FIMEK

Journal of Agronomy, Technology and Engineering Management

Article

The effect of different sulfur levels on seed yield and oil content of some rapeseed cultivars

Davut Karaaslan [1], Ozlem Toncer [1,*] and Ferhat Ozturk [2]

[1] Department of Field Crops, Faculty of Agriculture, Dicle University, 21280 Diyarbakır, Turkey; toncer@dicle.edu.tr

[2] Department of Field Crops, Faculty of Agriculture, Sirnak University, 73000 Sirnak, Turkey

* Correspondence: toncer@dicle.edu.tr

Received: 4 November 2019; Accepted: 17 March 2020

Abstract: In recent years, S deficiency has been described as a limiting factor for crop production in most regions of the world. It has been determined that S deficiency decreases the quality and yield of plant tissue. Therefore, it is known that there is a linear relationship between the oil contents of the plants and the sulfur contents. *Brassica napus* L. (Cruciferae), is one of the cultivated medicinal food and oil plants. So, it is important to determine the most appropriate sulfur dose in the plant. This study aimed to determine the effect of different dosages of sulfur on the fatty oil with some agronomic properties in the rapeseed. This work, which was held in 2011 and 2012, was carried out in the experimental fields of the Faculty of Agriculture of the Dicle University. In the research, two cultivars of rapeseed (Licord and Licrown) and 6 of sulfur doses (0 kg/ha, 30 kg/ha, 60 kg/ha, 90 kg/ha, 120 kg/ha and 150 kg/ha) were applied. The highest yield in terms of seed yield was obtained from the 15 kg/ha sulfur dose in Licrown cv. range with 294 kg/ha in the second year, while the highest fatty oil content was obtained in 0 kg/ha in Licrown cv. with 45.7% and 45.4% in both years.

Keywords: *Brassica napus*; yield; fertilization; fatty oil; S

1. Introduction

Rapeseed is of great importance as the second most common oil bearing plant in the world, after soybean, and the European Union in the world. Rapeseed is relatively easy to grow and extraction of the seed oil is high, with an average oil content of 42% and a protein content of approximately 21% Canola has the lowest saturated fat content of any vegetative oil. Today there is an increasing demand for this oil by diet-conscious consumers [1]. The canola oil, which has winter and summer varieties, contains 63% omega-9 and 11% omega-3 fatty acids which are very useful for human health. As the crude oil obtained from canola seeds is refined after being refined, it is used as fuel in B-20% in diesel engines by converting it to biodiesel at normal pressure and temperature in the presence of a catalyst with methanol. Acikgoz and Deveci [2] also stated that Brassica vegetables have protective characteristics against cancer and chronic diseases with their content of antioxidant vitamins and mineral material. As a member of Brassica family, canola (*Brassica napus* L.) -fresh greens–with its nutrient content like some of the cabbage greens which are used as salad may also give similar benefits.

Elemental S is mainly produced as an inert byproduct of the desulphurization of combustible liquids (petrol and diesel) and gases (natural gas) in oil refineries [3]. The ground crust contains approximately 0.06% sulfur (S). The total sulfur content of temperate regions varies between 0.005-0.04%. It can be compared to the need for phosphorus requirement of the sour plants, which is the basic nutrient requirement of all living organisms. S plants are an important nutrient element for growth and growth. The quantity and quality of the product in the case of insufficiency is low. Sulfur has an important role in the synthesis of compounds such as glutathione, which significantly affects the quality of the product. Sulfur is a basic element in the formation of oil in oil plants. Therefore, it is known that there is a linear relationship between the fat contents of the plants and the sulfur contents. It has been known for a long time that sulfur is of an important effect on the formation of fatty oil in oil plants such as soybean, mustard, and groundnuts [4]. Schnug and Haneklaus [5] reported that deficiency symptoms are the visual response of plants to the level of mineral nutrition. General characteristics are the loss of chlorophyll (chlorosis), followed by the death of the plant tissue (necrosis). Only a few nutrient deficiencies come along with symptoms, which are characteristic in a way that they are useful for visual diagnosis. Visual diagnosis on single plants requires specific deficiency symptoms, which in the case of S can be easily identified in dicotyledonous, but not in gramineous plants. In cereal crops, an irregular appearance of the whole field indicates S deficiency. Due to unique symptoms on leaves, flowers and yield structure, the visual identification of severe S deficiency in Brassica species is particularly easy and unmistaken. The application of microscopy for earlier identification of S deficiency symptoms provides no significant advantage. In recent years, various research has been made to determine the optimum sulfur fertilizer rate for rapeseed [1]. Sulfur favors and stimulates the adsorption of nitrogen during flowering and seed formation; it also participates in the synthesis of glucosinolates and determines the amount and type of fatty acids formed [3].

