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Improving the Characteristics of Saline Clay Soils and their Effect on the Productivity of Faba Bean

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ABSTRACT

Two field experiments were conducted in clay saline soil at the Sahl El-Houssinia Agriculture Research Station, Sharkia Governorate, Egypt. Faba bean cultivar Nubaria 1 planted during winter seasons 2018/2019 and 2019 /2020 to study the effect of different sulfur sources *i.e.* calcium sulphate (CS), potassium sulphate(KS)and agricultural sulfur (AS) in four rates 0, 200, 400 and 600 kg/fed as control, low rate, medium rate and high rate, respectively with or without farmyard manure on inhibitory the hazardous effect of soil salinity stress on vegetative growth, yield and yield components and some soil chemical properties. Each experiment was carried out in a split split-plot design, where the sulfur sources were arranged randomly as the main plot and the rate of sulfur sources were distributed randomly as subplot and FYM (with or without) was arranged randomly as sub subplot. Yield and yield components, macro and micronutrients content and uptake by faba bean seeds were increased as a result of applied different sulfur sources and rates and/ or FYM and their combinations. Seed protein content, total carbohydrates and total chlorophyll were increased significantly as affected by the treatments. The control treatment (without fertilizers) increased proline content over the treatments. Sulfur treatments decreased values of soil pH and EC and increased soil available N, P, and K as well as Fe, Mn and Zn content after harvest. The superior treatment was observed when using sulfur with FYM, especially at the high rate (600 kg/fed.), which gave the highest values for all variables under study.

Keywords: farmyard manure, sulfur sources, faba bean, saline soil.

INTRODUCTION

Faba bean seeds (*Vicia faba* L.) are grown worldwide as a protein source for food and feed. At the same time, faba bean offers ecosystem services such as renewable inputs of nitrogen (N) into crops and soil via biological N_2 fixation and diversification of cropping systems. Faba bean has the highest average reliance on N_2 fixation for the growth of the major cool-season grain legumes. As a consequence, the N benefit for following crops is often high, and several studies have demonstrated substantial savings 40–80 kg N/fed from the amount of N fertilizer required to maximize crops yield grown after faba bean (Erik *et al.*, 2010). Sulfur is one of the essential elements needed for plant growth, it is ranking just after nitrogen, phosphorus and potassium. It is important for the formation of some amino acids, oils and proteins and it is a structural component of protoplasm, and forming of certain enzymes and vitamins (Hitsuda et al. 2005)

Sulfur is the fourth major essential nutrient element after N, P and K plays an important role in the growth and development of higher plants and increase stress tolerance in plants (Nazar *et al* ., 2011). Kineber *et al.* (2004) indicated that the application of S led to a decrease of soil pH value by the oxidation of S to sulphate through various species of soil pH improves the availability of micronutrients (Fe, Mn and Zn) and improvise the chemical properties of alkaline soil as well as increasing yields. Ashraf and Mostafa (2012) found that the N, P and K concentration in pea plants increased with treated sulfur compared with control under saline soil. Also, S improved the chemical properties of soils because it increased the activity of microorganisms which increase the nutrient cycling. This increasing the availability of absorbed nutrients by plant roots.

Calcium sulphate is soil amendment important for improved sodic soil and soil salinity. Sulfur – Oxidizing bacteria has promoted the availability of elemental sulfur in soil and solubilization of the otherwise –unavailable soil phosphorus (El-Tarabily *et al.*, 2006). Farmyard manure (FYM) is the most popular natural fertilizer and is considered as one of the most effective fertilizers in the soil environment (Slowinska-Jurkiewicz et al., 2013). Farmyard manure is one of the traditional organic manure for improving soils properties, either physical or chemical and biological besides conserving water holding capacity. Its effect may be directly in increasing crop yield by supplying some nutritional parameters (Samar M.A. Doklega 2017)

The study aims to improve the characteristics of saline clay soil and their effect on the productivity of Faba bean plants grown in the Sahl El-Houssinia plain region, Sharkia Governorate, Egypt.

MATERIALS AND METHODS

Two field experiments were conducted in clay saline soil at the Sahl El-Houssinia Agriculture Research Station, Sharkia Governorate, Egypt, located between Latitude 32º 00' 00" to 32º 15 00" N, Longitude 30º 50' 00" to 31º 15' 00" E. Faba bean cultivar Nubaria 1 planted during winter seasons 2018/2019 and 2019 /2020 to study the effect of different sulfur sources *i.e.* calcium sulphate (CS), potassium sulphate (KS) and agricultural sulfur (AS) in four rates 0, 200, 400 and 600 kg fed.$^{-1}$ as control, low, medium and high rate, respectively with or without farmyard manure on inhibitory the hazardous effect of soil salinity stress on

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vegetative growth, yield and its quality of faba bean (*Vicia faba* L. c.v Nubaria 1) as well as some chemical characteristics of the experiment soil after harvest. The main physical and chemical properties of soil study are presented in Table (1) and some characteristics of the farmyard manure in Table (2) which was determined according to Cottenie *et al.* (1982) and Page *et al.* (1982).

Table 1. Some physical and chemical properties of soil

Particle size distribution (%)					Texture		O.M (%)		CaCO3 (%)
Coarse sand	Fine sand	Silt	Clay						
3.30	23.10	30.75	42.85		Clay		0.55		10.20
pH (1:2.5)	EC (dS/m)	Cation (meq/l)				Anion (meq/l)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{--}	
8.15	9.85	13.78	23.90	59.94	0.88	10.77	54.20	33.53	
Macronutrients (mg/kg)				Micronutrients (mg/kg)					
N	P	K	S	Fe		Mn		Zn	
36.20	4.95	173	4.36	3.20		2.15		0.54	

Table 2. The main physical and chemical characteristics of the farmyard manure (FYM).

