	**
	2007	**			*	*			**		**
	Means	*		*	*	**			**	*	**
Year (Y)		*		**	**			**	**	*	**
N x S	2006						**				
	2007	*					**	*			
	Means					*	**				
N x Y						*	**	*	**	*	**
S x Y											
N x S x Y		**					*				

* significant at $P<0.05$ level ** significant $P<0.01$ level

There were significant differences among the sulphur applications by means of plant height values of fenugreek in 2007 ($P<0.01$) and two year's average ($P<0.05$). However, the effect of sulphur application was not significant in 2006 (Table 1). The highest plant height (40.8-40.0 cm) was obtained from 40 kg S ha^{-1} application in both years. The lowest plant height value (40.3-38.3 cm) was obtained in 20 kg S ha^{-1} application. Plant heights were increased by increasing sulphur doses. In the previous studies related to sulphur application in fenugreek, Jat and Shaktawat (2001) and Nehara et al. (2006) reported that the highest plant height was obtained from 100 kg ha^{-1} and 50 kg ha^{-1} S applications, respectively.

Nitrogen x sulphur fertilizer interaction was found statistically significant ($P<0.05$) in 2007 (Table 1). The highest plant height values in this interaction were obtained from 90 kg N ha^{-1} and 40 kg S ha^{-1} applications with 43.6 cm; the lowest value was obtained in the control plots and 20 kg S ha^{-1} application with 35.6 cm (Table 2).

Number of Branches

There were no significant differences in the number of branches between the experimental years (Table 1). The effects of nitrogen doses on the number of branches of fenugreek were statistically significant ($P<0.01$) in both experimental years and means of years. As the highest the number of branches (2.8 branch $plant^{-1}$) was obtained in 90 kg N ha^{-1} application in 2006, 60 kg N ha^{-1} application gave the highest number of branches (2.8 branch $plant^{-1}$) in 2007. There were no statistical differences between 60 and 90 kg ha^{-1} N applications for the number of branches in 2007. The lowest values (2.5 and 2.4 branch $plant^{-1}$) were obtained from control plots in both years (Table 2). The number of branches was increased by increasing nitrogen levels. Similar results have also been reported by Data et al. (2005) and Thapa and Maity (2004).

The effect of different sulphur levels on the number of branches of fenugreek was not significant in the experimental years (Table 1). As the values changed between 2.6 and 2.7 branch $plant^{-1}$ for first year, the all sulphur applications gave 2.6 branch $plant^{-1}$ for second year (Table 2). Apart from our results, Jat and Shaktawat (2001) and Nehara et al. (2006) stated that there was relation between the sulphur applications. They obtained the highest number of branches with increasing sulphur levels up to 100 kg ha^{-1} and 50 kg ha^{-1}.

First Pod Height

The results indicated that the effects of nitrogen and sulphur applications on the first pod height were statistically significant ($P<0.01$) in the experimental years (Table 1). First pod heights of fenugreek were 17.5 and 17.0 cm for 2006 and 2007, respectively (Table 2).

As shown in the Table 1, different nitrogen levels significantly ($P<0.01$) affected the first pod height of fenugreek in both years and in the average of years. The highest values (18.5-18.0) were obtained from 90 kg N ha^{-1} application in the experimental years. The lowest first pod heights (16.5 and 15.4 cm) were obtained from the control plots (Table 2). Previous studies (Data et al. 2005; Thapa and Maity 2004) supported our results.

There were statistical differences ($P<0.05$) among the sulphur doses on the first pod height of fenugreek in 2006 and in average of the years; but no significant differences were found in 2007 (Table 1). As the highest first pod height (17.8 cm) was recorded in 40 kg S ha^{-1} application in 2006, first pod heights of 17.2 and 17.3 were obtained from S_0 and S_{20} applications, respectively (Table 2). The first pod height increased with increasing sulphur levels. Similar results were obtained by Jat and Shaktawat (2001) and Nehara et al. (2006) who reported that overall yield traits of fenugreek increased with increasing sulphur levels.

