

Ameliorate salinity effect through sulphur application and its effect on some soil and plant characters under different water quantities

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ABSTRACT

The main objective of this work is to study the effect of sulphur application and irrigation water quantity on some soil properties of the calcareous soils and to limit the suitable concentration to obtain satisfactory yield of faba bean under saline conditions. The study area (Tamyia district, Fayoum Governorate, Egypt) is characterized by a hot and dry climate in general with annual rainfall average of 8 mm/year, whereas the evaporation rates average ranging between 3.5 to 10 mm/day. Faba bean (*Vicia faba* L.) was sown at 18 November 2010 and harvested at 26 April 2011. Total water consumed during faba bean growing season were 623.7 and 747.2 m³/fed for 100% and 120% irrigation treatments with increasing ranged between 3.5% and 3.7% in same sequence. Results showed that values of soil EC, pH and CaCO₃ was improved as a result of both irrigation and S treatments. The improvement resulted in a gradual reduction of the studied soil properties by about 10.3%, 3.2%; 17.0% and 23.1%, 4.3%; 11.3% comparing S treated plot relative to the control plot at 100 and 120% irrigation treatments. Application S improved water content under studied soil constant and these increases were 8.8%, 11.8%, 8.3% and 16.9% for SP, FC, WP and AW, respectively relative to the control plots. Irrigation 100% had a positive effect on the drainable pores% which increased by about 7.0% comparing with 120% irrigation treatments. While hydraulic conductivity increased by about 16.4% and percentage of increase drainable pores was 14.0% and 21.4% for 100% and 120% irrigation treatments comparing 3rd layer with the 1st one, respectively. Increasing irrigation water from 100% to 120% resulted increasing in the studied

macronutrients, N, P and K, by about 80.8%, 144.9% and 72.9%, respectively; while they increased in plant by about 118.8%, 132.8% and 62.2% as compared with the control one, respectively as a result of S application. Results showed that Na, Cl and Na/K ratio that increasing irrigation water caused increase by 2.02%, 11.11% for Na and Cl, while reduction in the ratio between Na and K was observed with value -15.7% as compared 120 with 100% irrigation treatments. S application cause slightly increases in Na content (3.55%) and moderately increases with Cl (34.38%), which led to decrease Na:K ratio by about 39.4%. Increasing irrigation water by 20% resulted in a gradual increase of both yield and water use efficiency (WUE) of faba bean plants compared with the control plants. Irrigation treatments significantly decreased the contents of proline in dry weight seed of faba bean gradually as a result of increase irrigation quantity (from 100% to 120%) and the reduction was 9.7%. While S addition decreased proline by about 15.9%. According to the interaction effect between irrigation and S application treatments, S improved proline content by about 20.4% and 11.2% relative to the control treatments under 100% and 120% irrigation treatments, respectively %.

Keywords: Calcareous Soil; Faba Bean; Sulphur; Soil Properties; Yield Characters; Fayoum

1. INTRODUCTION

The major limitation to legume production in many areas of the world is soil salinity [1], which is a long-standing problem for irrigated agriculture in arid and semiarid regions. [2] reported that in Egypt, the area of irrigated land that is salt-affected is 33%. Soil degrada-

tion led to deterioration of soil structure, nutrients loss, build-up of salts and desertification alone or in combination [3]. It was found that shoot growth is often suppressed more than the root growth by soil salinity [4]. However, fewer studies on the effect of soil salinity on root growth have been conducted [5]. The high salt content lowers osmotic potential of soil water and consequently the availability of soil water to plants. Under extreme salinity conditions, plants may be unable to absorb water and will wilt, even when the surrounding soil is saturated. So, the salt-induced water deficit is one of the major constraints for plant growth in saline soils. In addition, many nutrient interactions in salt-stressed plants can occur that may have important consequences for growth [1]. An understanding of growth and survival of plants under saline habitat conditions is needed.