Parameters	Values
density, gcm^{-3}	0.54
Moisture content, %	10.22
Organic carbon, %	17.52
Total nitrogen, %	0.98
C/N ratio	17.88
Total p, %	0.39
Total k, %	0.51
Organic matter, %	30.20
EC , dS m^{-1} (1:10 manure:water)	1.47
pH (1:10 manure:water)	7.62
Ca,%	0.82
Mg,%	0.32
Na,%	0.22
Available, Fe mg kg^{-1}	35.18
Available, Mn mg kg^{-1}	56.12
Available, Cu mg kg^{-1}	12.76
Available, Zn mg kg^{-1}	23.46

In both seasons, each experiment was carried out in a split split-plot design with three replicates. The sulfur sources, calcium sulphate (CS), potassium sulphate (KS) and agricultural sulfur (AS) were arranged randomly as the main plot, where the rate of sulfur sources were distributed randomly as subplot and FYM (with or without) was arranged randomly as sub subplot. The plot area was 35 m^2 (5 m width x 7 m length). Faba bean seeds (*Vicia faba* L.) cv. Nubaria 1 supplied from Food Legumes Department, Field Crop Research Institute, Agriculture Research Center, Giza, Egypt were sown after soil preparation. Seeding was carried out on 20th and 25th Nov. for the first and second seasons, respectively. Harvest was done on 26th and 29th of April for the first and second seasons, respectively. Plants were thinned to one plant per hill after 21 days from planting.

All plots of the experiment were fertilized with the recommended rates of N, P, and K in both seasons as follows: urea (46 % N) was applied at a rate of (40 kg N $fed.^{-1}$) on three equal doses after 31, 45, and 65 days from sowing. 31 kg $P_2O_5fed^{-1}$ as mono superphosphate (15.5% P_2O_5) during seedbed preparation and potassium were added at 75 kg K_2Ofed^{-1} as potassium sulfate (48% K_2O) in two equal doses after 30 and 45 days from sowing. Agricultural practices for growing faba bean were carried out as recommended by the Ministry of Agriculture. sulfur mixed with *Thiobacillus* strain (salt-tolerant PGPR) and was applied to soil before sowing. All area was divided in two division first division treated with FYM at the rate of 5 ton fed^{-1} and second division without FYM. All tillage processes were carried out before sowing.

All farming processes were carried out before planting. The soils of all the studies experimental plot units are subjected to some pretreatments processes as follows: a) levelling the soil surface by using the lazar technique. b) deep sub-soiling plough. c) establishment of filed drains at a distance of 10 m between each of two drains and a deep of 90 cm at drain beginning, their drainage water flow towards the main collectors of 2 m in depth and d) establishment of an irrigation canal in the middle part of the experimental field.

Laboratory analysis:

Plants samples of 10 plants were taken after 60 days from sowing to determine total Chlorophyll as described by Saric, *et al.* (1967) and proline content was estimated according to methods described by Bates *et al.* (1973). Total carbohydrates were determined in dry leaves using the method described by Dubois *et al* (1956).

Sufficient amounts of dried seed were milled to a fine powder and then digested with a mixture of concentrated sulfuric and perchloric acids for nutrient determination. The analyses of plants and soil were carried out using the methods described by Chapman and Pratt (1961) and Jackson (1973). Crude protein in faba bean seeds was calculated by multiplying total N-content by the converting factor 6.25 (Hymowitz, *et al.*, 1972).

At maturity, the middle three rows of each plot were harvested and air-dried to determine the following characteristics: plant height (cm), pod weight/plant, seed weight/plant, 100-seed weight (g), pod yield, (megagram, Mg/fed) and Seed yield (Mg/fed). Protein content (g/kg) = N content (g/kg) X 6.25. Seed macronutrients uptake (kg/fed) = N, P, and K content (g/kg) X seed yield (Mg/fed). Seed micronutrients uptake (g/fed) = Fe, Mn, and Zn content (mg/kg) X seed yield (Mg/fed).

After harvest: Topsoil samples (0-30 cm) were collected from all the experimental plots at the maximum growth stages, air dried, crushed, and sieved through a 2 mm sieve, and analyzed for soil EC, pH, and available macro and micronutrients contents according to some methods used for analyzing the initial soil Page *et al.* (1982).

Statistical analysis: Results were statistically analyzed using COSTATE software. The ANOVA test was used to determine significantly ($p \leq 0.01$ or $p \leq 0.05$) treatment effect and the Duncan Multiple Range Test was used to determine the significance of the difference between individual means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of different sulfur sources, rates and farmyard manure on some soil properties after faba bean harvest.

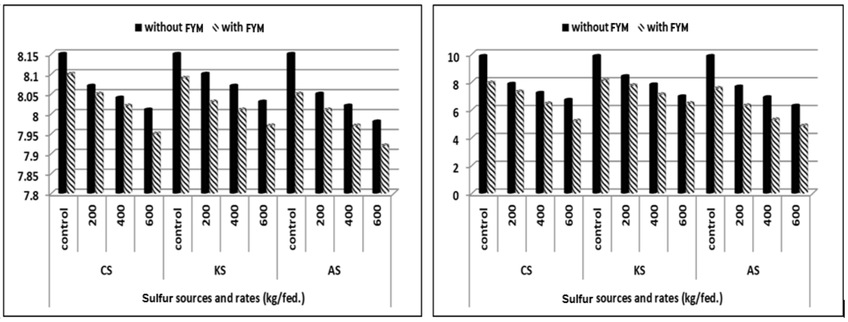
Soil pH

Results of soil analysis in Figure (1) show that values of soil pH in combined data of the two studied seasons was slightly reduced due to the addition of calcium sulphate (CS), potassium sulphate (KS) and agricultural sulfur (AS) and the reduction was pronounced in case of the high rate of treatments where the pH slightly decreased from 8.10 to 7.95