Number of Pods

The number of pods changed significantly ($P<0.01$) in the experimental years (Table 1). It was found that the first year produced higher number of pods (8.7 pod $plant^{-1}$) than that of the second year (8.3 pod $plant^{-1}$) (Table 1 and 2).

The effects of nitrogen doses on the number of pods of fenugreek were significant in 2006 ($P<0.05$), in 2007 ($P<0.01$) and in the average of two years (Table 1). The highest number of pods (8.9-8.7 pods $plant^{-1}$) was recorded in 90 kg ha^{-1} nitrogen application, while the lowest value (8.4-7.8 pod $plant^{-1}$) was obtained from the control plots in 2006 and 2007, respectively (Table 2). Increased nitrogen doses increased the number of pods in fenugreek in both years. In previous studies, Sharma (2000) reported that the highest number of pods was obtained from the higher nitrogen doses (60 kg N ha^{-1}). The number of pod values obtained in the study was compatible with the other researcher's findings. On other hand, Halesh et al. (2000) reported that the highest number of pods was obtained from 60 kg N ha^{-1}.

In 2006, there were no significant differences among the sulphur doses. The values changed between 8.5 and 8.9 number of pods. As the highest number of pod (8.5 pods $plant^{-1}$) was obtained from 20 kg ha^{-1} sulphur application, 40 kg ha^{-1} application gave the lowest number of pods in 2007 (Table 2). Our findings were in harmony with the results of Nehara et al. (2006).

Number of Seeds in Pod

There were no significant differences between the experimental years by means of the number of seed in pod (Table 1). Variance analyses showed that the effect of nitrogen doses on the number of seed in pod was significant ($P<0.01$) in 2007 and in the average of two years, while it was not significant in 2006 (Table 1). In point of mentioned feature, the highest value (13.9-13.6 seeds pod^{-1}) was obtained from 90 kg N ha^{-1} applications in 2006 and 2007, respectively. The lowest value was obtained from the control plots as 13.6-12.6 seeds pod^{-1} in the each two years, respectively (Table 2). Number of seeds in pod increased with increasing nitrogen levels. Similar results were reported by Data et al. (2005) who reported that the number of seeds in pod of fenugreek increased with increasing nitrogen levels. On the other hand, Shalaby and Mohamed (1976) reported that the number of seeds in pod decreased with increasing nitrogen levels.

The effect of different sulphur levels on the number of seeds in pod of fenugreek was not significant in 2006, while significant differences were found in 2007 ($P<0.05$) and in average of the years ($P<0.01$). The highest values were obtained (13.9-13.5 seed pod^{-1}) from 20 kg ha^{-1} S applied plots in both years, and the lowest values (13.6-12.8 seeds pod^{-1}) were obtained from the control plots, respectively (Table 2). Apart from our findings, Nehara et al. (2006) reported that the yield-attributing characters increased significantly with increase of sulphur levels. In terms of the number of seeds in pod, N x S interaction was not significant in both years of the study, while there were significant ($P<0.05$) differences in the average of years (Table 1).

Pod Length

The results indicated that the effect of nitrogen and sulphur applications on the pod length wasn't significant between years (Table 1). The effect of nitrogen doses on the pod length of fenugreek was not significant in the first experimental year, while it was significant ($P<0.01$) in the second year and two-years average (Table1). As the highest value (12.7 cm) was obtained from 90 kg N ha^{-1} fertilizer application in both years, 60 kg ha^{-1} and 30 kg N ha^{-1} nitrogen applications gave the lowest values (12.2-11.4 cm) in 2006 and 2007, respectively (Table 3). Pod lengths were affected positively by increasing nitrogen levels. These results are similar to the findings of Data et al. (2005), Thapa and Maity (2004) who reported that almost all the attributing parameters increased with increasing levels of nitrogen (50 kg/ha).