There are two major approaches to improving and sustaining productivity under saline condition: availability of fresh water to leach out excess salts in soil profile, and application of the suitable amendment, either singly or in combination [6], but the first approach has been used more extensively through acidification of irrigation water because it enables the plants to respond better not only to water but also to other production inputs such as soil physical and chemical properties.

Improvement of salt affected soil is usually initiated by the downward displacement of surface-accumulated salts [7]. [8] stated that management of salt-affected soils is a challenge, because salts affect many processes: 1) Crop growth (including yield, quality, and economic return), 2) Soil physical properties (such as aggregation and water infiltration), and 3) Sufficiency and toxicity of nutrients. They added science amelioration of salt affected soils depends on the movement of water through the soil profile to remove excess salts from the root zone, it is important that leaching and drainage for salinity control should 1) minimize flow of water through the soil profile to reduce dissolution of soil minerals and 2) reduce drainage volume.

Several products have been used as soil amendments such as CaCl_2 , HSO and CaSO_4 . For many years, elemental sulphur (S) and sulphuric acid, especially under drip irrigation systems, have been used for reclamation and improvement of saline and alkaline soils and oxidation of S is slow, so this method may be of limited value [9]. They added that S inoculated with *Thiobacillus* reduced both soil EC and pH, and Ca^{2+} release in soil solution and consequently modified soil SAR. However, the buffering capacity of lime limits the effect of both.

On calcareous soils, S may be added to furnish calcium indirectly [10], which is oxidized to sulfuric acid, which reacts with the calcium carbonate to form gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) that consider the cheapest, soluble calcium source [11]. Water movement in soil was improved

under acidification treatment except under increase salinity water and sulphuric acid (0.05%). Acidification of the water can result in immediate changes, though often of short duration, in the soil water pH.

Beans are reported to be sensitive to salt but some species may be moderately tolerant [12]. [13] mentioned that with cropping throughout the year, if the water requirement of crops were satisfied and drainage was accomplished properly, the risk of soil salinization could be avoided. Also, successful salt management requires frequent monitoring not only soil but also irrigation water. Salt stress, like many abiotic stresses factors, adversely affects plant growth and productivity. Plants exposed to salt stress adapt their metabolism in order to cope with the changed environment. Survival under these stressful conditions depends on the plant's ability to perceive the stimulus, generate and transmit signals and instigate biochemical changes that adjust metabolism accordingly [14].

The main objective of this work is to study the effect of sulphur application and irrigation water on some soil properties of the calcareous soils and to limit the suitable concentration to obtain satisfactory yield of faba bean under saline conditions.

2. MATERIAL AND METHODS

2.1. Site Description

Field trial was conducted at Tamyia district, Fayoum Governorate, Egypt, 29.77N, 31.30E (**Figure 1**). The study area is characterized by a hot and dry climate in general with scanty rainfall drops that may occurs between December-April with annual average of 8 mm/year, whereas the evaporation rates average ranging between 3.5 to 10 mm/day; the minimum and maximum air temperature values usually recorded in January and July, respectively [15].

2.2. Soil Preparation and Planting

Field trial was conducted to study the effect of elemental sulphur (S) application and different irrigation quantity on faba bean grown under saline soil conditions calcareous in nature. Canal irrigation water was used after acidified by 0.05% sulphuric acid to decrease soil pH and accelerate transformation elemental sulphur to the sulphate. Drip irrigation was used 75 cm between laterals (JR 30 cm among dripper, 4 liter/h). Farmyard manure, ammonium sulphate (20.5% N), single superphosphate (15.5% P_2O_5) and potassium sulphate (50% K_2O) at rate of 20 m^3 , 100, 150 and 50 kg/fed, respectively were spread in the soil surface before soil preparation and mixed well with the upper layer (30 cm). Faba bean (*Vicia faba* L. cv. Giza 40) seeds were selected for uniformity. Seedlings were thinned to three seedlings per



Figure 1. Experimental site location.

hole 10 days after planting. Faba bean plants lasted 160 days. The experiment was a factorial arrangement with two levels of irrigation water (100% and 120% from ETo) and two induced sulfur levels 0 (Control) and 200 kg/fed with three replicates.