for CS, 8.09 to 7.97 for KS and 8.10 to 7.92 for AS when application with FYM and decreased from 8.15 to 8.01 for CS, 8.15 to 8.03 for KS and 8.15 to 7.98 for AS without FYM. These results obtained are in agreement with Ayub et al. (2007) who reported that the sulfur reduced soil pH slowly from (8.5–7.7) in about 20 weeks followed by sulfur compared with control (8.5). The decrease in soil pH due to CS application was probably due to a combination of more than one factor, mainly the replacement of sodium by calcium and the formation of neutral salts with SO_4^{-} and a decrease in sodium concentration as a fraction of the cations. Concerning sulfur materials, Poraas et al. (2009) indicated that the use of acidic sulfur materials such as mineral sulfur had a very negligible influence on reducing the pH. Farook and Khan, (2010) stated that the use of sulfidic materials decreased soil pH by 0.1 to 0.2 pH units compared with the initial soils. The superior treatment that decreases soil pH than the other treatments was the addition high rate of AS combound with FYM . These results may be due to farmyard manure in improving the physical and chemical properties of soil such as aggregation, aeration permeability, water holding capacity and increasing the some macro and micro nutrients. It improves also drainage, reduce soil PH, increasing the microorganisms activity which reflected on the increment of the plant roots absorption and consequently caused a positive impact on vegetative parameters.

Soil salinity (EC)

As for soil salinity, the obtained data in Figure 1 indicate also that the application of the different sulfur sources caused an appreciated reduction in the EC values. However, the different sources of sulfur caused a clear decline in the EC values with increasing addition rates. The effect is more pronounced due to the addition of a high rate of AS with FYM treatment and the EC value 4.85 dS m^{-1} was recorded as compared with EC value of control (9.85 dS m^{-1}) and gave 50.8% rate of depression than the control. This trend can be due to improve soil structure, increasing aggregate stability and drainable pores. Consequently, these created conductive pores enhancing the leaching process of soluble salts through irrigation fractions. The efficiencies of sulfur sources in decreased soil soluble salt arranged as the following: AS > CS > KS and high > medium > low > control for sulfur rate.



Soil pH **Soil EC (ds m^{-1})**

Figure 1. Soil pH and EC (dS m^{-1}) as affected by sulfur sources and rates as well as farmyard manure (mean the tow seasons)

Available macronutrients (N, P and K)

Figure (2) reveals that the application of different sulfur sources and rates increased the concentration of available nitrogen, phosphorus, and potassium in the soil as compared with the control for all rates under study, especially when using sulfur with FYM.

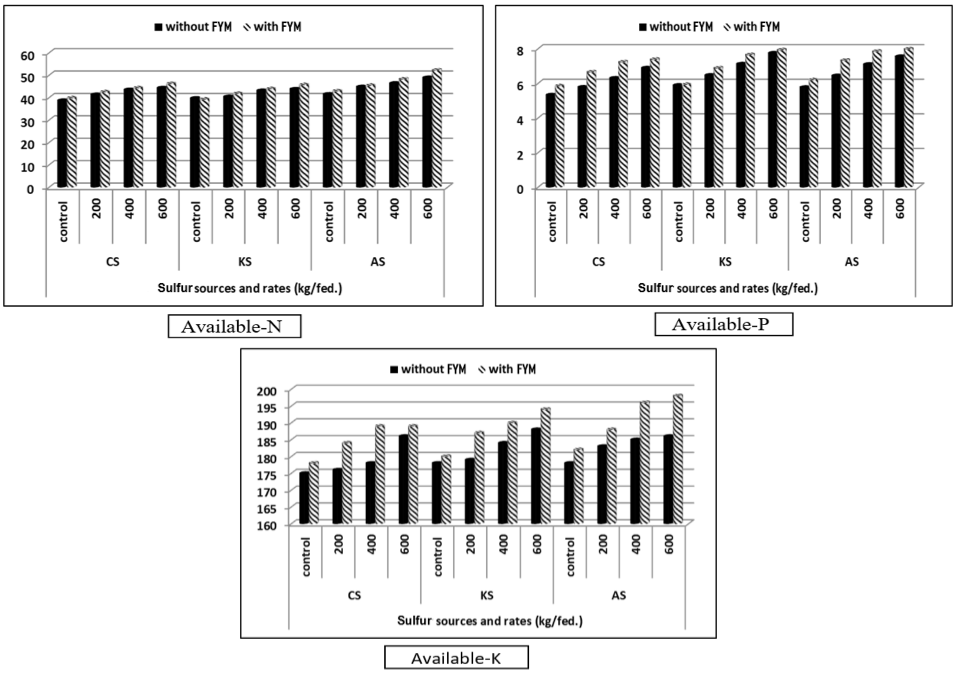


Figure 2. Available N, P and K (mg/kg) in the soil after harvest as affected by sulfur sources and rates as well as FYM (mean the tow seasons).

In this regard, El-Kouny (2009) pointed out that the application of elemental sulfur with compost increased total N and availability of P and K in the soil as compared with the control. The plots treated with AS showed the maximum accumulation of available N, P and K, (52.2, 7.98 and 198 mg kg^{-1}), respectively, especially at the high rate and found true FYM.

Available Fe, Mn and Zn.

The content of available Fe, Mn and Zn followed the same trend that observed for macronutrients hence, the application of CS, KS and AS treatments at different rates, especially with FYM have increased the concentration of available Fe, Mn and Zn in the soil as compared with the control. In this regard, Khan *et al.* (2007) reported that the application of sulfidic materials was effective in enhancing the release of essential plant nutrients into the growing media, which are very essential for crop production in poor soils. The highest soil available Fe, Mn and Zn contents for combined data (5.05, 3.58 and 0.79 mg kg^{-1}), respectively were obtained due to AS at a high rate of addition + FYM. The results showed a significant effect of FYM and S in improving the available soil nutrients (N, P, K, Fe, Mn, Cu and Zn) in which significantly increased with FYM and S applications at all rates.

