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ORIGINAL ARTICLE

RESPONSE OF FABA BEAN (*VICIA FABA* L.) TO POTASSIUM APPLICATION AND SPRAYING WITH SILICON UNDER SALINITY STRESS CONDITIONS

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Abstract: Field experiment was conducted during the Winter season of 2020-2021 at Al-Hartha Research Station of the College of Agriculture, University of Basrah (10 km north of Basrah center), in soil with a silty clay loam texture, to study the effect of three potassium levels (0, 80 and 160 kg K h^{-1}) and four concentrations of silicon (0, 3, 6 and 9 mM l^{-1}) on growth and yield of broad bean in soil affected by salinity (11.40 ds m^{-1}). A factorial experiment was used in randomized complete block design, with three replications. The results showed that 80 kg K h^{-1} gave the highest value for plant height, number of pods per plant, seed yield and biological yield, with an increase by 27.7%, 83.2%, 85.8% and 67.1%, respectively compared to the control treatment, while the 160 kg K h^{-1} recorded the highest leaf area. The concentration of silicon 9 mM L^{-1} gave the highest values for plant height, number of pods, weight of 100 seeds, seed yield and biological yield per plant, with an increase by 6.5%, 32.5%, 4.2%, 47.1% and 41.0%, respectively compared to the control treatment. The interaction between potassium and silicon had a significant effect on some characteristics studied, the combination of 80 kg K h^{-1} * 9 mM L^{-1} gave the highest mean for plant height (67.20 cm), number of pods per plant (13.63), seed yield (2900 kg h^{-1}) and biological yield (6883.3 kg h^{-1}).

***Key words*:** Faba bean, Potassium, Stress conditions, Factorial experiment.

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1. Introduction

Broad bean is one of the most important and widespread legume crops in the world, it is one of the main sources of protein (25-40%) and energy for the population in many countries, it is cultivated for obtaining green pods or soft or dry seeds [Liang *et al*. (2015)]. It is also grown in agricultural rotations to improve soil properties because it fixes atmospheric nitrogen. Plant growth is greatly affected by increased soil salinity. That is attributed to the osmotic or ionic effect or may cause disorders in minerals nutrition. Broad bean is classified as a medium tolerant plant to soil salinity. Among the most important means used for overcoming some stresses, especially salt stress is the use of potassium (K) or silicon (Si). Potassium is one of the major elements necessary for the growth and physiological function of plants which have a direct or indirect effect on energy use, opening and closing stomata, activation of 60-120 enzymes, regulating the osmotic effort of plant cells, increasing their permeability, contributing to the process of photosynthesis and the transfer of its products, stimulating cells to divide and elongation, especially meristematic cells in the developing tops and leaf cells [Hasanuzzaman *et al*. (2018), Noaema *et al*. (2020)]. Silicon has important role in many physiological processes, the most important of which are improving the efficiency of photosynthesis, increasing the effectiveness of roots to absorb nutrients, reducing the toxicity of sodium and chlorine ions, increasing the effectiveness of antioxidant enzymes, and reducing the

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toxicity of heavy metals [Adrees *et al*. (2015), Al-Hasany *et al*. (2020)]. Silicon performs many functions in the plant, including protecting the plant when exposed to prolonged periods of drought, frost, pests, diseases and others [Guntzer *et al*. (2012)]. It also works to strengthen the cell walls, which leads to mechanical support for the aerial parts of the plant [Guerriero *et al*. (2016)]. As it stimulates the plant to develop some mechanisms that enable it to resist or withstand various stress conditions, whether biotic or abiotic, especially in salt stress conditions [Liang *et al*. (2006), Al-Hasany *et al*. (2021)]. Spraying silicon on bean plants leads to stimulating the antioxidant system through an increase in the activity of antioxidant enzymes such as Ascorbate peroxidase (APX) and Catalase (CAT) and thus improves crop growth under saline stress conditions. Due to the scarcity of studies on this subject in the southern region of Iraq which is characterized by high salinity, this study was conducted to find out the response of bean plant grown in saline soil to apply potassium and spraying silicon.

Table 1: Some chemical and physical properties of soil.

Character	pH	E.C.	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	Clay	Silt	Sand	Texture
Value	7.66	11.4	28.5	23.3	53.7	2.2	75.9	27.1	6.4	252	688	60	Silty clay loam
Unit		ds m^{-1}	meq l^{-1}							g kg^{-1} soil			

2. Materials and Methods

The experiment was conducted during winter season of 2021, at Al-Hartha Research Station of the College of Agriculture, University of Basra (10 km north of Basra center) to study the effect of application of three levels of potassium (0, 80 and 160 kg K ha^{-1} as K_2SO_4), it has been denoted with symbols K_0, K_1 and K_2 respectively; and spraying silicon at four levels (0, 3, 6 and 9 mmol l^{-1}), with symbols S_0, S_1, S_2 and S_3 and their interaction on growth and yield of beans in soil was affected by salinity. A factorial experiment (3×4) was carried out according to the randomized complete block design with three replications. Random samples were taken to test the physical and chemical properties (Table 1). The soil was divided into three blocks, each block containing 12 experimental units. Each experimental unit contains six rows (3 meters length, 0.75 m between and 0.25 m within). The bean variety planted was Luz do onito, one plant was left in each hole. Silicon was added in three batches (30, 60 and 90 days after germination). As for the control treatment, it was sprayed with distilled water only. Service operations were conducted whenever needed, ten random plants were chosen from the inner lines, to study some of growth, yield components, seeds yield. Data were analyzed using SPSS statistical program ver. 23 and the least significant difference (L.S.D) was used to compare the means at $P>0.05$.