2.3. Irrigation Process and Quantity

Irrigation water was added as a ratio from ETo (Fayoum Meteo Station) at 100% and 120%. No. of irrigations water were 6 (during Nov, Dec 2010 and Jan 2011), 8 (Feb), 12 (Mar) and 1 (April), 2011 with monthly amounts ranged between 23.5 to 241.9 and 28.2; 290 m³/fed for April and March with total calculated 601.4 and 721.7 m³/fed for 100% and 120% irrigation treatments, respectively. The total water consumptive during faba bean growing season was 623.7 and 747.2 m³/fed with increasing ranged between 3.5% and 3.7%, respectively.

2.4. Soil Analysis

Some soil characteristics of the investigated soil used in the experiment before cultivation are determined after [16] *i.e.* CaCO₃ (14.21%), OM (0.46%), ECe (7.75 dSm⁻¹ in soil paste extract), pH (8.32 in soil:water 1:2.5), soluble cations were Ca²⁺ 9.32, Mg²⁺ 4.20, Na⁺ 62.74 and K⁺ 1.20 meq/liter while soluble anions were HCO₃⁻ 4.12, Cl⁻ 52.26, SO₄ = 21.09 meq/liter in extracted soil paste. Soil is loamy sand in texture.

Hydraulic conductivity (HC) was measured in the la-

boratory under a constant head technique [17] using the following formula: $HC = (QL)/(At \Delta H)$, where: HC: water quantity flowing through saturated soil sample/area/unit time, Q: volume of water flowing through saturated soil sample per unit time (L³/t), A: cross sectional flow area (L²) L: length of the soil sample and ΔH : differences in hydraulic head across the sample (L) and t: time (hr).

Soil water retention at 0.1 (FC) and 15.0 (WP) bars were estimated after [18]. Soil available water was calculated by subtracting FC – WP.

2.5. Plant Analysis

Plant samples were taken at harvest for measurement of dry weight of shoot, total-N, proline, and some mineral contents of shoots. Seed yield and some chemical constituents of the yielded seeds were also determined at harvest.

Total-N and mineral contents of N, P, K and Na were determined after [16]. Proline was estimated according to [19].

2.6. Statistical Analysis

The data were subjected to the analysis of variance (ANOVA) appropriate to the split plot in a randomized complete block design applied after testing the homogeneity of error variances according to the procedure outlined by [20]. The significant differences (LSD) between treatments were compared with the critical difference at 5% probability level.

3. RESULTS AND DISCUSSION

Table 1 illustrated the effect of both irrigation treatments and sulphur application on the soil EC, pH, and CaCO₃ in different soil depth at the end of the faba bean growth period. Data on hand noticed that maximum values of the determined previous characteristics were observed in the surface layer (0 - 5 cm) in the case of the EC and soil pH, 2nd layer (5 - 10 cm) in CaCO₃, except under irrigation with 120% from ETo with S application.

According to the interaction effect among irrigation treatments and soil depth on the EC, pH and CaCO₃, there were gradually increase in the studied soil properties in the surface and decreased with depth in both irrigation treatments (**Figure 1**).

Salts in the root zone can reduce crop yield by making it difficult for roots to extract water from the soil. Salts increase soil osmotic potential, causing water to move from areas of lower salt concentration (plant tissue) into the soil where the salt concentration is higher, which can cause plants to wilt even when soil moisture is adequate. [21] stated that to assess the ecological effect (status) of salt affected soil, salts on the irrigated soil, it is necessary to determine the change of the main soil characters which are affected directly from accumulated salts such as soil EC and He found that S application in soil increases anion and cation solubilization, which led directly to increase soil EC, as well as a higher pH in the soil without S application.

The increase in the amount of the irrigation water to the soil cultivated by faba bean resulted a gradual decrease in EC, pH and CaCO₃ content at the end of the

growing season by about 0.66%, -1.87% and -5.04% (**Figure 1**).