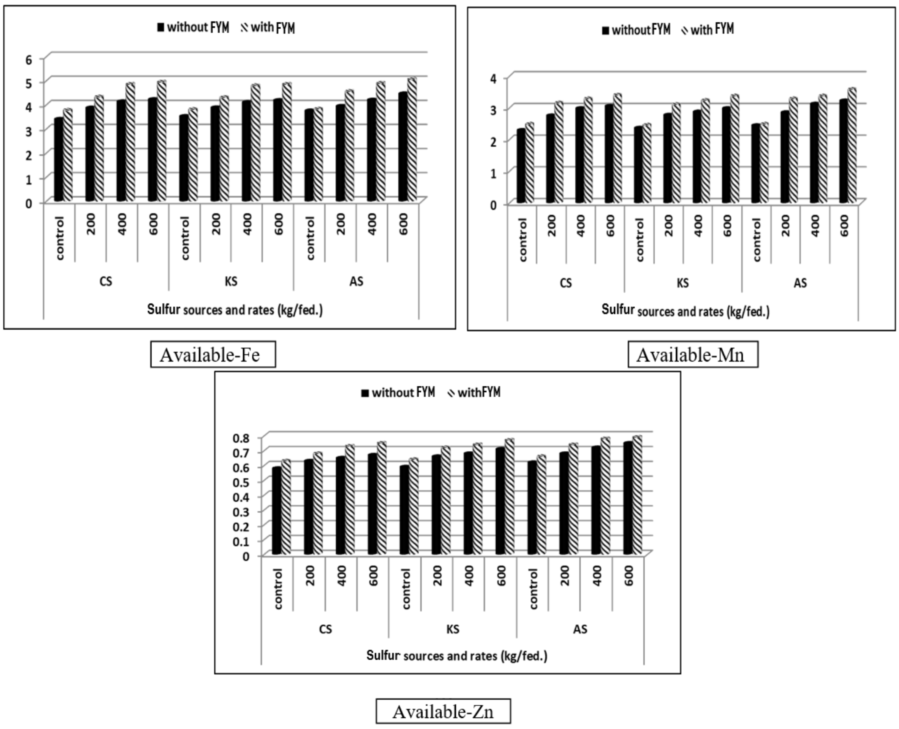


Figure 3. Available Fe, Mn and Zn (mg/kg) in the soil after harvest as affected by sulfur sources and rates as well as FYM (mean the tow seasons)

Yield and its attributes.

Growth characters.

Some growth characters of faba bean plants are shown in Table (3) calcium sulphate, potassium sulphate and agricultural sulfur at different rates as well as FYM significantly increased plant height, pod weight/plant, seed weight/plant and 100-seed weight as compared to the control treatment. These increases may be due to calcium, while it is essential for plant cell wall structure, provides normal transport and retention of other elements as well as strength in the plant. Among the treatments, AS was found to be the best source of S followed by KS and then CS because of its influence on reducing soil pH, improving soil structure and increasing the availability of certain plant nutrients. Also, probably may be due to FYM that improved soil physical and chemical properties which reflect on yield and yield components.

Data also indicated that application of agricultural sulfur at a high rate when added with FYM gave the highest values and increased the plant height, pod weight/plant, seed weight/plant and 100-seed weight by about (23.9, 36.0, 40.5 and 16.4%), respectively when compared with control plants of AS addition. Ali *et al.* (2012) reported that S application significantly enhanced wheat growth and yield. This was most probably due to increased Ca and K and decreased Na contents resulting in a healthy environment for plant growth. These results are in harmony with those obtained by Ali *et al.* (2008) and Mazhar *et al.* (2011). As for sulfur addition rate, the effect followed the sequence: 600 ≥ 400 > 200 > control for plant height, pod weight/plant, and seed weight/plant while was 600 > 400 > 200 > control for 100-seed weight.

Pod and seed yield

Table (3) also shows that pod and seed yields were significantly increased due to FYM and/or sulfur fertilization and their combinations. The favourable effect of sulfur sources might be attributed to the role of calcium, which is essential for the plant as previously mentioned. Also, calcium is essential for many plant functions, some of them are proper cell division and elongation, enzyme activity and metabolism. These results are well supported by the findings of Sabir *et al.* (2007) and Farook and Khan, (2010). The treatment of AS at a high rate + FYM was superior to the other treatments and gave the maximum pod and seed yields. These results are in agreement with Sadiq *et al*. (2007), and Jena and Kabi, (2012).

Concerning the statistical analysis, the effect of sulfur sources was insignificant while, the data presents the following descending order for the effect of sulfur rates: 600 ≥ 400 > 200 > control for pod yield and 600 > 400 > 200> control for seed yield. AS with FYM, the order was: with FYM > without FYM. The interaction effect between the treatment (S, R and FYM) had an insignificant effect between them, except for R x FYM with pod yield.

Table 3. Yield attributes and yield of faba bean plant as affected by sulfur sources and rates as well as farmyard manure (mean the tow seasons)