Different sulphur applications had significant ($P<0.05$) effects on the pod length of fenugreek in 2006. But these applications were not significant in 2007 and in average of the years (Table 1). Regarding with this parameter the highest value (12.7 cm) was obtained from 40 kg ha^{-1} sulphur dose in 2006, whereas the highest value (12.3 cm) was obtained from the control plots in 2007. While control plots gave the lowest value (12.2 cm) in the first year, 40 kg S ha^{-1} application gave the lowest value (11.9 cm) in the second year (Table 3). Our results are in agreement with the results of Nehara et al. (2006) who reported that significant increases occured with increasing of sulphur applications.

Table 2. Means of some yield components affected by different nitrogen and sulphur applications

		Plant height (cm)		Number of branches (branch plant^{-1})		First pod height (cm)		Number of pods (pods plant^{-1})		Number of seeds in pod (seeds pod^{-1})	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
	N_0	36.1	37.2e-g	2.6	2.4	16.1	15.1	8.4	8.0	13.9	12.5
S_0	N_3	41.0	37.0 fg	2.6	2.5	17.1	17.1	8.7	8,1	13.8	12.9
	N_6	41.7	38.5 d-f	2.6	2.8	17.6	17.4	8.3	8.7	13.7	13.2
	N_9	42.7	40.9 bc	2.8	2.8	18.1	17.3	8.7	8.3	13.2	13.0
S_0 mean		40.4	38.4 b	2.7	2.6	17.2 b	16.7	8.5	8.2 ab	13.6	12.8 b
	N_0	39.9	35.6 g	2.6	2.4	16.4	15.3	8.5	8.1	13.3	12.9
S_2	N_3	39.0	36.6 fg	2.6	2.4	16.6	16.9	9.0	8.3	14.2	12.9
	N_6	40.9	39.2 c-e	2.8	2.7	17.7	17.4	9.3	8.5	13.7	13.9
	N_9	41.3	41.9 ab	2.9	2.9	18.7	18.7	9.0	9.0	14.4	14.4
S_2 mean		40.3	38.3 b	2.7	2.6	17.3 b	17.0	8.9	8.5 a	13.9	13.5 a
	N_0	39.5	36.2 g	2.4	2.5	16.8	15.8	8.3	7.3	13.5	12.4
S_4	N_3	40.5	40.8 bc	2.6	2.4	17.6	16.6	8.4	7.8	13.5	12.6
	N_6	41.0	39.4 cd	2.7	2.8	18.1	18.3	8.9	8.5	13.8	13.4
	N_9	42.4	43.6 a	2.8	2.6	18.6	17.9	9.2	8.8	14.0	13.5
S_4 mean		40.8	40.0 a	2.6	2.6	17.8 a	17.1	8.7	8.1 b	13.7	13.0 b
N_0 mean		38.5 c	36.3 c	2.5 c	2.4 b	16.5 d	15.4 c	8.4 b	7.8 b	13.6	12.6 b
N_3 mean		40.2 b	38.1 b	2.6 bc	2.4 b	17.1 c	16.9 b	8.7 ab	8.0 b	13.8	12.8 b
N_6 mean		41.2 ab	39.0 b	2.7 ab	2.8 a	17.8 b	17.7 a	8.8 ab	8.5 a	13.7	13.5 a
N_9 mean		42.2 a	42.2 a	2.8 a	2.7 a	18.5 a	18.0 a	8.9 a	8.7 a	13.9	13.6 a
Means		40.5 a	38.9 b	27	2.6	17.5 a	17.0 b	8.7 a	8.3 b	13.7	13.1
CV (%)		5.3	6.7	6.9	9.2	5.3	7.3	6.2	6.4	3.8	5.4

*There were no significant differences between the mean values shown with the same letters in 5 % probability level.