With respect to the effect of the irrigation treatment, both soil EC and pH values decreased with depth under both 100 and 120% irrigation treatments. Regardless S application the change in the studied soil characteristics for different soil depth under irrigation treatment 120% comparing with 100% were -7.3%, -3.9%, -0.6%; -2.6%, -2.5%, 0.6%; -4.1%, -5.7%, -5.3% and 57.0%, 18.0%; -1.4% for soil EC, pH and CaCO₃, respectively (**Table 2**). Same trend was obtained when comparing depth change values for control plots with sulphur treated ones.

The most important promotive effect for soil EC and pH was observed at the depth (10 - 15 cm) than the 1st one (0 - 5 cm) with values 20.0%, 25.9%, 19.2%; 12% and 3.4%, 5.0, 1.8 and 12.7, respectively. Regarding to the CaCO₃ content, the change in the values happened in the 3rd layer (10 - 15 cm) comparing to the 1st one was slightly and the values were 2.4%, 0.0%, 4.7%, 0.0% in same sequences.

Also, values of soil EC, pH and CaCO₃ was improved as a result of both irrigation and S treatments. The improvement resulted in a gradual reduction of the studied soil properties by about 10.3%, 3.2%; 17.0% and 23.1%, 4.3%; 11.3% comparing S treated plot relative to the control plot at 100% and 120% irrigation treatments. These finding may be attributed to the variations were not very significant. In treatments with S, it is very probable that there was increased microbial activity which also resulted in increased CO₂ level in the leach, resulting in a

Table 1. Effect of the irrigation and elemental sulphur treatments on some soil characteristics after faba bean crop.

Treatments	Irrigation	100%			120%			
		Depth cm	EC	pH	CaCO ₃	EC	pH	CaCO ₃
Control	Sulphur	5	7.75	8.28	13.98	7.80	8.12	13.05
		10	7.10	8.21	14.05	7.10	8.07	12.81
		15	6.20	8.00	13.65	6.30	7.97	12.44
		Mean	7.02	8.16	13.89	7.07	8.05	12.77
Sulphur	Sulphur	5	7.32	8.08	11.28	6.17	7.82	11.16
		10	6.15	7.94	12.04	5.64	7.68	11.78
		15	5.42	7.68	11.28	4.52	7.61	11.17
		Mean	6.30	7.90	11.53	5.44	7.70	11.37
LSD 5%	Irrigation	Sulphur	1.11	0.02	0.12	0.14	0.09	0.09
		Sulphur	0.29	0.42	0.21	0.45	0.17	0.21
		IxS	0.57	ns	0.37	0.69	0.31	0.42

Table 2. Effect of the irrigation and elemental sulphur treatments on some soil water constants after faba bean crop.

Treatments		Depth (cm)	SP	FC	WP	AW	DP	HC cm/h	
Irrigation	Sulphur								
100%	Control	5	23.9	19.1	11.8	7.3	4.8	4.75	
		10	24.8	20.3	11.9	8.4	4.5	5.30	
		15	25.6	20.7	12.6	8.1	4.9	5.85	
		Mean	24.8	20.1	12.1	7.9	4.7	5.30	
	Sulphur	5	25.2	20.2	12.1	8.1	5.0	5.34	
		10	26.8	22.0	13.2	8.8	4.8	6.89	
		15	27.3	22.1	14.4	7.7	5.2	7.87	
		Mean	26.4	21.4	13.2	8.2	5.0	6.70	
	120%	Control	5	24.6	20.0	11.7	8.3	4.6	5.64
			10	25.6	21.0	12.0	9.0	4.6	7.25
			15	27.1	21.7	12.4	9.3	5.4	7.82
			Mean	25.8	20.9	12.0	8.8	4.9	6.90
Sulphur		5	26.4	22.7	12.5	10.2	3.7	6.21	
		10	28.1	23.9	12.9	11.0	4.2	7.35	
		15	31.2	26.5	13.4	13.1	4.7	7.65	
		Mean	28.6	24.4	12.9	11.4	4.2	7.07	
LSD 5%		Irrigation	Mean	27.2	22.6	12.5	10.1	4.5	7.0
			Irrigation	1.2	0.6	0.3	3.1	0.2	0.22
		Sulphur	Sulphur	2.0	1.2	0.8	0.8	0.5	0.63
			IxS	3.2	2.1	1.6	1.7	0.7	1.05