Sulfur source (S)	Sulfur rate (R) Kg/fed	Plant height (cm)			Pod weight/plant, g			Seed weight/plant, g			100-seed weight, g			Pod yield, Mg/fed			Seed yield, Mg/fed		
		FYM addition																	
		without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean
CS	Control	77.5	77.1	77.3	25.3	28.0	26.7	15.2	16.9	16.1	66.2	70.6	68.4	2.18	2.33	2.26	1.50	1.60	1.55
	200	83.2	83.8	83.5	27.2	30.1	28.7	17.0	19.4	18.2	68.9	75.3	72.1	2.29	2.65	2.47	1.75	1.96	1.86
	400	84.0	86.1	85.1	27.9	31.0	29.4	17.2	19.7	18.5	69.5	77.9	73.7	2.30	2.85	2.58	1.88	2.09	1.99
	600	85.2	88.5	86.9	28.3	32.9	30.6	17.9	20.0	18.9	72.1	82.1	77.1	2.36	2.96	2.66	1.93	2.15	2.04
Mean		82.5	83.9	83.2 b	27.2	30.5	28.8c	16.8	19.0	17.9 c	69.2	76.5	72.8 c	2.28	2.70	2.49	1.77	1.95	1.86
KS	Control	78.3	78.3	78.3	26.8	28.7	27.7	15.9	17.1	16.5	68.4	72.3	70.4	2.19	2.39	2.29	1.53	1.62	1.58
	200	80.6	85.8	83.2	28.0	32.1	30.1	17.1	20.4	18.8	72.1	76.9	74.5	2.21	2.88	2.55	1.83	2.08	1.96
	400	83.9	89.3	86.6	28.9	33.0	30.9	17.9	21.7	19.8	74.9	79.0	76.9	2.34	2.95	2.65	1.92	2.18	2.05
	600	84.1	91.0	87.6	29.2	33.4	31.3	18.4	22.0	20.2	75.3	81.9	78.6	2.36	2.99	2.68	1.98	2.39	2.19
Mean		81.7	86.1	83.9 b	28.2	31.8	30.0b	17.3	20.3	18.8 b	72.7	77.5	75.1 b	2.28	2.80	2.54	1.82	2.07	1.94
AS	Control	79.8	80.0	79.9	27.2	29.2	28.2	16.3	17.9	17.1	73.0	74.2	73.6	2.23	2.44	2.34	1.56	1.64	1.60
	200	84.3	88.2	86.3	29.0	33.5	31.2	18.6	21.6	20.1	74.4	78.3	76.4	2.27	2.93	2.60	1.89	2.13	2.01
	400	88.5	94.2	91.4	30.1	36.2	33.2	18.9	22.0	20.5	77.8	84.2	81.0	2.47	3.05	2.76	1.98	2.20	2.09
	600	89.1	98.9	94.0	30.9	37.0	33.9	19.1	22.9	21.0	79.5	85.0	82.3	2.58	3.10	2.84	2.06	2.40	2.23
Mean		85.4	90.3	87.9 a	29.3	34.0	31.6a	18.2	21.1	19.6 a	76.2	80.4	78.3 a	2.39	2.88	2.63	1.87	2.09	1.98
Mean of FYM		83.2	86.8		28.2b	32.1a		17.4 b	20.1a		72.7 b	78.1 a		2.32 b	2.79 a		1.82 b	2.04 a	
Mean of sulfur rate, R	Control		78.5 c			27.5 c			16.5 c			70.8 d			2.29 c			1.58 d	
	200		84.3 b			30.0 b			19.0 b			74.3 c			2.54 b			1.94 c	
	400		87.7 a			31.2 a			19.6 ab			77.2 b			2.66 ab			2.04 b	
	600		89.5 a			31.9 a			20.0 a			79.3 a			2.73 a			2.15 a	
F-test		S:*		R: **	S:**		R:**	S: **		R: **	S: **		R: **	S: NS		R: **	S: NS		R: **
			FYM:NS			FYM:*			FYM: *			FYM:**			FYM: **			FYM: **	
			SxR: NS			SxR: NS			SxR: NS			SxR: NS			SxR: NS			SxR: NS	
			Sx FYM:NS			Sx FYM:NS			Sx FYM: *			Sx FYM: **			Sx FYM: NS			Sx FYM: NS	
			Rx FYM:NS			Rx FYM: *			Rx FYM: NS			Rx FYM: **			Rx FYM: *			Rx FYM: NS	
			SxRx FYM: NS			SxRx FYM: NS			SxRx FYM: NS			SxRx FYM: NS			SxRx FYM: NS			SxRx FYM: NS	

Calcium sulpate, CS; Potassium sulphate, KS , agricultural Sulfur, AS and farmyard manure , FYM

Seed Quality

Total protein, proline, carbohydrates and chlorophyll

As shown in Table (4) data present that all seed quality parameters significantly affected by the addition of sulfur sources, rates, and FYM. The differences among the sulfur rates were as follow: 600 ≥ 400 > 200 > control and AS > KS ≥ CS for sulfur sources. This promoting effect could be clarified the effect of sulfur materials on enhancing the growth of faba bean and improving the fertility of the studied soil. The maximum value of protein content (27.6%) was recorded in the plants treated with AS at a high rate + farmyard manure which recorded 34.0% increases over the control treatment (without sulfur addition). The interaction effect between the treatment (S, R and FYM) had an insignificant effect between them.

As for proline content values in fresh weight of leaves significantly decreased by the application of different sulfur sources and rates especially with FYM. The differences were significant within the treatments. The high rate of sulfur fertilizer might be caused by the induction or activation of proline syntheses from glutamate or decrease in its utilization in protein syntheses or enhancement in protein turnover. Thus, proline may be the major source of energy and nitrogen during immediate post-stress metabolism and accumulated proline supplies energy for growth and survival, thereby inducing salinity tolerance (Gad 2005). The treatment of control (without fertilizers) increased proline content over the treatments and gave the highest value (35.2 mg/g f.w). The increases followed the order: control > low> medium> high rate and followed the pattern of: CS > KS > AS for sulfur sources.

Concerning total carbohydrates and chlorophyll content, data reveal that there were significant increases due to the addition of treatments. The difference between the sulfur sources and rates were significant. The highest carbohydrates and chlorophyll content 52.8 and 10.9 mg/g fresh weight of leaves, respectively were obtained due to the application treatment of AS at a high rate (600 kg/fed.) + FYM representing an increase of 17.1 and 76.4 %.

Seed macronutrients content and uptake

Data in Table (5) shows that N, P, and K content and uptake were increased owing to the application of sulfur treatments solely or in combination with FYM. The effect of sulfur sources was significant for N-content and P-uptake while had an insignificant effect in increasing P and K-content as well as N and K-uptake by faba bean seeds. Concerning sulfur rates, the effect was significant for all nutrients content and uptake and followed the sequence effect as follow: 600 ≥ 400 > 200 > control for N and K-content; 600 ≥ 400 ≥ 200 > control for P-content; 600 > 400 > 200 > control for N and K-uptake and 600 ≥ 400 ≥ 200 > control for P-uptake. Given the effect of FYM, the effect was significant for both the nitrogen and phosphorous content and their uptake, while it was not significant for the potassium content and uptake. This promoting effect could be related to the supplementary effect of sulfur and FYM on reducing soil pH, improving soil structure and increasing the availability of nutrients in the soil and also, improves the use efficiency of other essential plant nutrients, particularly nitrogen and phosphorus Mazhar *et al.* (2011). These results are in a harmony with those obtained by Ali *et al*. (2008) and Haq *et al.* (2007).