Sulfur is a basic element in the formation of oil in oil plants. Therefore, there is a linear relationship between the fat content of the plants and the sulfur content. It has long been known that sulfur has an important effect on fat formation in oil plants such as soybean mustard and peanut [4]. Hence, this study was carried out to determine the effect of sulfur on some agronomic characters and fatty oil content in rapeseed cultivars which are an important oil plant.

2. Materials and Methods

In a field experiment, rapeseed cultivars (Licord and Licrown) were grown on a strongly acidic alfisol of Diyarbakir, Southeast Türkiye. The experimental farm is located at 25°45′43″N latitude and 93°53′04″E longitude, at an altitude of 670 m above mean sea level (MSL), with an average annual rainfall of 495 mm. The average rainfall is about 574 mm in 2011, 625.7 mm in 2012 mm that most rainfall concentrated between winter and spring. Treatments were arranged in a split-plot design with three replicates on the silty-clay soil with a pH of 7.65 to 7.80 and a lime content of 8.67%. The soil structure in the experimental area also was fine-textured alluvial material or lime with the main substance, the red-brown soil containing low phosphorus and organic materials, in flat and deep levels near or medium-deep slopes, ABC profile zonal soil. Sulfur fertilizer in four levels (0, 30, 60, 90 and 150 kg S /ha) and two rapeseed cultivar (Licord and Licrown). Row spacing was 30 cm, in each subplot there were 6 rows 5m long. Plots and blocks were separated by 1m unplanted distances. Canola seeds were sowed in the second week of October both two years. The recommended dose of sulfur was applied through single super phosphate (SSP). Fertilizer's basic dose of N, P, K at the rate of 150-80-0 kg ha^{-1} was applied in the form of urea and triple superphosphate. The field was immediately irrigated after planting. Weeds were controlled manually. Investigated characters were plant height (cm), number of branches per plant, number of pods per plant, Number of Seed per Pod, Thousand Seed Weight (g), Seed Yield (kg/da), Oil Yield (%). The dried seed samples were then ground for chemical analyses. Seed oil content (%) was analyzed following the Association of Official Analytical Chemists (AOAC) method.

In the study, the data obtained from the experiment were analyzed with the JMP 13 statistical package program and the results were grouped according to the LSD multiple comparison test.

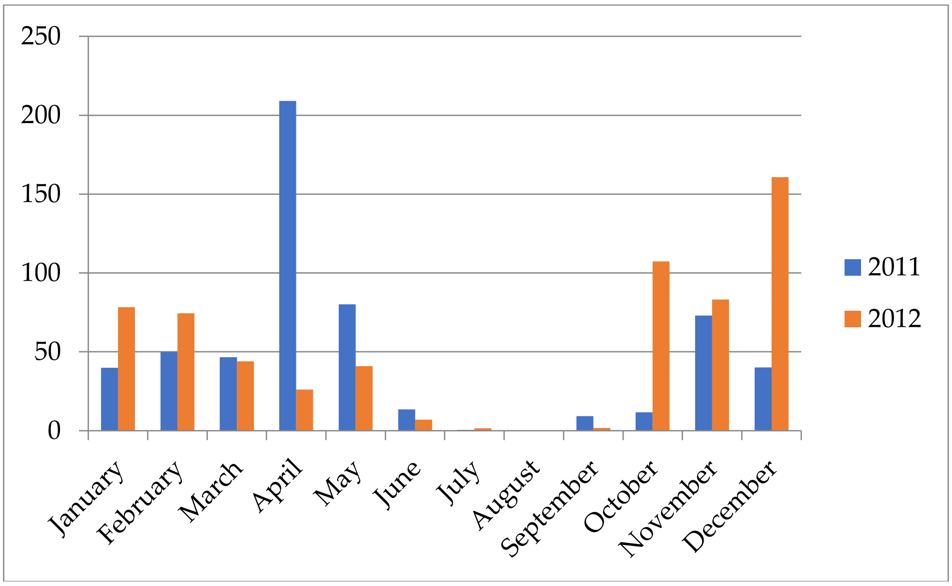

Figure 1. The total amount of precipitation in the experimental years.