SP: saturation %, FC: field capacity, WP: wilting point, AW: available water, DP: drainable pores %, HC: hydraulic conductivity.

lower pH than in the untreated one, due to the lack of readily available energy source for the microbes and unfavourably high pH values as proposed by [22]. On the other hand, dissolved calcium, as a result to transforms some of CaCO_3 to CaSO_4 and increase Ca^{2+} in the soil phase probably replaced the sodium in the colloidal complex, this is supposed because the treatments with sulphur probably induced higher Na leaching.

Data in **Table 2** showed a clearly response of soil water constant, *i.e.*, saturation percent (SP), field capacity (FC), and wilting point (WP) in different soil depths to the both irrigation and S applied treatments. According to the irrigation treatments effect, data noticed that increasing irrigation quantity by 20% (from 100% to 120% from ETo) increased water content all the studied soil water constants by about 6.3, 8.6, 24.7 for SP, FC and AW, respectively. While water content at WP slightly reduced by -1.6%.

Regarding to the effect of S application, it is clearly obvious that S application improved water content under studied soil constant and these increase were 8.8, 11.8, 8.3 and 16.9% for SP, FC, WP and AW, respectively relative to the control plots. From these results, both increasing irrigation water (more than crop water requirement) and application S led to pronounced effect of excess water content in different soil layers, especially the upper ones (0 - 15 cm), and then provide the plant by its needed.

Also, results revealed that there was significant increase in water content for the studied soil depths at most studied soil water constant where comparing soil depth 10 - 15 cm with surface layer (0 - 5 cm) and the increase percentage were 7.7, 9.1, 13.1; 2.8 and 14.3, 12.9, 6.6; 21.4% for SP, FC, WP and AW, respectively (**Table 2**). With respect to the soil water constants of three studied soil depths as affected by S application, data mentioned

that there were increases in all studied constants *i.e.* SP, FC, WP and AW by about 8.7, 8.5, 6.6; 11.4 and 13.4, 13.5, 13.0; 14.1 for S untreated and treated plots when comparing 3rd depth with the 1st one, respectively (**Table 2**).

The interaction effect of irrigation and S treatment on the drainable pores% (DP) and saturated hydraulic conductivity (HC) were shown in **Table 2**. Results indicated that the highest values were obtained at 100% irrigation treatment, untreated S; depth 10 - 15 cm (5.4%) and 120% irrigation treatment, treated S; depth 10 - 15 cm (8.65 cm·h⁻¹). While the lowest values of the drainable pores (DP) and HC were attained in 100% irrigation treatment, untreated S; depth 0 - 5 cm (3.7%) and 120% irrigation treatment, treated S; depth 10 - 15 cm (4.75%), respectively.

Regarding to irrigation treatment, and regardless to the soil depth data noticed that irrigation 100% had a positive effect on the DP% which increased by about 7.0% comparing with 120%. While HC increased by about 16.4% and percentage of increase DP was 14.0% and 21.4% for 100% and 120% irrigation treatments comparing 3rd layer with the 1st one, respectively. But the improvement in the 3rd layer relative to the 1st one was better in 100% than 120% with values 36.0% and 30.5%, respectively in case of HC values.