3. Results and Discussion

3.1 Plant height

Results in Table 2 show a significant effect of potassium and silicon and their interaction on plant height, it is noted that the application of potassium at 80 kg ha^{-1} recorded the highest height (57.88 cm) by increasing 21.72%, compared to control (K_0), which recorded 47.55 cm. This increase may be due to the positive and direct role of potassium in the physiological functions in plant. It has a role in stimulating cells to divide and elongate, especially meristematic cells in the developing tops, forming good vegetative and root growth, which increases the efficiency of water and nutrients absorption [Al-Mosuly (2013)]. This agrees with Al-Duleimi *et al.* (2015). The result indicated that spraying 9 mmol Si l^{-1} gave the highest height (58.08 cm) with an increase by 6.47% compared to control. This may be due to the role of silicon in improving the mechanical strength of the stems and leaves and thus providing the best condition to intercept light radiation and increase the plant's ability to photosynthesis. This, in turn, leads to an increase in the vegetative growth of the plant. This result agrees with Abdul Qados *et al.* (2015). Interaction between $K_1 \times S_3$ recorded the highest height (67.20 cm) with an increase by 59.12% compared to K_0S_0, which gave 42.23 cm (Table 2).

3.2 Leaf area

The results from Table 2 indicate that the addition of potassium at the level of K_2 recorded the highest leaf area of 1833.02 cm^2 with an increase by 41.62% compared to control, which recorded 1294.25 cm, this increase may be attributed to the role of potassium in

Table 2: Effect of potassium application and sprayed silicon and their interaction on some growth and yield characteristics of the bean crop.

Treatment		Plant height	Leaves area	Pods No. plant^{-1}	Seeds No. pod^{-1}	100 seeds weight	Seeds yield	Biological yield
Potassium	K0	47.55	1294.25	5.70	5.042	120.25	1391.01	3757.83
	K1	57.88	1503.52	10.44	5.125	123.57	2584.36	6280.50
	K2	52.26	1833.02	10.38	5.000	119.77	2454.86	5701.41
L.S.D (P < .05)		**3.96**	**135.56**	**0.68**	**N.S**	**N.S**	**99.20**	**257.05**
Average silicon	S0	54.55	1303.40	7.94	4.789	120.41	1807.64	4533.11
	S1	50.87	1536.77	8.12	5.189	120.07	2017.15	4894.77
	S2	46.75	1446.96	8.79	5.111	118.79	2090.13	5165.77
	S3	58.08	1887.26	10.52	5.133	125.52	2658.73	6392.66
L.S.D (p<0.05)		**4.57**	**156.53**	**0.78**	**N.S**	**2.69**	**114.54**	**296.82**
K0	S0	42.23	935.25	4.73	4.500	123.68	1059.73	3069.00
	S1	42.33	1140.09	3.51	5.067	119.27	829.73	2497.00
	S2	44.00	1587.70	4.51	5.200	114.06	1062.26	2712.66
	S3	61.66	1513.98	10.06	5.400	124.00	2612.34	6752.66
K1	S0	59.66	1281.67	9.18	5.133	118.65	2173.19	5688.00
	S1	55.03	1793.14	9.65	5.533	122.81	2607.60	6112.00
	S2	49.63	1423.47	11.48	4.933	122.08	2656.40	6438.66
	S3	67.20	1515.80	11.45	4.900	130.74	2900.26	6883.33
K2	S0	61.76	1693.27	9.91	4.733	118.90	2190.00	4842.33
	S1	55.26	1677.09	11.20	4.967	118.13	2614.13	6075.33
	S2	46.63	1329.72	10.38	5.200	120.23	2551.72	6346.00
	S3	45.40	2631.99	10.05	5.100	121.82	2463.60	5542.00
L.S.D (P< 0.05)		**7.92**	**271.12**	**1.36**	**N.S**	**N.S**	**198.40**	**514.11**

increasing the division and elongation of leaf cells, regulating the osmotic effort and maintaining the inflated pressure of the cell, which is necessary to expand the cells and improve the leaf area and the formation of a deep root system to absorb the largest amount of water and nutrients and transfer them to the plant, as well as the increase in the height of the plant leads to an increase in the vegetative part of the plant and thus increases the leaf area. This result is in agreement with what was found by Al-Falahi and Abdul Kafoor (2021). Regarding to silicon, it was noticed that spraying 9 mmol Si l^{-1} recorded the highest leaf area (1887.3 cm^2) compared to 1303.40 cm^2 by the control treatment. This increase can be attributed to the fact that foliar application of silicon can increase the efficiency of the enzymatic activity and affects the epidermal cells at the angle of inclination of the leaf in a way that makes them standing, which increases the efficiency of light interception, and thus enhances the process of photosynthesis [Liang *et al*. (2015)]. This result agrees with Abdul Qados *et al.* (2015) and Abu-Muriefah (2015), while the interaction $K_2 \times S_3$ recorded the highest leaf area of 2631.99 cm^2 compared to 935.25 cm^2 obtained by using $K_0 \times S_0$.

