

EFFECTS OF SULPHUR ON THE YIELD, YIELD COMPONENT CHARACTERS AND OIL CONTENT OF OILSEED RAPE

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Abstract: The effects of four sulphur levels: S₀, S₁, S₂ and S₃, including 0, 12, 24 and 36 kg S ha⁻¹, respectively, along with 115 kg N ha⁻¹ were studied on yield-related traits of oilseed rape (*Brassica napus* L.). The significant variance of treatments was determined for plant height, yield component characters, seed yield and oil content. The sulphur application significantly increased most of the traits compared to the S₀ level. The S₃ (36 kg S ha⁻¹) treatment led to the highest mean value of plant height (132 cm) which was classified with S₂ (24 kg S ha⁻¹) in the same statistical group. Sulphur had an increasing effect on pods per plant, and it ranged from 92 to 196 for S₀ and S₃ applications, respectively. S₀ and S₁ with 92 and 121 pods per plant were grouped in the same statistical group. In addition, S₂, and S₃ with 165 and 196 pods per plant showed no significant statistical difference. The sulphur application significantly increased seed yield compared to control (S₀ level), and it ranged from 2744 to 3215 kg ha⁻¹ in S₀ and S₃, respectively. The average oil contents of 45.69, 46.96, 47.46 and 49.53 % were detected for 0, 12, 24 and 36 kg S ha⁻¹, respectively.

Key words: sulphur, oilseed rape, yield components, oil content.

Introduction

The same as other crops, growth, growing stages, yield component characters, the seed yield of oilseed rape depends upon biotic and abiotic agents (Rameeh et al., 2004). Soil fertility status will vary depending on the type of cultivation and cultivation management. Most soils are usually deficient in organic matter, indicating nitrogen, potassium and phosphorus deficiencies (Malik et al., 2004; Sharifi, 2012). Sulphur (S) is considered the fourth major nutrient along with nitrogen, phosphorus and potassium. Sulphur is important for oilseed rape

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production, and S deficiency frequently constrains canola yield (Jan et al., 2008). Sulphur is essential for the synthesis of compounds such as amino acids, cystine and methionine. In this regard, it activates complex enzyme systems in most plants (Havlin et al., 2005). In addition, sulphur greatly affects rapeseed developmental stages, the most important of which are the increase in protein and oil in oilseed rape (Zhao et al., 1993; Jan et al., 2002; Sattar et al., 2011). Sulphur deficiency mainly leads to a decrease in nitrogen uptake, and the end of this process has an important effect on yield components and finally causes a decrease in seed yield (Fismes et al., 2000; Brennan and Bolland, 2008). In general, characteristics such as total dry matter, harvest index, yield components and grain yield in some rapeseed and mustard genotypes will improve with the increase of sulphur intake (Scherer 2001; Chen et al., 2006; Malhi et al., 2007). About 1.5 kg of sulphur is required to form 100 kg/ha of rapeseed, therefore, to achieve a yield of 2000 kg/ha, approximately 30 kg/ha of sulphur will be required (Jackson, 2000; Kumar et al., 2002; Malhi and Gill, 2002; Kandil and Gad, 2012). As the amount of sulphur consumption increases, the amounts of oil, protein and glucosinolates of canola seeds will also increase (Jackson, 2000; Malhi et al., 2007; Rameeh, 2015). The consumption of sulphur fertilizers leads to an increase in nitrogen efficiency, which improves the amount and, to some extent, the quality of fatty acids. However, the responses of different Brassica species to the absorption of sulphur and the improvement of fatty acids are different (Ahmad and Abdin, 2000; Fismes et al., 2000). The amount of sulphur uptake and transfer in various types of canola cultivars is a function of consumption time, growth stage and plant organs. In this regard, double low varieties of oilseed rape (canola) in comparison with single low varieties of Brassica contain lower sulphur concentrations in seeds and higher sulphur concentrations in pods. In both groups of improved oilseed varieties, including industrial and canola cultivars, a lack of sulphur sources leads to the reduced efficiency of nitrogen consumption (Ceccoti, 1995; Mirzashahi et al., 2010). Low nitrogen uptake efficiency due to sulphur deficiency may lead to soil nitrogen losses (Cheema et al., 2001). According to Abdullah et al. (2010), seeds of Brassica may have a nitrogen-free structural material, in which case part of the structure material is expected to decrease as the grain weight increases, while oil and protein molecules compete to stay in the remaining space (Cheema et al., 2001; Rameeh, 2018). Sulphur plays an essential role in the synthesis of chlorophyll and is also an important component for the synthesis of oil (Brennan and Bolland, 2008; Rehman et al., 2013). Sulphur also plays an important role in the chemical composition of Brassica seeds. Sulphur increases the percentage of seed oil and glucosinolate content (Jan et al., 2002; Subhani et al., 2003; De Pascale et al., 2008). Depending on the external source, sulphur concentrations in different Brassica species, vary between 1 and 16 g/kg in dry matter (Cheema, et al., 2001; Balint and Rengel, 2009).