Table 4. Seed quality of faba bean plant as affected by sulfur sources and rates as well as farmyard manure (mean the tow seasons)

Sulfur source (S)	Sulfur rate (R) Kg/fed	Protein content, %			Proline, mg/g d.w			Carbohydrates (%)			Chlorophyll, mg/g f.w		
		FYM addition											
		without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean
CS	Control	19.6	20.1	19.9	35.2	28.3	31.8	44.0	46.7	45.3	5.85	6.55	6.20
	200	20.5	23.4	22.0	29.1	20.0	24.6	45.2	48.2	46.7	6.11	7.45	6.78
	400	23.5	24.9	24.2	22.8	17.9	20.3	45.9	49.0	47.4	6.75	8.00	7.38
	600	24.3	25.4	24.9	18.1	14.2	16.2	46.4	49.1	47.7	6.93	8.22	7.58
Mean		22.0	23.5	22.7 c	26.3	20.1	23.2 a	45.4	48.2	46.8 c	6.41	7.56	6.98 c
KS	Control	19.5	21.7	20.6	33.5	24.3	28.9	44.9	47.0	45.9	5.93	6.86	6.40
	200	20.1	24.7	22.4	25.9	15.9	20.9	46.0	49.3	47.6	6.65	7.66	7.16
	400	23.1	25.6	24.4	17.1	13.1	15.1	46.2	49.8	48.0	6.89	8.85	7.87
	600	24.1	25.9	25.0	15.8	11.9	13.8	46.9	50.1	48.5	7.10	9.41	8.26
Mean		21.7	24.5	23.1 b	23.1	16.3	19.7 b	46.0	49.0	47.5 b	6.64	8.20	7.42 b
AS	Control	20.6	21.6	21.1	30.7	20.9	25.8	45.1	47.9	46.5	6.18	7.08	6.63
	200	24.0	25.4	24.7	22.4	13.3	17.9	46.8	50.0	48.4	7.23	8.26	7.75
	400	25.3	26.4	25.9	16.3	10.6	13.4	47.0	52.1	49.6	7.97	9.10	8.54
	600	25.6	27.6	26.6	13.9	9.3	11.6	47.9	52.8	50.4	8.06	10.9	9.47
Mean		23.9	25.3	24.6 a	20.8	13.5	17.2 c	46.7	50.7	48.7 a	7.36	8.83	8.10 a
Mean of FYM		22.5 b	24.4 a		23.4 a	16.6 b		46.0 b	49.3 a		6.80 b	8.19 a	
Mean of sulfur rate, R	Control		20.5 c			28.8 a			45.9 c			6.41 d	
	200		23.0 b			21.1 b			47.6 b			7.23 c	
	400		24.8 a			16.3 c			48.3 ab			7.93 b	
	600		25.5 a			13.9 d			48.9 a			8.43 a	
F-test		S:** R: ** FYM:** SxR: NS Sx FYM: NS Rx FYM: NS SxRx FYM: NS			S:** R: ** FYM: ** SxR: NS Sx FYM: NS Rx FYM: ** SxRx FYM: NS			S:** R: ** FYM:** SxR: NS Sx FYM: ** Rx FYM: NS SxRx FYM: NS			S:** R: ** FYM: * SxR: NS Sx FYM: NS Rx FYM: ** SxRx FYM: NS		

Calcium sulpate, CS; Potassium sulphate, KS agricultural Sulfur, AS and farmyard manure , FYM

Table 5. Macronutrients content and uptake by faba bean plant as affected by sulfur sources and rates as well as farmyard manure (mean the tow seasons)

Sulfur source (S)	Sulfur rate (R) Kg/fed	Macronutrient content, %									Macronutrient uptake, kg/fed								
		N			P			K			N			P			K		
		FYM addition																	
		without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean
CS	Control	3.14	3.22	3.18	0.35	0.38	0.37	1.30	1.40	1.35	48.9	52.4	50.6	5.31	6.19	5.75	20.1	22.7	21.4
	200	3.28	3.75	3.52	0.37	0.46	0.42	1.75	1.93	1.84	58.0	73.7	65.9	6.63	9.29	7.96	30.6	38.5	34.6
	400	3.75	3.98	3.87	0.42	0.49	0.46	1.88	2.05	1.97	71.0	83.8	77.4	8.23	10.5	9.37	35.7	43.3	39.5
	600	3.89	4.06	3.98	0.45	0.53	0.49	1.95	2.16	2.06	75.8	88.4	82.1	9.07	11.6	10.4	38.2	47.2	42.7
Mean		3.52	3.75	3.63 b	0.40	0.47	0.43	1.72	1.89	1.80	63.4	74.6	69.0	7.31	9.40	8.36 b	31.2	37.9	34.5
KS	Control	3.12	3.47	3.30	0.36	0.42	0.39	1.42	1.44	1.43	49.5	57.1	53.3	5.97	7.23	6.60	22.2	23.7	23.0
	200	3.22	3.95	3.59	0.41	0.47	0.44	1.84	1.98	1.91	59.3	83.6	71.4	7.63	10.3	8.95	33.9	41.7	37.8
	400	3.69	4.10	3.90	0.44	0.53	0.49	1.89	2.16	2.03	71.8	90.2	81.0	8.71	11.8	10.3	36.8	48.5	42.6
	600	3.85	4.15	4.00	0.47	0.55	0.51	1.99	2.22	2.11	76.9	99.5	88.2	9.51	13.3	11.4	39.8	53.4	46.6
Mean		3.47	3.92	3.69 b	0.42	0.49	0.46	1.79	1.95	1.87	64.4	82.6	73.5	7.95	10.7	9.31ab	33.2	41.8	37.5
AS	Control	3.29	3.45	3.37	0.39	0.44	0.42	1.44	1.48	1.46	52.8	57.3	55.0	6.18	7.54	6.86	23.6	24.9	24.2
	200	3.84	4.07	3.96	0.44	0.52	0.48	1.88	2.13	2.01	73.2	87.9	80.6	8.55	11.4	9.96	35.7	47.1	41.4
	400	4.05	4.22	4.14	0.48	0.55	0.52	1.97	2.28	2.13	82.6	93.9	88.3	9.81	12.0	11.0	39.3	50.8	45.0
	600	4.09	4.42	4.26	0.52	0.58	0.55	2.11	2.38	2.25	85.2	108.2	96.7	11.1	14.5	12. 8	44.6	58.8	51.7
Mean		3.82	4.04	3.93 a	0.46	0.52	0.49	1.85	2.07	1.96	73.5	86.8	80.1	8.91	11.4	10.2 a	35.8	45.4	40.6
Mean of FYM		3.60 b	3.90 a		0.43 b	0.49 a		1.79 b	1.97 a		67.1 b	81.3 a		8.06 b	10.5 a		33.4 b	41.7 a	
Mean of sulfur rate, R	Control		3.28 c			0.39 b			1.41 c			53.0 d			6.40 c			22.9 d	
	200		3.69 b			0.45 ab			1.92 b			72.6 c			8.96 b			37.9 c	
	400		3.97 a			0.49 a			2.04 a			82.2 b			10.2 ab			42.4 b	
	600		4.08 a			0.52 a			2.14 a			89.0 a			11.5 a			47.0 a	
F-test		S: ** R:** FYM: ** SxR: NS Sx FYM: NS Rx FYM: NS SxRx FYM: NS			S: NS R: ** FYM: * SxR: NS Sx FYM: NS Rx FYM: NS SxRx FYM: NS			S: NS R: ** FYM: NS SxR: NS Sx FYM: NS Rx FYM: NS SxRx FYM: NS			S: NS R: ** FYM:** SxR: NS Sx FYM: NS Rx FYM: * SxRx FYM: NS			S: * R: ** FYM: * SxR: NS Sx FYM: NS Rx FYM: NS SxRx FYM: NS			S: NS R:** FYM: NS SxR: NS Sx FYM: NS Rx FYM: * SxRx FYM: NS		

