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Evaluation of Sulfur Fertilizer on Canola Yield under Salinity Conditions

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ABSTRACT
Soil and water salinity damage and decrease canola yield. However, plant yield should be increased using effective methods. This study aimed at investigating the effect of sulfur application fertilizers on canola yield. To this end, the experiment was conducted in split plot arrangement based on randomized complete blocks design with three replications at Shavoor Research Station in south west of Iran. Main plots was the source of sulfur fertilizer (Sulfur element, gypsum, sulfuric acid, golden bio-sulfur) and sub plots were the rate of sulfur application including 6 levels (0, 50, 500, 1000, 1500, 2000 $KgS.ha^{-1}$). Results showed sources and rate that of sulfur fertilizers had significant different effects ($p<0.01$) on canola yield and biologic yield but they had no effect on seed thousand weight and seed in capsule. The highest seed yield and biologic yield obtained from Golden bio sulfur application. The findings also revealed that interactive effects had significant effects ($p<0.01$) on seed and biologic yield but they had no effects on seed weight and seed in capsule. Sulfur fertilizer application is an effective method for compensation damage yield of canola in salinity conditions.

Keywords: *Brassica napus, In vivo, Nutrition, Soil, Water.*

INTRODUCTION
The world population is increasing rapidly and may reach 6 to 9.3 billion by the year 2050, whereas the crop productions decreasing rapidly because of the negative impact of various environmental stresses; therefore, it is now very important to develop the agricultural management to cope with this upcoming problem of food security (Nazar *et al*., 2011). Among abiotic stress, high salinity stress is the most severe environmental stress, impairing crop production at least 20% of irrigated land worldwide. So increased salinity of arable land is expected to have devastating global effects, resulting in up to 50% land loss by middle of twenty-first century (Mahajan and Tuteja, 2005). 4.1 million hectares of irrigated lands with saline-sodic soils in Iran causing an economic loss of over one billion dollars (Qadir *et al*., 2003).

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Obviously, where salinity cannot be kept at acceptable levels using crop types and varieties with acceptable yields is a good approach under saline conditions (Sharifi, 2012, Ghatei *et al*., 2013). After the cereals, oil seeds are the second food source in the world. These crops contain oil source of fate acid and protein. Among the oil plants, canola is the plant with the high level of quality and nutrition indices. Also, it has been recognized as one of most important oil plants of the world and is the third source of herbaceous oil in the world after soybean and palm (Gohargani *et al*., 2012). Because of the limitations in increasing the area of arable land, crop production in marginal soils has been suggested, but this causes various problems including saline soils and water (Mohammed, 1998). Sulfur plays an important role in increasing the yield and oil quality of canola. In other words, it plays a significant role in the yield of canola oil as well as a modifier in the soil (Kaya *et al*., 2009). The Sulfurous fertilizers not only increase the yield and quality of oil products but also improve the consumption efficiency of the other fertilizers as nitrogen and phosphorus, Sulfur fertilizers increased the yield of ground nut, soybean and canola, to 13.3, 8.9, 4.5 kg, respectively (Grant *et al*., 2012). The importance of cations and anions in irrigation water is clear as they influence soil physical and chemical properties. If Na^+ concentration in irrigation water is nine times that of Ca^{2+} ions, problems related to water infiltration into soil often arise, soil particle distribution is affected, and small pores in surface soil are blocked (Mohajermilani and Tavassoli, 1992). Considering sodic soils in Iran often contain calcium in the form of calcium carbonate, it may be possible to amend such soils by sulfur application. This will improve physical and chemical properties of soil and make macro- and micronutrients such as P, Fe, and Zn available to plants (Mirzashahi *et al*., 2010). Azza *et al*. (2006) have reported that saline water application had significant decrease in all growth parameters in *Dalbergiasissoo*, while application of sulfur was significantly increased those parameters under irrigation with normal or saline water up to 4000 ppm. All *et al*. (2002) have declared that sulfur application on root zone of sunflower, significantly increased the level of toleration against salinity due to increasing of plant dry and fresh weight. Al-Solimani *et al*. (2010) showed that sulfur fertilizer increased seed yield, yield components, seed protein and oil contents of canola in saline condition. Also, irrigation with 10.000 $mg.l^{-1}$ salinity water significantly decreased number of branches per plant, number of fruit per plant and seed weight. Ali and Aslam (2005) reported that application of sulphuric acid at 50 liters per hectare with the first irrigations as fertigation in wheat, improved soil environment by reducing impact of salinity- sodicity and high pHs which increased the seed yield by three times as compared to control. Application of recommended dose of NPK + 25 Kg H_2SO_4 ha^{-1} with the first irrigation was the best management strategy to minimize the negative effects of first irrigation to wheat in saline sodic soil. In Iran, 27-28 million hectares 16-17% of the total land area in the country have gypsum soils (Kandil and Gad, 2012). Irrigation water also plays an important role in providing sulfur and, in most cases, the sulfate in irrigation water satisfies plant needs in calcareous soils; and irrigation water analysis must be considered when fertilizer recommendations are made (Fuehring, 1972). Sulfur application, together with Thiobacillus bacteria, has had useful effects in amending soils and in improving crop nutrition status in many cases (Besharati and Saleh- Rastin, 2000). Sulfur is a necessary element in crop production, especially in producing oil crops that need sulfur as much as, or more than, phosphorous to produce maximum yield (Malhi *et al*., 2007). Sulfur application in China raised canola yield by 13.4% (Messick and Fan, 1999). Moreover, sulfur fertilizers increased the efficiencies of other fertilizers such as nitrogen and phosphorous fertilizers so that peanut, soybean, and canola yields increased by 13.3, 8.9, and 4.5 kg for every kilogram of S applied to the soil, respectively (Lin, 1998). Walker and Bernal (2008) showed that use of organic amendment materials increased cation exchange capacity (CEC), saturated exchange sites with Ca, Mg, and K, and prevented Na from entering the exchange phase. Therefore, this research was conducted to study effects of sources and amounts of sulfur on canola yield under saline conditions of soil and irrigation water.