The opposite was true after S application and the increment values were 31.6% and 34.4% for control and treated treatments. The maximum HC value (7.87 cm/h) resulted in 3rd soil layer treated with S, while the minimum one (4.75 cm/h) was obtained in the 1st soil layer as affected by irrigation treatment 100% and the change between them was 60.5%. This finding agreed with those obtained by [3,23], who stated that sulfuric acid injected in irrigation water increases the electrical conductivity of the soil solution, which helps in increase electrolyte concentrations that increase the rate of water penetration

through decrease clay swelling under sodic conditions. Also, [11,24] reported that permeability is thereby improved by increased clay flocculation coupled with decreased clay swelling. Because the solubility of gypsum is relatively low, more time and water are required for it to react well. As a single amendment, sulfuric acid is thought to be superior to gypsum. However, with increased hydraulic conductivity, potential amendment losses preclude the effectiveness of sulfuric acid.

Changing in the HC may be attributed to one or more of the following: 1) surface layer exposed to the weather condition and hence dry/wet cycles was carried out, which affect directly on the soil aggregate formation [25], 2) sulphur was well mixed in the upper layer than the deep ones, 3) increased water content in the deep layer did not allow to form aggregation well, that help in increasing redox potential, and 4) release Ca²⁺ in soil solution plays an important role in adjust soil SAR and encourage formation of soil aggregates. [26] found that surface applications of gypsum, sulfuric acid and [gypsum and Ca(NO₃)₂] were equally effective in improving infiltration rates compared to the control within one year of application. They added that most surface applied amendments improved crop yields in three of four years.

Table 3 illustrated some recorded (studied plant characters such as plant height, No. of branches/plant, No. of pods/plant, seeds weight/plant, seed yield and seed index. Data noticed that the highest values of the studied plant characters were observed under irrigation treatment 120% and under sulphur application. According to the effect of irrigation treatment, one can notice that irrigation treatment 120% was better than 100% under all studied characters. The increase of the characters value in was 12.7%, 21.3%, 55.8%, 12.9%, 3.5% and 5.4% comparing 120% to 100% irrigation treatments in same sequence. Regardless, irrigation treatments effect, sulphur application has a promotive effect on the studied

Table 3. Effect of irrigation treatment and sulfur application on the plant characters of faba bean plants.

Irrigation	Sulfur	Plant height (cm)	Branches	Pods	Seeds	Seed index w/100 seeds	Seed yield plant	Yield tone/fed
			Plant					
100%	Control	87.0	3.3	3.7	19.7	118.1	37.2	1.562
	Sulfur	109.4	4.3	5.0	22.3	121.3	43.9	1.842
	Mean	98.2	3.8	4.3	21.0	119.7	40.5	1.702
120%	Control	107.6	4.7	6.7	21.4	120.4	39.4	1.653
	Sulfur	113.8	6.7	6.7	26.0	127.4	46.0	1.931
	Mean	110.7	5.7	6.7	23.7	123.9	42.7	1.792
LSD 5%	Irrigation	1.6	0.2	0.3	0.4	1.8	1.3	0.023
	Sulphur	3.2	0.5	0.9	1.1	3.1	3.2	0.071
	IxS	5.1	0.9	1.6	1.8	4.2	5.2	0.142

plant characters. The increments of the studied characters value were 14.7%, 25.0%, 11.5%, 17.5%, 3.4%, and 17.2% as compared with the control (sulphur untreated plot) in same sequences. Relative to the interaction effect between irrigation and S application treatments, most of the highest values were obtained in sulphur treated plots under irrigation treatment 100 followed by 120% (**Table 3**).

Also, data noticed that increased irrigation by 20% increased yield by about 5.8% under control treatment, while the increase percentage was 4.9 comparing S treated plot under 120% with 100% irrigation treatments. Regardless S effect, yield increased by about 5.3% as a result of increase irrigation water by 20%. Whereas, treated soil by S increased yield by about 16.8% and 17.9% under 100% and 120% irrigation treatments. These results explained on the base of accumulation of excessive salt in irrigated soils (by 100%) expressed in soil EC can reduce crop yields, reduce the effectiveness of irrigation, ruin soil structure, and affect other soil properties [27].