3. Results and Discussion

Application of S improved growth and yield attributes of rapeseed in investigated characters. The seed yield, thousand seed weight, pod per plant and seed per pod were influenced significantly by sulfur levels, cultivar and interaction of sulfur levels × canola cultivar.

Results showed that plant height were significantly affected using different sulfur concentrations. The highest plant height (182.5 cm) was in Licord cultivars in 30 kg S ha^{-1}, the lowest plant height (150.9 cm) also was in the same cultivar with 90 S ha^{-1}. The cultivars used in the study generally have higher plant height at low sulfur doses. Sah et al. [6] reported that the application of sulfur resulted in significant variation in the growth characters of Indian mustard. Kumar and Yadav [7] also reported that the plant height increased significantly with each increment in the dose of sulfur up to 15 kg S ha^{-1}. The analysis of the variance showed significant variations between S doses, cultivars, and interaction regarding the effects for branch number per plant. The highest number of branches was obtained in the second year from 12.6 pieces/plant and 12.3 pieces/plant, respectively from the Licrown variety at 150 kg S ha^{-1} and 120 kg ha^{-1} sulfur doses. The lowest number of branches was obtained in the first year by application of 150 kg ha^{-1}sulfur dose in Licrown variety with 5.8 pieces/plant. Significant differences in branch numbers per plant occurred between differences between years. Generally, high prescriptions in 2012 led to significantly higher branching. Verma and Dawson [8] stated that branching are a genetic character but environmental conditions and different sowing method may also influence the number of branches per plant and play an important role in enhancing seed yield. Kumar et al. [9] stated that variation in several primary branches plant due to different treatments of sulfur doses was significant at the harvest stage of the crop. The number of primary branches plant increased gradually with each increment in S doses from 0 kg S ha^{-1} to 60 kg S ha^{-1}. The highest number of pods per plant was obtained 653.0 per plant in the Licrown cultivar with 90 kg/ha sulfur dose in the second year follow with 637 plants per plant at 150 kg/ha sulfur dose in Licrown variety in the same year. The lowest number of pod per plant recorded in the plant was obtained in the first year from a dose of 90 kg/ ha sulfur in Licrown cultivar with 135.1 pods per/ plant. The differences in the amount of precipitation between the years of the experiment may have revealed this situation (Figure 1). Thus, Kutcher et al. [10] stated that the analyses demonstrated the negative impacts of high temperatures and low precipitation, and the positive effects of greater-than-average precipitation, and to a lesser extent, cooler-than-average nocturnal temperatures. Sharifi [1] found that a maximum number of pod per plant was recorded at the application of 75 kg S ha^{-1} (92.04) and a minimum of it was recorded at 0 kg S ha^{-1}. Interaction between cultivars and different levels of S application had a significant effect on a number of seed per pod.

Table 1. Effect of sulfur fertilization on some growth and yield characteristics of two rapeseed cv.