MATERIALS AND METHODS

Field and treatment information

This research was done as split plot experiment based on randomized complete block design with three replications at Shavoor Research Station, located in south west of Iran. Main plot was the sources of sulfur fertilizer including sulfur element, gypsum, sulfuric acid and golden bio-sulfur and subplot were the rate of sulfur application including 0, 50, 500, 1000, 1500 and 2000 $kg.ha^{-1}$. The station has latitude of 50˚31˚ between the Karkheh and Karoon Rivers. The maximum monthly temperature is 51 C˚, the maximum and minimum relative humidity 73 and 27%, respectively, and the average annual rainfall 241.7 mm. Soil samples were taken in each replication from depths of 0-30 cm and determine soil salinity status (Table 1). Soil structure classification was fine, mixed, hyperthermic, Aeric Hapaquepts.

Table 1. Some soil characteristics analysis

Depth (cm)	Ec_e ($dS.m^{-1}$)	pH	OC (%)	Texture	P (ppm)	K (ppm)
0-30	8.7	7.8	0.43	ClayLoam	2	212

Crop Management

Chemical fertilizers applied based on soil testing. The rest of the N fertilizer applied in equal amounts at the start of tillering and at the beginning of stem elongation. Sulfur fertilizer treatments applied before planting. Hyola-401 cultivar were planted in a soil with the salinity level of 8 $ds.m^{-1}$ Treflan herbicide, as pre plant was used for weed control. The area plots were four m^2 and each plot containing four cultivation lines. After planting, water with salinity level of about 6-8 $ds.m^{-1}$ prepared by using saline water at station (drainage) and natural saline water (with salinity level of over 30 $ds.m^{-1}$) , and soil salinity was kept at 6-8 $ds.m^{-1}$ by monitoring soil salinity level through taking samples repeatedly. Considering prevailing conditions in the field effect of rainfall was ignored. At the end of the experiment, samples were taken from experimental plots and factors were measured.

Traits measure

To determine the yield components during physiologic maturity, 10 plants were chosen randomly from each plot. Number of seeds per pod and 1000 seed weight were assessed. In final harvest area, from each plot (one- squared meter area), seed and biological yields were calculated.

Statistical analysis

The analysis of variance was done by MSTATC software and the means were compared using Duncan's multi range test at 5% probability level.