Due to the importance of the sulphur effect on quantitative and qualitative parameters of oilseed rape, the present experiments were performed to investigate the effect of different sulphur levels on plant height, yield component characters, seed yield, and oil content.

Material and Methods

A field experiment was conducted on the farm located in Abendankash, Sari, Iran ($53^{\circ} 7' E$ longitude and $36^{\circ} 32' N$ latitude, 60 m above sea level). The soil was classified as deep loam soil (Typic Xerofluents, USDA classification), and the average percentages of clay, silt, sand and organic matter were 28, 56, 16 and 2.24, respectively, with a pH of 7.3. Soil samples were found to have 45 kg ha^{-1} of mineral nitrogen (N) in the upper 30-cm profile. The field experiment plots received 50 kg P ha^{-1} and 75 kg K ha^{-1} . The seed of the improved canola cultivar Hyola401 was under study. The experiment was conducted in a randomized complete block design with four replications. Seeds were sown at a uniform rate of 4 kg/ha in the rows of each experimental plot. The treatments under study included different amounts of ammonium sulphate (containing 21% of nitrogen and 24% of sulphur) and urea fertilizer (containing 46% of nitrogen): S_0 : $250 \text{ kg urea ha}^{-1}$, S_1 : $227 \text{ kg urea} + 50 \text{ kg ha}^{-1}$ ammonium sulphate ha^{-1} , S_2 : $204 \text{ kg urea ha}^{-1} + 100 \text{ kg ammonium sulphate ha}^{-1}$ and S_3 : $182 \text{ kg urea} + 150 \text{ kg ha}^{-1}$ ammonium sulphate ha^{-1} . S_0 , S_1 , S_2 and S_3 included 0, 12, 24 and 36 kg S ha^{-1} , respectively, and, therefore, all the treatments contained 115 kg ha^{-1} of pure nitrogen. All stage-related measures were performed uniformly for all experimental units. Plant protection measures, including pest and weed control, were also carried out uniformly for each plot. The yield of each experimental plot was determined based on two middle lines and adjusted to kg ha^{-1} . Ten randomly selected plants from each plot were used to measure the following traits: plant height, number of pods per main stem, number of pods per plant, pod length and number of seeds per pod. Random seed samples from each plot were also used to measure 1000-seed weight, oil and protein content. Oil content was detected with the help of nuclear magnetic resonance spectrometry (Madson 1976). The recorded data were analyzed according to randomized complete block design criteria (Steel and Torrie, 1980). SAS software, version 9 (SAS INSTITUTE INC. 2004), was used to analyze the variance and compare the means, and the Excel software was used to draw the graph.

Results and discussion

The significant mean squares indicating significant different effects of treatments (different levels of sulphur) were determined for plant height, pods per

main axis, pods per plant, pod length, 1000-seed weight, seed yield, and oil content (Table 1).

Table 1. The randomized complete block (RCBD) analysis of variance for the studied traits.

S.O.V	df	MS						
		Oil (%)	Seed yield (kg ha ⁻¹)	1000-seed weight (g)	Seeds per pod	Pod length (cm)	Pods per plant	Pods per main axis
Replication		167.3**	1166.8**	2634.1	0.65*	3.25	0.10	3912
Treatments		67.3*	627.7*	6327.2*	2.85**	41.64*	0.31*	365024**
Error		11.3	138.2	781.9	0.15	7.14	0.05	85432

*, ** Significant at p=0.05 and 0.01, respectively.

As influenced by different sulphur levels, the comparison of plant height means is presented in Table 2 and Figure 1. The sulphur application resulted in a significant plant height increase. The S₃ (36 kg S ha⁻¹) treatment produced the tallest plant (132 cm), which was classified with S₂ (24 kg ha⁻¹) in the same statistical group (Table 2). Sulphur enhances cell division, elongation, and expansion, and it, therefore, tends to increase plant height. The obtained result is in agreement with the results of Ahmad et al. (2006) and Singh and Meena (2004) on mustard. The number of pods on the main axis varied from 27 to 79 in S₀ and S₃, respectively, and the trait tended to increase with the application of sulphur. The sulphur application caused an increase in pods per plant, and it ranged from 92 to 196 in S₀ and S₃, respectively. S₀ and S₁ with 92 and 121 pods per plant belonged to the same statistical group. Also, S₂ and S₃ with 165 and 196 pods per plant were classified in the same statistical group (Table 2).