Nitrogen x sulphur interaction had significant ($P<0.01$) effect on the pod length in both experimental years and in the average of years (Table 1). While the highest pod length (13.3 cm) was obtained from 30 kg N ha^{-1} and 20 kg S ha^{-1} application in 2006, it was obtained from control plots received 60 kg N ha^{-1} (13.6 cm) in 2007. While the lowest pod length (11.7 cm) was obtained from 60 kg N ha^{-1} and 20 kg S ha^{-1} applications in the first year, it was obtained from control plots with 30 kg N ha^{-1} applications (11.3 cm) in the second year (Table 3).

Thousand-seed Weight

There were statistical differences ($P<0.01$) between the years for thousand-seed weight of fenugreek and the first experimental year produced higher thousand seed weight (18.5 g) than the second year (18.0 g) (Table 1 and 3). Thousand-seed weight were affected significantly ($P<0.05$) by different doses of nitrogen in both years, while it was not significantly affected in average of the years (Table 1). The highest values were obtained from 30 kg N ha^{-1} (18.8 g) and 90 kg N ha^{-1} (18.3 g) applications for 2006 and 2007, respectively (Table 3). It was reported in the previous studies

that application of N had increases on the other characters except for seed yield of fenugreek (Shalaby and Mohamed, 1976); Nitrogen fertilization had no significant effects on the quality of the seeds (Abdelgani et al., 1999). 1000-seed weight (14.4 g) was obtained from increasing nitrogen levels up to 50 kg N ha^{-1} (Thapa and Maity, 2004).

Thousand-seed weight was significantly ($P<0.05$) affected by sulphur fertilization in the first experimental year. But, it was not affected signicantly in the second experimental year and in the average of the years (Table1). As the highest value (18.8 g) was obtained from 40 kg S ha^{-1} application in 2006, 20 kg ha^{-1} sulphur application gave 18.2 g thousand-seed weight in 2007 (Table 3). The lowest values (18.2-17.9 g) were obtained from 20 kg S ha^{-1} and 40 kg S ha^{-1} applications in 2006 and 2007, respectively. Nehara et al. (2006) stated that the yield-attributing characters of fenugreek were significantly increased up to 50 kg S/ha applications.

The effect of nitrogen x sulphur interaction on thousand seed weight of fenugreek was significant ($P<0.05$) in 2007 (Table 1). The highest thousand seed weight value in this interaction was obtained from 30 kg N ha^{-1} and 20 kg S ha^{-1} applications (18.8 g), whereas control plots and 40 kg S ha^{-1} interaction gave the lowest thousand-seed weight (17.1 g) (Table 3).

Seed Yield

There were significant ($P<0.01$) differences between the seed yield values of fenugreek in the experimental years (Table 1). Seed yield was recorded as 704.0 kg ha^{-1} in 2006, while its average value was 670.0 kg ha^{-1} in 2007 (Table 3). These differences in the average seed yields may be resulted from meteorological changes between the years.

The effect of nitrogen doses on the seed yield was significant ($P<0.01$) in both years and in the average of two years (Table 1). The highest seed yields (831.0-796.0 kg ha^{-1}) were recorded in 90 kg ha^{-1} nitrogen application, while the lowest values (549.0-503.0 kg ha^{-1}) were found in the control applications in both years (Table 3). In the present study, seed yield was significantly influenced by different levels of nitrogen. Similar results have been reported by Sharangi et al. (2005) who obtained maximum seed yields from 60 kg N ha^{-1} (between 716 and 1184 kg ha^{-1}). Sharma (2000) found that the highest seed yield per plot was 725 g from 60 kg N ha^{-1} application. Thapa and Maity (2004) obtained the highest seed yield as 1020 kg ha^{-1} in 50 kg N ha^{-1}. Data et al. (2005) stated that the maximum seed yield was recorded from 45 kg N ha^{-1} (1250 kg ha^{-1}). Similarly, some researchers reported that increasing N doses increased the seed yields in safflower, black cumin and fennel (Yıldırım et al., 2005; Tunçtürk et al., 2010 and Tunçtürk et al., 2011).