RESULTS AND DISCUSSION

Biologic yield

Results indicated that S application significantly increased canola biologic yield under saline soil conditions (α= 1%). (Table 2). The maximum biologic yield was achieved by applying sulfur at 2000 kg.ha^{-1}. However, it was in the same statistical group at 1000 and 1500 kg.ha^{-1}. Among the different sources of S, the largest biologic yield belonged to sulfuric acid and bio-sulfur, respectively, and the least to gypsum treatment (Table 3). Study of the interaction effects of the two factors, sulfur source and rate of S application, on canola biologic yield revealed that the highest biologic yield was achieved when 1500 kg.ha^{-1} of golden bio-sulfur was applied and the lowest was in the control treatments of all S sources (Table 4). Increase in biological yield might be due to increase in plant height and net assimilation rate. Increase in plant height due to higher nutrient absorption, especially Nitrogen, stimulation of carbohydrates and protein assimilation, which in turn enhanced cell division and formation of more that resulted in enhanced vegetative growth and biological yield. The results are similar to finding of another researchers (Karmanimanesh *et al.*, 2013, Havlin *et al.*, 2004).

Table 2. Analysis of variance of agronomical traits

S.O.V	df	Biologic yield	Seed yield	1000-seed weight	Number of seed per pod
Replication	2	2087807.9	12467.4	0.34	32.93
Sulfur sources (S)	3	33154339.6**	2517749.6**	0.12^{ns}	318.23^{ns}
Sulfur levels (M)	5	27300796.9**	7128717.2**	0.029^{ns}	46.58^{ns}
S × M	15	6203022.7**	1244092.9**	0.031^{ns}	264.07^{ns}
Error	46	1209424.4	163201.5	0.039	188.3
CV (%)	-	7.67	14.6	7.69	3.47

ns: no significant differences, **: significant differences at 1%

Table3. Mean Comparison of agronomical traits

	Treatment	Biologic yield (kg.ha^{-1})	Seed Yield (kg.ha^{-1})	1000- seed weight (gr)	Number of seed per pod
Sources	**S element**	5650^{b*}	2373^{c*}	2.53^{a}	19.7^{a}
	Gypsum	4596^{c}	2538^{b}	2.95^{a}	19.95^{a}
	Sulfuric Acid	7084^{a}	2951^{a}	2.58^{a}	19.5^{a}
	Bio-S Golden	7568^{a}	3189^{a}	2.59^{a}	19.95^{a}
Rates	**S0**	3451^{d}	1266^{c}	2.55^{a}	19.8^{a}
	S1(50)	5846^{c}	2813^{b}	2.54^{a}	19.6^{a}
	S2(500)	6271^{bc}	2870^{b}	2.65^{a}	19.8^{a}
	S3 (1000)	6967^{ab}	2930^{b}	2.58^{a}	19.85^{a}
	S4 (1500)	7094^{b}	3262^{a}	2.6^{a}	19.85^{a}
	S5 (2000)	7716^{a}	3462^{a}	2.52^{a}	19.8^{a}

* Means in each column followed by similar letter (s) are not significantly different at the 5% probability level.