Table 2. The mean comparison of yield components, seed yield and oil percentage.

Treat-ments	Plant height (cm)	Pods per main axis	Pods per plant	Pod length (cm)	Seeds per pod	1000-seed weight (g)	Seed yield (kg ha ⁻¹)	Oil (%)
S ₀	118.3b	29.6b	92b	5.83c	17.7b	3.84a	2744b	45.69c
S ₁	122.4b	48.3ab	121b	6.83b	19.0b	4.00ab	2844ab	46.96cb
S ₂	129.3a	63.3ab	165a	7.32b	22.2ab	4.02ab	3190ab	47.46b
S ₃	132.2a	79.3a	196a	8.17a	26.0a	4.31a	3215a	49.53a

S₀: 250 kg urea ha⁻¹, S₁: 227 kg urea+50 kg ha⁻¹ ammonium sulphate ha⁻¹, S₂: 204 kg urea ha⁻¹ +100 kg ammonium sulphate ha⁻¹ and S₃: 182 kg urea+150 kg ha⁻¹ ammonium sulphate ha⁻¹.

The results are in agreement with those obtained by Chen et al. (2006). Pod length varied significantly among the treatments, wherein the S₃ (36 kg ha⁻¹) treatment showed the highest pod length (Table 2 and Figure 1). Pod length ranged from 5.83 to 8.17cm in sulphur treatments of S₀ and S₃, respectively.

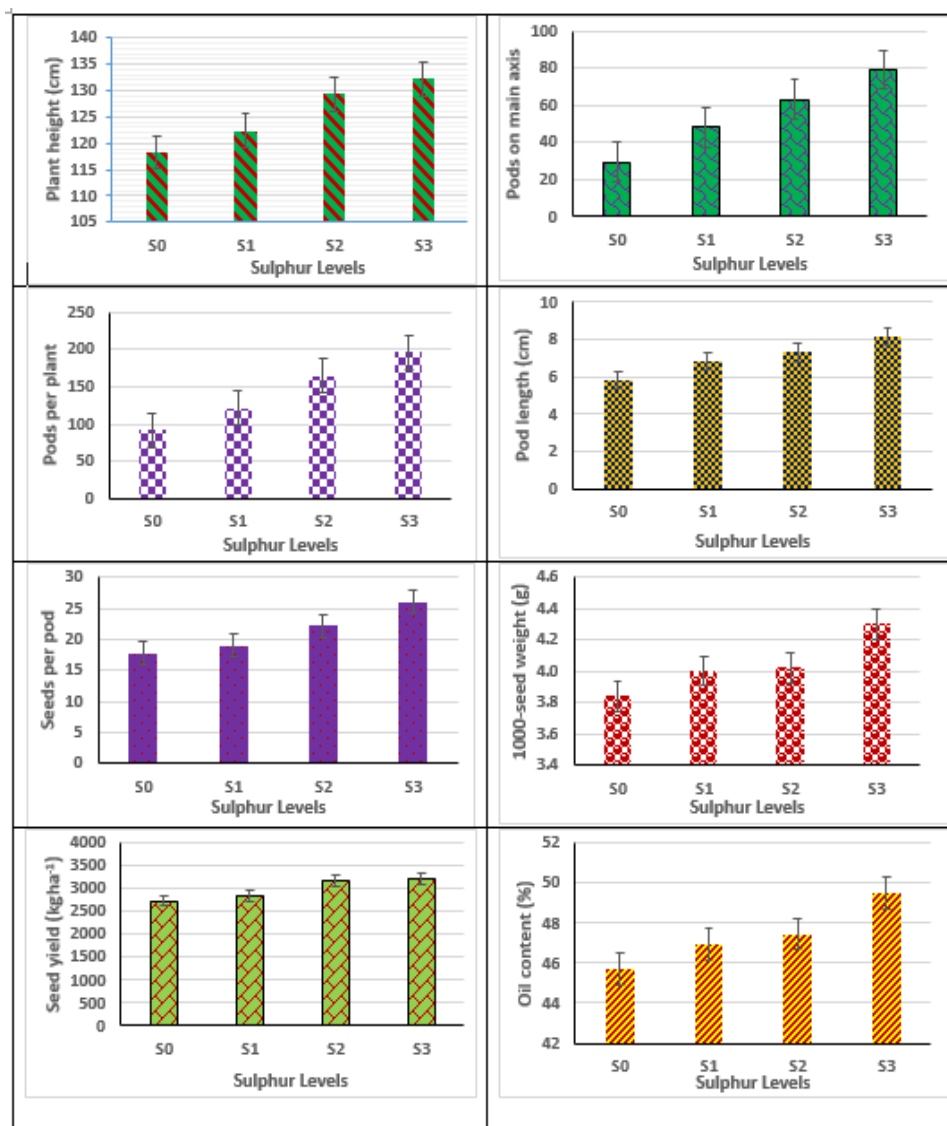


Figure 1. Means of plant height, yield component characters, seed yield and oil content of oilseed rape var. Hyola401 at different levels of sulphur (S₀, S₁, S₂ and S₃ including 0, 12, 24 and 36 kg S ha⁻¹, respectively).