Calcium sulpate, CS; Potassium sulphate, KS, agricultural Sulfur, AS and farmyard manure , FYM

The highest N, P, and K content and uptake (4.42, 0.58, and 2.38% for content, respectively as well as 108.2, 14.5, and 58.8 kg/fed., for uptake, respectively) were obtained owing to addition AS at a high rate (600 kg/fed) + FYM.

Seed micronutrients content and uptake

As shown in Table (6) Fe, Mn and Zn content and uptake followed the same trend that for macronutrients. The addition of sulfur fertilizers at different rates solely or with FYM significantly increased Fe, Mn and Zn content and uptake compared to the control. FYM + high rate of AS was most effective and giving the highest increase in Fe, Mn and Zn content and uptake as compared to the other treatments. These increases may be attributed to the role of microorganisms in improving these micronutrients availability, (Figure 3) which was likely attributed to reducing the pH of the soil making the nutrients more available and lowering the redox statues of iron and manganese leading to reduction of higher Fe^{3+}& Mn^{4+} to Fe^{2+} and Mn^{2+} and/or transformation of insoluble chelated forms of micronutrients into more soluble ions (Castilho *et al.,* 1993). The positive effect could be related to the S-supplementary as reported by Kubenkulov *et al.* (2013) who reported that sulfur addition regulates the soil pH and total soluble salts (TSS) for the soda-saline soils, which seems the main cause to converge the values of pH, EC and SAR toward safe limit which improving the availability of nutrients.

Table 6. Micronutrients content and uptake by faba bean plant as affected by sulfur sources and rates as well as farmyard manure (mean the tow seasons).

Sulfur source (S)	Sulfur rate (R) Kg/fed	Micronutrient content, mg/kg									Micronutrient uptake, g/ fed								
		Fe			Mn			Zn			Fe			Mn			Zn		
		FYM addition																	
		without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean	without	With	Mean
CS	Control	59.3	64.6	61.9	27.4	30.2	28.8	44.1	46.2	45.2	89.2	103	96.3	41.4	48.7	45.0	66.5	74.1	70.3
	200	61.4	69.2	65.3	28.1	32.1	30.1	45.0	48.0	46.5	108	136	122	49.3	64.0	56.7	79.0	94.6	86.8
	400	63.1	73.1	68.1	28.8	32.9	30.8	45.8	48.1	47.0	119	153	136	54.2	69.0	61.6	86.4	100	93.4
	600	63.8	77.1	70.5	29.6	34.1	31.9	45.9	49.3	47.6	124	166	145	57.5	73.8	65.6	88.8	106	97.3
Mean		61.9	71.0	66.5 c	28.5	32.3	30.4 c	45.2	47.9	46.6 c	110	140	125 b	50.6	63.9	57.2 b	80.2	93.7	87.0 b
KS	Control	62.9	66.2	64.5	28.2	31.9	30.1	45.0	47.8	46.4	96.6	107	102	43.8	52.2	48.0	69.0	77.3	73.1
	200	63.5	74.2	68.9	29.8	35.3	32.5	47.3	49.3	48.3	116	155	136	54.6	73.7	64.2	86.8	103	94.8
	400	66.2	78.2	72.2	31.4	37.2	34.3	47.9	53.1	50.5	128	171	149	60.9	81.6	71.3	92.0	116	104
	600	69.3	80.3	74.8	32.0	39.6	35.8	48.1	54.0	51.1	137	192	165	63.8	94.8	79.3	95.5	129	112
Mean		65.5	74.7	70.1 b	30.4	36.0	33.2 b	47.1	51.1	49.1 b	120	156	138ab	55.8	75.6	65.7 ab	85.8	106	96.1ab
AS	Control	63.3	68.1	65.7	28.9	32.3	30.6	46.3	48.0	47.2	99.2	112	106	45.2	53.7	49.4	72.9	78.9	75.9
	200	65.2	78.3	71.8	31.3	37.7	34.5	48.2	52.1	50.2	124	167	145	59.7	80.4	70.1	91.4	111	101
	400	67.8	83.7	75.7	33.0	40.6	36.8	48.9	56.2	52.5	135	185	160	66.5	89.8	78.2	96.5	123	110
	600	70.4	87.3	78.9	33.6	42.1	37.9	49.0	57.1	53.1	145	210	178	69.7	103	86.2	101	137	119
Mean		66.7	79.3	73.0 a	31.7	38.2	34.9 a	48.1	53.4	50.7 a	126	168	147 a	60.3	81.7	71.0 a	90.5	113	102 a
Mean of FYM		64.7 b	75.0 a		30.2 b	35.5 a		46.8 b	50.8 a		118 b	155 a		55.5 b	73.7 a		85.5 b	104 a	
Mean of sulfur rate, R	Control		64.1 d			29.8 d			46.2 c			101 d			47.5 d			73.1 d	
	200		68.7 c			32.4 c			48.3 b			134 c			63.6 c			94.3 c	
	400		72.0 b			34.0 b			50.0 a			148 b			70.3 b			102 b	
	600		74.7 a			35.2 a			50.6 a			162 a			77.0 a			110 a	
F-test		S:** R: **			S: ** R: **			S:** R: **			S: * R: **			S:* R: **			S: * R: **		
		FYM:**			FYM: *			FYM: *			FYM: **			FYM:*			FYM:**		
		SxR: **			SxR: **			SxR: NS			SxR: NS			SxR: NS			SxR: NS		
		Sx FYM: **			Sx FYM: *			Sx FYM: NS			Sx FYM: *			Sx FYM: *			Sx FYM: *		
		Rx FYM: **			Rx FYM: **			Rx FYM: **			Rx FYM: **			Rx FYM: **			Rx FYM: *		
		SxRx FYM: **			SxRx FYM: NS			SxRx FYM: NS			SxRx FYM: NS			SxRx FYM: NS			SxRx FYM: NS		