Table 3. Means of some yield components affected by different nitrogen and sulphur applications

		Pod length (cm)		Thousand-seed weight (g)		Seed yield (kg ha^{-1})		Protein content (%)		Protein yield (kg ha^{-1})	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
S_0	N_0	11.8 b	11.6 b	19.1	18.2 a-c	541.0	469.0	22.4	22.1	121	104
	N_3	12.2 ab	11.3 b	18.8	17.5 bc	617.0	643.0	22.9	22.7	141	146
	N_6	12.6 ab	13.6 a	18.7	18.1 a-c	762.0	714.0	23.7	23.3	181	166
	N_9	12.3 ab	12.7 ab	18.2	18.4 ab	820.0	770.0	23.8	24.1	195	183
S_0 mean		12.2 b	12.3	18.7 ab	18.1	658.0 b	649.0 b	23.1 b	23.0	159 b	149 b
S_2	N_0	12.2 ab	11.7 b	18.2	17.7 a-c	556.0	517.0	22.6	22.4	126	115
	N_3	13.3 a	11.5 b	18.5	18.8 a	673.0	672.0	23.0	23.0	155	154
	N_6	11.7 b	12.4 ab	18.4	17.7 a-c	792.0	715.0	23.5	23.5	185	168
	N_9	12.9 ab	12.7 ab	17.9	18.4 ab	853.0	815.0	23.8	24.1	203	196
S_2 mean		12.5 ab	12.1	18.2 b	18.2	719.0 a	680.0 a	23.2 b	23.2	167 a	158 a
S_4	N_0	13.1 a	12.0 b	18.8	17.1 c	548.0	524.0	22.6	22.2	124	116
	N_3	12.5 ab	11.4 b	19.2	17.7 a-c	666.0	667.0	23.3	22.9	155	153
	N_6	12.4 ab	11.9 b	18.6	18.6 ab	795.0	735.0	24.2	23.6	192	174
	N_9	12.7 ab	12.5 ab	18.2	18.1 a-c	820.0	802.0	24.2	24.2	198	194
S_4 mean		12.7 a	11.9	18.8 a	17.9	707.0 a	682.0 a	23.5 a	23.3	168 a	159 a
N_0 mean		12.4	11.8 b	18.7 a	17.7 b	549.0 d	503.0 d	22.5 c	22.2 d	123 d	112 c
N_3 mean		12.6	11.4 b	18.8 a	18.0 ab	652.0 c	661.0 c	23.1 b	22.8 c	150 c	151 c
N_6 mean		12.2	12.6 a	18.6 ab	18.1 ab	783.0 b	721.0 b	23.8 a	23.5 b	186 b	169 b
N_9 mean		12.7	12.7 a	18.1 b	18.3 a	831.0 a	796.0 a	23.9 a	24.1 a	199 a	191 a
Means		12.5	12.1	18.5 a	18.0 b	704.0 a	670.0 b	23.3 a	23.2 b	165 a	155 b
CV (%)		4.8	7.9	3.2	3.9	16.3	16.6	2.8	3.3	187	194

*There were no significant differences between the mean values shown the same letters in 5 % probability level.

There were statistically significant ($P<0.01$) differences among the sulphur doses on the seed yields of fenugreek in the both years (Table 1). The highest seed yields (719.0 kg ha^{-1} and 707.0 kg ha^{-1}) were obtained from 20 kg S ha^{-1} and 40 kg S ha^{-1} applications, respectively in the first year. Also, it was obtained (682.0 kg ha^{-1}) from 40 kg S ha^{-1} application in the second year. According to experimental years, the lowest values of seed yield (658.0-649.0 kg ha^{-1}) were obtained from the control plots (Table 3).