		Plant height (cm)			Number of Branches per Plant			Number of Pods per Plant		
Cultivars	**S Doses**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**
Licord	0	154.4	193.6	173.0^{ab}	6.8^{g}	12.0^{ab}	9.4	167.2^{hij}	486.0^{c}	326.6
	3	158.8	206.3	182.5^{a}	5.9^{gh}	8.0^{f}	6.9	140.2^{jk}	432.3^{d}	286.2
	6	152.2	176.0	164.1^{c}	6.7^{gh}	11.0^{bc}	8.8	168.3^{hij}	483.6^{c}	326.0
	9	139.8	162.0	150.9^{d}	6.7^{gh}	9.3^{de}	8.0	169.4^{hij}	550.6^{b}	360.0
	12	150.5	173.0	161.7^{c}	6.2^{gh}	10.3^{cd}	8.3	163.1^{hijk}	451.0^{c}	324.2
	15	150.2	183.6	166.9^{bc}	6.2^{gh}	8.6^{ef}	7.4	161.2^{hijk}	279.0^{g}	220.1
Licrown	0	156.2	190.0	173.1^{b}	6.8^{g}	10.0^{cd}	8.4	176.6^{hi}	394.0^{e}	285.3
	3	158.03	175.6	166.8^{bc}	6.2^{gh}	8.6^{ef}	7.4	157.1^{ijk}	358.6^{f}	257.9
	6	158.3	176.3	167.3^{bc}	5.9^{gh}	10.3^{cd}	8.1	189.4^{h}	496.3^{c}	342.8
	9	146.8	176.3	161.5^{c}	6.5^{gh}	11.0^{bc}	8.3	135.1^{k}	653.0^{a}	394.0
	12	149.6	173.0	161.3^{c}	6.3^{gh}	12.3^{a}	9.3	147.0^{ijk}	451.0^{d}	299.0
	15	151.2	187.3	169.3^{ab}	5.8^{gh}	12.6^{a}	9.2	150.6^{ijk}	637.0^{a}	393.8
Mean $_{years}$		152.1	181.1		6.3	10.3		160.4	475.5	
LSD (p = 0.05)		**cv*doses: 2.58**			**year*cv*doses: 11.5**			**year*cv*doses: 12.9**		

The highest number of seeds per pod was obtained from 30 kg ha^{-1} sulfur dose in Licrown cultivar in the second year. The lowest number of seeds per plant (20.7) was obtained in the first year from 90 kg ha^{-1} sulfur dose in Licord cultivar. Most of the research is that increasing doses of sulfur increase the number of seeds in pod. Sharifi [1] found that a maximum number of grains per pod was increased with the application of 75 kg S ha^{-1} (22.5) and a minimum of it was recorded at 0 kg S ha^{-1} (14.3). When the varieties and doses were evaluated in terms of the weight of 1000 seed weight, the highest 1000 seed weight was obtained from a dose of 150 kg/ha sulfur in Licrown cv. with 5.5 g in 2011, the lowest value was determined from the application of 90 kg/ha in the Licrown cv. in 2011 and was also determined in the same cultivar at 150 kg S ha^{-1} in 2012. Sharifi, 2012 reported that 1000-grain weight: maximum 1000-grain weight was recorded at the application of 75 kg S ha^{-1} (3.61) and a minimum of it was recorded at 0 kg S ha^{-1} (2.49). Maximum seed yield (2940 kg ha^{-1}) was found in the second year from the doze of 150 kg S ha^{-1} sulfur dose in Licrown cultivar. When was applied 120 kg S ha^{-1} dose gave the lowest seed yield (668 kg ha^{-1}). Seed yield was generally higher in the second year all cultivars. Especially in the first year in April, the excess rainfall, flowering, pod filling, and seed yields are thought to affect negatively. The positive effect of sulfur fertilization on seed yield was reported by several authors. Varényiová et al. [11] stated that the highest average yield of 3.96 t ha^{-1} was reached at the treatment where a medium dose of sulfur (40 kg ha^{-1}) was applied. Among treatments fertilized by sulfur, the lowest average yield of 3.67 t ha^{-1} was found at the treatment where the highest dose of sulfur was used. Researchers also indicated that the highest dose of sulfur (65 kg ha^{-1}) in combination with nitrogen can have a hindering effect on yield. Sharifi [1] reported grain yield is the main target of crop production. The grain yield was significantly affected by both canola cultivars and various levels of sulfur fertilizer. Sulfur fertilizer significantly increased the grain yield. The grain yield varied between 81 ton/ha in zero levels of sulfur fertilizer and 1.067 ton/ha in 75 kg S ha^{-1}. Verma et al. [12] reported that the results revealed that the application of 60 kg S/ha gave significantly higher seed yield, economics, oil yield, protein yield and nutrients uptake (kg/ha) than control, 20 and 40 kg S/ha during experimental years. Sienkiewicz-Cholewa and Kieloch [13] found that sulfur at 40 and 60 kg S/ha doses affected the increase in oilseed rape grain yield by 11–12% compared to the not fertilized treatment. Tuncturk and Tuncturk [14] recommended for the highest seed yield (1418.0 kg ha^{-1}) should be used at 25 kg ha^{-1} sulfur application. Different cultivars, dose and years interactions had a significant effect on oil rate S application with control (0 kg S ha^{-1}) observed maximum oil contents in both years as 45.7% and 45.4%, while 150 kg S ha^{-1} noted minimum oil contents (38.4%) in Licrown cv. Varényiová et al. [11] reported that the higher dose of sulfur had no significant effect on the oil content. The oil content was significantly increased with the increasing doses of sulphur to 20 kg ha^{-1}. Tuncturk and Tuncturk [14] reported that highest oil content (41.1%) were obtained using 25 kg ha^{-1} sulphur application in second year field experiment. There are also some studies which show significant effect of S on oil content of rapeseed [15,16].