Calcium sulpate, CS; Potassium sulphate, KS, agricultural Sulfur, AS and farmyard manure , FYM

The responses percentage to Fe, Mn and Zn uptake by faba bean seeds over control was 112, 128 and 87.9 %, respectively. Jena and Kabi, (2012) stated that sulfur application increased Fe, Mn, Zn and Cu uptake by rice plants. Sulfur fertilization enhanced the uptake of N, P, K and Zn in the plant due to its synergistic effect, the efficiency of these elements is enhanced which results in increased crop productivity. The application of S fertilizer is useful not only for increasing crop production and quality of the product but also improves soil conditions for a healthy crop. These results are in a harmony with those obtained by Ahmed et al. (2016). The Mean effect of sulfur addition rate followed the order: 600 > 400 > 200 > control for Fe, Mn and Zn content and uptake except for Zn-content the order was:600 ≥ 400 > 200 > control. As for the mean effect of sulfur sources, the differences were as follow: AS > KS > CS for Fe, Mn and Zn content while it was: AS ≥ KS ≥ CS for Fe, Mn and Zn uptake.

CONCLUSION

The findings of the present study suggested that the application of sulfur with FYM is also an effective technology in improving the chemical properties, like pH and EC of salt-affected soils and, subsequently yield attribute of faba bean plants. The agricultural sulfur at a rate of 600 kg/fed with FYM was superior for the amelioration and enhancing the properties of the salt-affected soil than the other sources and rates, which could also be an effective and suitable alternative amendment for improving the different qualities of salt-affected soils and yield of faba bean.

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تحسين صفات الأراضي الطينية الملحية وتأثيرها علي إنتاجية الفول البلدي

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أقيمت تجربتان حقليتان خلال موسمى النمو الشتوى 2019/2018 و 2020/2019 في تربة طينية ملحية بمحطة سهل الحسينية للبحوث الزراعية ، محافظة الشرقية ، مصر لتقييم تأثير أضافة الكبريت للتربة من مصادر مختلفة وهي كبريتات الكالسيوم ، كبريتات البوتاسيوم و الكبريت الزراعي وذلك بأربع معدلات هي 0 ، 200 ، 400 و 600 كجم/ فدان لتمثل (الكنترول ، المعدل المنخفض ، المعدل المتوسط و المعدل المرتفع) علي التوالي مع أو بدون السماد البلدى حول التأثير التثبيطي لملوحة التربة على النمو الخضري والمحصول ونوعية الفول البلدي وبعض الخصائص الكيميائية للتربة وكان تصميم التجربة قطع منشقة مرتين حيث تم وضع مصادر الكبريت فى القطع الرئيسية ومعدلات الكبريت فى القطع الشقية الأولى والسماد البلدى فى القطع الشقية الثانية. ويمكن تلخيص أهم النتائج المتحصل عليها كما يلي: أدت إضافة المصادر المختلفة من الكبريت وكذلك المعدلات المختلفة مع أو بدون إضافة السماد البلدى إلى زيادة القيم المتحصل عليها لمحصول الفول البلدى ومكوناته ومحتوى وامتصاص العناصر الغذائية الكبرى والصغرى. ازدادت معنوياً قيم محتوى البروتين وكذلك الكلوروفيل الكلى والكربوهيدات الكلية بينما انخفضت قيم البرولين المتراكم نتيجة المعاملات تحت الدراسة. أدت معاملة الكنترول (بدون الأسمدة) إلى زيادة محتوى البرولين عن باقى المعاملات. أدت إضافة المعاملات المختلفة إلى انخفاض قيم كل من حموضة التربة pH وكذلك التوصيل الكهربائى (EC) بينما زادت قيم العناصر الكبرى والصغرى. كانت أفضل النتائج التحصل عليها لجميع القياسات تحت الدراسة عند إضافة المستوى الأعلى من الكبريت الزراعى 600كجم/ فدان مع إضافة السماد البلدى مقارنة بالمعاملات.