Seed yield increased with the increase of sulphur doses in fenugreek. Many research results showed that the highest seed yields were obtained from the maximum sulphur applications (Jat and Shaktawat, 2001; Jat and Shaktawat, 2003; Dayanand, 2004 and Nehara et al., 2006). Some

researchers reported that increases on seed yields were obtained in cicer (Kamiloğlu, 2008) and lentil (Parsak, 2006) with increasing sulphur doses.

Seed Protein Content

As shown in the Table 1, seed protein content of fenugreek changed significantly ($P<0.05$) by the experimental years (Table 1). Seed protein contents were 23.3 and 23.2 % in 2006 and 2007, respectively (Table 3).

The effect of nitrogen doses on the seed protein content of fenugreek was significant ($P<0.01$) in the experimental years and in the average of the years (Table 1). According to years, the highest seed protein content (23.9-24.1 %) was obtained from 90 kg ha^{-1} nitrogen dose, and the lowest value (22.5-22.2 %) was obtained from the control plots (Table 3). On the contrary, Abdelgani et al. (1999) reported that protein content of fenugreek seeds was not affected by nitrogen doses. Similar results were obtained from soybean where nitrogen fertilizer did not affect protein content significantly (Gaydou and Arrivets, 1983). However, as compatible with our study results 50 kg N ha^{-1} were found to increase protein content of faba bean (Babiker et al., 1995).

The effect of increasing sulphur doses on the seed protein content of fenugreek was significant ($P<0.05$) in 2006 and in the average of the years, but the second year there were no significant differences (Table 1). According to both years averages the highest values (23.5-23.3 %) were obtained from 40 kg ha^{-1} sulphur application. Control plots gave the lowest values (23.1-23.0 %)(Table 3).

Seed Protein Yield

The results indicated that the effects of nitrogen and sulphur applications on the protein yield were significant ($P<0.01$) in the experimental years (Table 1). Seed protein yields were 165 kg ha^{-1} and 155 kg ha^{-1} in 2006 and 2007, respectively (Table 3).

Increasing nitrogen doses affected significantly ($P<0.01$) protein yields of fenugreek in both years and in the average of the years (Table 1). According to years, the highest protein yield (199-191 kg ha^{-1}) was obtained from 90 kg ha^{-1} nitrogen dose, whereas control plots gave the lowest protein yield (123-112 kg ha^{-1}) (Table 3).

The effects of increasing sulphur doses on the protein yields of fenugreek was significant ($P<0.01$) in both experimental years and in the average of the years. The highest values (168-159 kg ha^{-1}) were obtained from 40 kg ha^{-1} sulphur doses in 2006 and 2007, respectively. Also, there were not significantly differences between 20 kg ha^{-1} and 40 kg ha^{-1} sulphur doses. The lowest values (159-149 kg ha^{-1}) were obtained from the control plots in both experimental years (Table 1 and 3).

CONCLUSION

The effects of different nitrogen doses on the all yield and yield components of fenugreek were found significant. Similarly, the effect of sulphur doses were significant on the other parameters except for the number of branches. In this study, while increasing nitrogen doses positively affected all the yield components of fenugreek, the effects of sulphur were different on the investigated traits. The whole yield components were positively affected by nitrogen applications up to 90 kg N ha^{-1}. On the other hand, investigated traits except for the number of branches, first pod height and the number of seeds in pod were positively affected by sulphur applications up to 40 kg ha^{-1}. Consequently, the highest seed yields (853.0 and 815 kg ha^{-1}) were obtained from 90 kg N ha^{-1} application. Also, in terms of sulphur applications the highest seed yields (853.0 and 815 kg ha^{-1}) were taken from 20 kg S ha^{-1}applications in 2006 and 2007, respectively. The highest protein content (24.2 %) was obtained from 90 kg N ha^{-1} and 40 kg S ha^{-1} applications in both experimental years.

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