Table 4 showed plant fresh and dry weight, and N, P, K, Na and Cl. According to the irrigation treatment, data mentioned that 120% irrigation treatment was better than 100% and had the highest values of the previous faba bean plant characters. Plant fresh and dry weight of faba bean was improved and increased by about 8.6% and 21.3% when increase irrigation water by 20%, respectively. Regarding to the S effect, application S developed faba bean fresh and dry weight by about 5.2% and 2.3% relative to the control treatment.

Data in **Table 3** showed that, increasing irrigation water by 20% from 100% to 120% resulted in a gradual increase of both yield and water use efficiency (WUE) of faba bean plants compared with the control plants. Irriga-

tion water resulted in increasing yield by 5.3% comparing 120% with 100% and 17.3% comparing S treated plot with untreated one.

While WUE values were -12.1% and 17.0% in same sequences. The inhibitory effect of salt stress on yield was also reported by other investigators using various plant species [28,29]. The decrease WUE at 100% irrigation treatment due to increasing salinity levels and could be ascribed to the increase salts in soil and hence increase osmotic pressure. Also, the improvement in yield relative to 120% irrigation treatments was not matched to the amount of water used in 100% one.

With respect to the N, P and K content, data revealed that increase irrigation water from 100% to 120% from ETo resulted increasing in the studied macronutrients (N, P and K) by about 80.8%, 144.9% and 72.9%, respectively.

According to the effect of S application on N, P and K content, results noticed that they increased in plant by about 118.8%, 132.8% and 62.2% as compared with the control one, respectively. This decrease in total N was also observed by [30,31]. This decrease in total N content may be attributed to water disruption of the machinery consequent to water deprivation.

Regarding to the Na, Cl and Na/K ratio, results showed that increasing irrigation water caused increase percentage by 2.02%, 11.11% for Na and Cl while reduction in the ratio between Na and K was observed with value -15.7% as compared 120% with 100%. Regardless irrigation treatment S application cause slightly increases in Na content (3.55%) and moderately increases with Cl (34.38%), which led to decrease Na: K ratio by about 39.4.

Irrigation treatments significantly decreased the contents of proline in dry weight seed of faba bean gradually (**Table 3**) as a result of increase irrigation quantity (from

Table 4. Effect of irrigation treatment and sulfur application on the nutrient content in faba bean plants.

Treatments		Plant weigh (g)		N	P	K	Na%	Cl%	Na/K	Free proline (mg·g ⁻¹ DW)
Irrigation	Sulfur	Fresh	Dry	%						
100%	Control	195.6	63.8	1.61	0.290	1.45	1.96	0.08	1.4	0.98
	Sulfur	219.2	76.0	1.78	0.623	2.29	3.36	0.24	1.5	1.09
	Mean	207.4	69.9	1.70	0.457	1.87	2.66	0.16	1.4	1.04
120%	Control	212.3	64.0	2.25	0.591	1.64	3.15	0.29	1.9	1.03
	Sulfur	223.8	79.1	5.20	1.538	3.08	5.09	0.50	3.3	1.24
	Mean	218.1	71.5	3.72	1.064	2.36	4.12	0.40	2.6	1.14
LSD 5%	I	1.0	1.3	0.5	0.290	0.18	0.16	0.18	0.1	0.03
	S	2.3	3.2	1.3	0.571	0.31	0.43	0.22	0.2	0.09
	I × S	6.11	8.79	1.7	0.883	0.56	0.78	0.34	0.2	0.13

100% to 120%) and the decrease percentage was 9.7%. While S addition decreased proline by about 15.9%. According to the interaction effect between irrigation and S application treatments, S improved proline content by about 20.4% and 11.2% relative to the control treatments under 100% and 120% irrigation treatments, respectively. This result supported by [32] who found that increasing soil salinity lead to increase in sodium content in tomato plants. Also, the inhibitory effect of salt stress on shoot dry weight was also reported by other investigators using various plant species [31]

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