3.3 Yield components

Application of 80 kg K ha^{-1} (K_1) recorded the highest number of pods in plant (10.98), with an increase by 72.36% compared to control, which gave 6.37 pods plant^{-1} (Table 2). This increase may be due to the role of potassium in plant growth through its contribution to the process of photosynthesis and the transmission of its products, completion of many important vital activities in the plant, which reflected positively on yield components [Taiz and Zeiger (2010)]. With regard to silicon, it is noted from Table 2 that spraying 9 mmol Si l^{-1} gave the highest number of pods per plant (10.80) with a significant increase by 35.95% compared to control, which gave 7.94 pods plant^{-1}. This increase may be due to the fact that silicon improves the activity of the photosynthesis process and the efficiency of its representation in the plant. This result agrees with Abu-Muriefah (2015) on bean plants. As for the interaction between the two factors, the combination K_1S_3 recorded a significant difference from the other interactions and gave the largest value of 13.63 pods plant^{-1} as for the interaction between the concentrations of the two elements in the above trait, it recorded a significant effect, as the interaction treatment between the concentration of silicon and the addition of potassium K_1S_3 outperformed by giving the highest value of 13.63 pods^{-1} compared to the lowest value obtained by the combination K_0S_0 which was 4.73 pods plant^{-1}.

As for the number of seeds in a pod, the results of Table 2 showed that Potassium application and sprayed plants with silicon and their interaction did not have a significant effect on this trait. Perhaps because of the principle of compensation, as the increase of one of the components will affect the other components negatively, or it may not be affected by the factor under study.

Regarding the weight of 100 seeds, the results of Table 2 indicated that the addition of potassium did not have a significant effect on this character. As for silicon, it is noted that sprayed 9 mmol Si l^{-1} recorded the highest weight of 100 seeds (125.52 g), with an increase by 4.24% compared to control, which gave 120.41 g. This increase may be due to the influential role of silicon in increasing the content of chlorophyll and the rate of photosynthesis, changing the behavior of stomata and reducing the rate of transpiration in leaves, and this means that the efficiency of photosynthesis has increased significantly and reflected positively on weight of seed. This result agrees with Abdul Qados *et al*. (2015)].

3.4 Seed yield

The data in Table 2 showed that potassium application and sprayed plants with silicon and their interaction a significant effect on the seed yield of bean plants. The highest seed yield reached to 2584.36 kg ha^{-1} by using 80 kg K ha^{-1} with an increase by 85.79% compared to control, which recorded 1391.01 kg h^{-1}. This is due to the increase that occurred in some yield components, especially the number of pods in plant (Table 2), which resulted from the role of potassium in stimulating the vital activities of the plant, which leads to an increase in vegetative growth indicators, which in turn increases the percentage of flowers and fruit set, and thus increase the yield. This result agrees with Al-Duleimi *et al.* (2015).

Spraying 9 mmol Si l^{-1} (S_3) recorded the highest seeds yield of 2658.73 kg h^{-1} compared with 1807.64 kg h^{-1} by using the control treatment with an increase by 47.08%. This increase in yield may be attributed to the role of silicon in increasing yield components (Table 2). This result agrees with Parande *et al*. (2013) on bean plants. The interaction the two treatments $K_1 \times S_3$ achieved the highest mean seed yield of 2900.26 kg ha^{-1} compared with $K_0 \times S_0$ that reached 1059.73 kg ha^{-1}.

3.5 Biological yield

The results of Table 2 showed that the addition of potassium and sprayed plants with silicon and their interaction had a significant effect on the biological yield. It is noted that the highest biological yield was obtained by using 80 kg K ha^{-1} reached to 6280.5 kg h^{-1} with an increase by 67.13% compared to control, which recorded 3757.83 kg h^{-1}, the reason for the increase in biological yield is due to the role of potassium in increasing vegetative growth (plant height and leaves area) and increasing seeds yield (Table 2). The results of Table 2 indicated that sprayed S_3 level of silicon gave the highest biological yield (6392.66 kg h^{-1}) with an increase by 41.02% compared to control which recorded 4533.11 kg h^{-1}. This result agrees with Abu-Muriefah (2015) in bean plants, as silicon has a role in increasing the vegetative growth indicators and seeds components which leads to an increase in the biological yield. As for the interaction between the two factors, the combination treatment $K_1 \times S_3$ outperformed by giving the highest biological yield (6883.33 kg h^{-1}) compared to the lowest value recorded by the combination treatment $K_0 \times S_0$, which was 3069.00 kg ha^{-1}.

4. Conclusion

From this study, we conclude that application of 80 kg K h^{-1} and spraying plants by 9 mmole l^{-1} silicon can stimulate the growth and yield of broad bean planted in saline soil.

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