The sulphur application significantly increased 1000-seed weight compared to the S₀ level. Among S treatments, the highest 1000-seed weight (4.31g) was shown by S₃ (36 kg S ha⁻¹), which was on a par with S₁ (12 kg S ha⁻¹) and S₂ (24 kg S ha⁻¹) with 1000-seed mean values of 4 and 4.02 g, respectively. Rapeseed seed yield

potential is a function of the main yield components, including the number of plants per unit area, the number of seeds per plant and the 1000-seed weight. The high performance of the treatments related to the application of sulphur may be due to the increase in the reproductive structure of the plant caused by the high capacity of the sink and the high capacity of the transfer of photoassimilates from source to sink (Chen et al., 2006; Malhi et al., 2007). The sulphur application significantly increased seed yield compared to control (S_0 level), and it ranged from 2744 to 3215 kg ha⁻¹ in S_0 and S_3 , respectively.

The oil content varied from 46.69% to 49.35% and was significantly increased to 36 kg ha⁻¹ with the increasing doses of sulphur. Sulphur plays an essential role in the synthesis of chlorophyll and is also an important component influencing the synthesis of oil (Brennan and Bolland, 2008; Rehman et al., 2013). Sulphur also plays an important role in the chemical composition of Brassica seeds, increasing the percentage of seed oil and glucosinolate content (Jan et al., 2002; Subhani et al., 2003; De Pascale et al., 2008).

Conclusion

The sulphur application significantly increased most traits compared to the S_0 (control) level. The S_3 (36 kg S ha⁻¹) treatment produced a high mean value of plant height (132 cm) which was classified along with S_2 (24 kg ha⁻¹) in the same statistical group. Sulphur had an increasing effect on yield component characters, comprising the number of pods on the main axis, number of pods per plant and 1000-seed weight. S_0 and S_1 with 92 and 121 pods per plant were in the same statistical group as well as S_2 and S_3 with 165 and 196 pods per plant. The sulphur application significantly increased seed yield compared to the S_0 level, and it ranged from 2744 to 3215 kg ha⁻¹ in S_0 and S_3 , respectively. Due to the significantly increasing effect of the maximum level of sulphur application on seed yield and oil content, 36 kg ha⁻¹ of S can be recommended for canola production in the region.

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UTICAJI SUMPORA NA PRINOS, KOMPONENTE PRINOSA I SADRŽAJ ULJA ULJANE REPICE

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R e z i m e

Proučavani su uticaji četiri tretmana sumpora: S_0 , S_1 , S_2 i S_3 , uključujući 0, 12, 24, odnosno 36 kg S ha⁻¹, zajedno sa 115 kg N ha⁻¹, na osobine uljane repice (*Brassica napus* L.) povezane sa prinosa. Utvrđen je značajan uticaj tretmana na visinu biljke, komponente prinosa, prinos semena i sadržaj ulja. Primena sumpora značajno je povećala većinu osobina u poređenju sa dozom S_0 . Tretman S_3 (36 kg S ha⁻¹) doveo je do najveće srednje vrednosti visine biljke (132 cm) koja je imala istu statističku značajnost sa S_2 (24 kg S ha⁻¹). Sumpor je imao sve veći efekat na broj mahuna po biljci, i to od 92 do 196 u tretmanu S_0 odnosno S_3 . Rezultati u tretmanima S_0 i S_1 sa 92 i 121 mahuna po biljci imali su istu statističku značajnost. Pored toga, S_2 i S_3 sa 165 i 196 mahuna po biljci nisu pokazali značajnu statističku razliku. Primena sumpora značajno je povećala prinos semena u odnosu na kontrolu (doza S_0), i on se kretao od 2744 do 3215 kg ha⁻¹ u tretmanima S_0 odnosno S_3 . Prosečan sadržaj ulja od 45,69, 46,96, 47,46 odnosno 49,53% zabeležen je za 0, 12, 24 odnosno 36 kg S ha⁻¹.

Ključne reči: sumpor, uljana repica, komponente prinosa, sadržaj ulja.

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