Table 2. Effect of sulfur fertilization on some growth and yield characteristics of two rapeseed cv.

		Number of Seed per Pod			Thousand Seed Weight (g)			Seed Yield (kg/day)			Oil Content (%)		
Cultivars	**S Doses**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**	**2011**	**2012**	**Mean**
Licord	0	27.5^{h}	35.0^{cd}	31.2	4.6^{c}	3.2^{f}	3.9	98.1^{g}	185.0^{e}	141.6	43.4^{c}	43.5^{c}	43.5
	3	30.7^{f}	34.6^{d}	32.7	4.1^{cd}	3.5^{def}	3.8	85.2^{g}	249.1^{b}	167.1	42.3^{efg}	42.4^{ef}	42.4
	6	29.5^{fg}	30.6^{f}	30.1	3.2^{f}	3.5^{def}	3.4	78.4^{g}	213.1^{cde}	145.7	42.5^{e}	42.5^{de}	42.5
	9	19.4^{k}	34.0^{de}	26.7	4.7^{bc}	3.4^{ef}	4.0	96.0^{g}	233.0^{bcd}	164.5	44.3^{b}	44.3^{b}	44.3
	12	20.7^{j}	35.0^{cd}	27.8	3.5^{c}	3.5^{def}	3.5	66.8^{g}	204.3^{de}	135.5	44.3^{b}	44.5^{b}	44.4
	15	27.1^{h}	33.0^{e}	30.0	4.1^{cde}	3.5^{def}	3.8	76.3^{g}	219.4^{bcd}	147.8	41.2^{h}	41.5^{h}	41.3
Licrown	0	25.5^{i}	30.3^{f}	27.9	3.3^{f}	3.2^{f}	3.2	74.4^{g}	246.7^{bc}	160.6	45.7^{a}	45.4^{a}	45.6
	3	25.1^{i}	46.0^{a}	35.5	4.3^{c}	3.5^{def}	3.9	140.6^{f}	230.4^{bcd}	185.5	41.7^{fgh}	41.5^{gh}	41.6
	6	24.9^{i}	37.0^{b}	30.9	5.4^{ab}	3.3^{f}	4.3	79.9^{g}	249.7^{b}	164.8	41.3^{h}	41.2^{h}	41.2
	9	21.4^{j}	36.0^{bc}	28.7	3.1^{f}	3.4^{ef}	3.2	89.7^{g}	248.8^{b}	169.2	43.3^{c}	43.3^{cd}	43.3
	12	24.7^{i}	34.3^{d}	29.5	4.5	3.3^{f}	3.9	79.3^{g}	241.1^{bc}	160.2	39.6^{i}	39.3^{ij}	39.4
	15	28.3^{gh}	34.0^{de}	31.1	5.5^{a}	3.1^{f}	4.3	68.3^{g}	294.7^{a}	181.5	38.6^{jk}	38.4^{k}	38.5
Mean years		25.4	35.0		4.2	3.4		86.1	234.6		42.35	42.31	
LSD (p = 0.05)		**year*cv*doses: 2.58**			**year*cv*doses: 11.5**			**year*cv*doses: 12.9**			**year*cv*doses: 12.9**		