Table 4. Mean Comparison of interaction effect of agronomical traits

	Treatment	Biologic yield (kg.ha^{-1})	Seed Yield (kg.ha^{-1})	1000- seed weight (gr)	Number of seed per pod
S element	**S0**	4342^{g-j}	1075^{j}*	2.3^{a}	20.05^{a}
	S1(50)	5417^{f-i}	2433^{g-i}	2.64^{a}	19.9^{ab}
	S2(500)	5417^{f-i}	2500^{f-i}	2.64^{a}	19.75^{ab}
	S3 (1000)	5667^{f-h}	2042^{i}	2.6^{a}	19.9^{ab}
	S4 (1500)	6208^{e-g}	2708^{e-i}	2.54^{a}	19.7^{ab}
	S5 (2000)	6850^{d-f}	3479^{b-e}	2.5^{a}	18.95^{ab}
Gypsum	**S0**	3375^{ij}	2450^{g-i}	2.6^{a}	19.85^{ab}
	S1(50)	3367^{ij}	2375^{g-i}	2.6^{a}	20.25^{a}
	S2(500)	3833^{h-j}	2417^{g-i}	2.67^{a}	19.55^{ab}
	S3 (1000)	4000^{h-j}	2250^{h-i}	2.5^{a}	19.9^{ab}
	S4 (1500)	6375^{e-g}	2858^{d-h}	2.6^{a}	20.15^{a}
	S5 (2000)	6625^{d-f}	2875^{d-h}	2.6^{a}	19.95^{ab}
Sulfuric Acid	**S0**	2453^{j}	708^{j}	2.67^{a}	19.9^{ab}
	S1(50)	7308^{c-f}	3317^{b-e}	2.4^{a}	18.3^{b}
	S2(500)	8625^{a-d}	3225^{c-f}	2.67^{a}	19.85^{ab}
	S3 (1000)	9161^{a-c}	3554^{b-d}	2.64^{a}	19.6^{ab}
	S4 (1500)	5500^{f-h}	2875^{d-h}	2.67^{a}	19.25^{ab}
	S5 (2000)	9453^{ab}	4027^{ab}	2.4^{a}	20.1^{ab}
Bio-S Golden	**S0**	3633^{h-j}	830^{j}	2.64^{a}	19.5^{ab}
	S1(50)	7292^{c-f}	3125^{c-g}	2.5^{a}	19.85^{ab}
	S2(500)	7208^{c-f}	3340^{b-e}	2.64^{a}	20.05^{a}
	S3 (1000)	9042^{a-c}	3767^{bc}	2.6^{a}	20^{a}
	S4 (1500)	10290^{a}	4604^{a}	2.6^{a}	20.15^{a}
	S5 (2000)	7942^{b-e}	3467^{b-e}	2.6^{a}	20.1^{a}

* Means in each column with similar letter (s) are not significantly different at the 5% probability level.

Seed yield

Analysis of variance concerning seed yield indicated that management of plant nutrients played a considerable role in increasing yield (Table 2). Results showed that under saline conditions, soil or water, sulfur played a positive role in increasing canola yield ($p<0.01$) (Table 2). Application of sulfur at 50 to 2000 kg.ha^{-1} increased yield from 2813 to 3462 kg.ha^{-1}, which indicated the positive effect of sulfur in improving plant yield under saline conditions (Table 3). Moreover, 1500 and 2000 kg.ha^{-1} rates of sulfur application were in one statistical group, and 50 to 1000 kg.ha^{-1} rates in another, compared to the control (Table 4). Soil and foliar applied S significantly improved leaf area index, crop growth rate, and net assimilation rate and chlorophyll contents. Plant height, number of branches, number of pod per plant, seed number per pod, 1,000-seed weight, biological and seed yield were also increased by soil applied sulfur and foliar application (Rehman *et al*., 2013). Nazar *et al.* (2011) reveled that sulfur can decrease salt stress via improvement of physico-chemical properties of saline and alkaline soil, increasing of permeability, decreasing of pH, and loss and removal of irrigation water bicarbonate.

1000-seed weight

The results showed that the effects of various sulfur sources and sulfur rates on 1000-seed weight were not significant differences (Table 2). Interaction effects of these two factors on 1000-seed weight did not show any significant differences (Table 4). Increased 1000-seed weight with applied sulfur fertilizer might result from improved partitioning of total dry matter into seed. The result is agreement with finding of Jagetiya and Kaur (2006).

Number of seed per pod

Effects of individual treatments and their interaction effects were not significantly different (Table 2). So the mutual effects of these two factors on this property did not show any significant differences either (Table 4). The similarly, in previous researches, it was reported that due to increasing salinity levels, yield and yield associated traits were reduced (Mahmoodzadeh, 2008). In salinity condition Ca and K ameliorate the adverse effects of Na on different plant traits. Salinity impairs Ca uptake in plants, possibly by displacing it from the cell membrane or affecting the membrane function (Rameeh *et al*., 2012, Amador *et al*., 2007).

CONCLUSION

Results showed that sulfur application led to a significantly increasing in seed yield and biologic yield due to positive effect of sulfur in improving soil condition and plant uptake. Effects of various sulfur sources and levels on seed yield, 1000-seed weight and number of seed per pod were not significant differences. Sulfuric acid and bio-sulfur were best sulfur sources. So best results are obtained when sulfur is applied at 1500 $kg.ha^{-1}$ under saline conditions. In general, sulfur could decrease some negative saline condition on canola yield

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