4. Conclusions

In this study carried out in Diyarbakır conditions, sulfur doses differed agronomically on varieties. In terms of seed yield, the best sulfur dose was obtained from Licrown with 150 kg ha^{-1}, 0 kg ha^{-1} of sulfur dose gave the best fatty oil content in Licrown cv.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Sharifi, R.S. Sulphur fertilizer effects on grain yield and the sum of physiological indices of canola (*Brassica napus* L.) Available online: https://www.semanticscholar.org/paper/Sulphur-fertilizer-effects-on-grain-yield-and-the-Sharifi/9cd192f4f0ee468390b42b9aa7b2cbb9631d28e8 (accessed on Mar 30, 2020).
2. Acikgoz, F.E. Comparative analysis of vitamin C, crude protein, elemental nitrogen and mineral content of canola greens (*Brassica napus* L.) and kale (*Brassica oleracea* var. *acephala*). *Afr J Biotechnol* **2011**, *10*.

3. López-Mosquera, M.E.; López-Fabal, A.; Seoane Labandeıra, S. Utilización de azufre elemental como enmienda ácida en suelos para el cultivo de *Brassica napus*. *Revista SJSS* **2015**, *5*, 144–153.
4. Kaymak, M.R. The ımportance of sulfur for soil and plant nutrition. MSc, Cukurova University, Institute of Natural and Applied Sciences, Department of Soil Science: Adana, 2011.
5. Schnug, E.; Haneklaus, S. Sulphur deficiency symptoms in oilseed rape (*Brassica napus* L.) - The aesthetics of starvation. *Phyton* **2005**, *45*, 79–95.
6. Sah, D.; Sewak, R.; Singh, A.K.; Swami, S. Growth, yield and profitability of indian mustard [*Brassica juncea* (L.) Czern & Coss] with different weed control measures and sulphur levels. *Agric Sci Dig* **2013**, *33*, 15–20.
7. Kumar, H.; Yadav, D.S. Effect of phosphorus and sulphur levels on growth, yield and quality of Indian mustard (*Brassica juncea*) cultivars. *Ind J Agronomy* **2007**, *52*, 154–157.
8. Verma, H.; Dawson, J. Yield and Economics of Mustard (*Brassica compestris* L.) as Influenced by Sowing Methods and Levels of Sulphur and Boron. *Int J Curr Microbiol App Sci* **2018**, *7*, 380–386.
9. Kumar, V.; Tyagı, S.; Choudhary, S.K. Growth, yield and quality of ındian mustard (*Brassica juncea* L.) with doses and different sources of sulphur. *Indian Journal of Ecology* **2017**, *44*, 422–426.
10. Kutcher, H.R.; Warland, J.S.; Brandt, S.A. Temperature and precipitation effects on canola yields in Saskatchewan, Canada. *Agric For Meteorol* **2010**, *150*, 161–165.
11. Varényiová, M.; Ducsay, L.; Ryant, P. Sulphur nutrition and its effect on yield and oil content of oilseed rape (*Brassica Napus* L.). *Acta Univ Agric Silvic Mendelianae Brun* **2017**, *65*, 555–562.
12. Kumar Verma, C.; Prasad, K.; Yadav, D.D. Studies on response of sulphur, zinc and boron levels on yield, economics and nutrients uptake of mustard (*Brassica juncea* L.). *Crop Res* **2012**, *44*, 75–78.
13. Sienkiewicz-Cholewa, U.; Kieloch, R. Effect of sulphur and micronutrients fertilization on yield & nbsp; and fat content in winter rape seeds (*Brassica napus* L.). *Plant Soil Environ* **2016**, *61*, 164–170.
14. Tuncturk, R.; Tuncturk, M. The effect of different sulphur doses on the yield and quality of rapeseed (*Brassica napus* L.). *Fresenius Environ Bull* **2017**, *26*, 6952–6957.
15. Kumar, S.; Verma, S.K.; Singh, T.K.; Shyambeer, S. Effect of nitrogen and sulphur on growth, yield and nutrient uptake by Indian mustard (*Brassica juncea*) under rainfed condition. *Indian J Agric Sci* **2011**, *81*, 145–149.
16. Ray, K.; Sengupta, K.; Ak, P.; Banerjee, H. Effects of sulphur fertilization on yield, S uptake and quality of Indian mustard under varied irrigation regimes. *Plant Soil Environ* **2016**, *61*, 6–10.