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IMPACT OF FOLIAR APPLICATION OF SILICON ON SALINITY TOLERANCE OF TWO OLIVE (*Olea europaea* L.) CULTIVARS

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ABSTRACT

Salt stress is a major limiting factor for the growth and productivity of plants worldwide. This factorial experiment within a randomized complete block design with three replications was carried out to study the influence of foliar spray with three levels of silicon (K_2SiO_3) (0, 100, and 200 mg .L^{-1}) on the effect of four concentrations of water salinity (1.6 ,3 , 6 , and 9 dS/m^{-1}) in two olive (*Olea europaea* L.) cultivars (Bashiki and Shami). Most of the seedling cultivars were one-year-old. The results showed that the Bashiki cultivars were significantly better than Shami by giving the best values for the height of the seedlings, leaves number, and percentage of the mineral element. It was observed that treatment with 9 dS/m^{-1} is negatively influenced in the two varieties in vegetative properties and the percentage of N, P, K but an increase of sodium, chloride, and proline in leaves. Moreover, treatment of silicon (100 mg L^{-1}) reduced the salinity effects on the olive seedlings. The results of the interaction between the study factors showed that plants treated with the combination of (1.6 dS/m^{-1}+ silicon (100 mg L^{-1})) led to an increase in all studied trait. We found considerable differences between the two cultivars. silicon treatments can reduce the reverse effects of salinity on olive cultivars.

Keywords: Olive, Proline, Salinity, Seedling , Silicon.

Olive (*Olea europaea* L.) belongs to the Oleaceae family. It is a slow-growing tropical tree that grows for hundreds of years. The olive tree has many economic benefits. Its fruit contain a high percentage of oil, which is one of the best vegetable oils. Besides improved digestion and increased activity of the gland benefits, it also contains a low proportion of protein ranging from 5-15 % of mature fruit meat. Some industries like soap industry also depend on it(García-González *et al.,* 2009).

The olive tree withstands the harsh conditions of high temperatures and lack of moisture and grows in a variety of soil in terms of quality and fertility. It withstands light, heavy and calcareous soil with good permeability. Soil with good soil fertility and moisture content is suitable to encourage the vegetative and fruit growth of the olive tree. Olives are medium tolerant to salinity (Chartzoulakis, 2005). Soil salinity or irrigation water salinity is one of the most important problems facing agriculture on a global scale, especially in arid and semi-arid regions (Munns and Tester, 2008). Salinity causes many types of damage to developing plants in the saline medium including: obstructing the absorption of some basic elements, ionic poisoning of the cell because of the combination of high rates of sodium, chlorine, and sulfate above the energy-carrying cell of that species, lack of water absorption because of osmotic tension applied to the root of the growing plant in the high salt medium, and genotoxic toxicity, as it increases the concentration of salts in the cell cytosol to a certain extent, breaks the cell DNA and dies off (Nimbolkar *et al.,* 2020).

Salinity also affects the plant functions and shape, as the plant root system architecture, stems exhibit a stunted growth with leaf burn symptoms, the walls of the cells thicken and harden because of the salts accumulation in the cells and some compounds such as glucan, starch , and lipid grains accumulate in chloroplast and collect sodium ions in the vacuole and increase their volume, synthesis activities of IAA, SA, ABA and ethylene in plants growing under saline stress. The best way to achieve plant tolerance for salinity is to develop saline tolerant varieties. However, this aim is difficult to achieve at present because salinity is a complex characteristic controlled by multiple genes (multigenic trait) that is difficult to transfer even using plant genetic engineering techniques (Munns and Tester, 2008). So, it is necessary to use alternative technologies in this study to reduce the damage of salinity to plants, one element that appears to be used to reduce the harmful effects of salinity is the silicon component (Si). Although silicon is not a necessary element of the plant, it is one of the most important beneficial elements and has several roles in physiological processes such as improving the efficiency of photosynthesis, increase the effectiveness of the roots to absorb the elements which are necessary for plant growth, reducing the toxicity of Na^+ ions, increasing the proportion of K^+ to Na^+ , increase the effectiveness of antioxidant enzymes

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and reduce the toxicity of heavy elements (Adrees *et al.,* 2015). It also works to strengthen cell walls, leading to mechanical support of plant air parts and plant stimulation to develop some mechanisms that enable it to withstand conditions of biotic and abiotic stress, especially salt stress (Guerriero *et al.,* 2016). It also has a role in reducing transpiration from stomata and increasing the accumulation of proline, calcium ion, and chlorophyll. It helps to form an excellent thick layer of silica gel associated with cellulose cell wall epidermis which helps reduce water loss (Xiaopeng *et al.,* 2006).

This study aims to reduce the damage of salinity on the olive cultivars used in the study using the spraying of silicon and improve indicators of growth.

MATERIALS AND METHODS

A study was conducted at a greenhouse belonging to AL-Mussaib Technical College, AL-Furat Al-Awsat Technical University during the growing season, 2018 on the two olive cultivars Beshiki and Shami. One-year-old seedlings brought in from the Horticulture, and palm plantation at AL- Mahaweel, Iraq were cultivated in perforated containers, filled with 15 kg of river soil (Table 1). Seedlings were irrigated with four saline concentrations (control, 1.6, 3, 6, and 9 dS/ m^{-1}) (Table 2), using sodium chloride (NaCl) and for equal times until saturation after salting the soil in a continuous washing method for 15 days. It transports the salt water to each saline level through the soil from top to bottom until the salinity of the filtrate becomes equal to the salinity of the added solution. This shows that the solid-state of equilibrium has been reached. We sprayed the seedlings with potassium silicate (K_2SiO_3) (38% Si) with three concentrations (0, 100, 200 mg L^{-1}) in the early morning and until complete wetness levels using a hand spray with the addition of Tween 20 with 0.1% concentration with three times spraying and 20 days interval between spraying for reducing the effect of irrigation water salinity. We conducted a factorial experiment according to Randomized Complete Blocks Design (Al-Rawi and Khalaf Allah, 2000).

All data were recorded as the mean of 12 seedlings in each experimental unit during the growing stage, which included seedling height, leaves a number, leaf area (cm^2), chlorophyll content, nitrogen, phosphorus, potassium, sodium, chloride, and proline content in leaves.

RESULTS AND DISCUSSION

Height of seedling

Table 3 shows that the treatments of the (Bashiki cv.), (silicon 100 mg L^{-1}) and (salinity 3 dS/m^{-1}) significantly excelled by reporting height 111.75, 114.54, 121.62 cm, respectively, compared with the (Shami cv.), (silicon 0 mg L^{-1}) and salinity (9 dS/ m^{-1}) treatments which gave (105.37, 102.31, 86.08 cm) respectively. Bi-interaction treatments between (Bashiki +salinity 3 dS/ m^{-1}), (Bashiki +silicon 100 mg L-1) and (silicon 100 mg L^{-1} +salinity 3dS/ m^{-1}) significantly excelled the other cultivar by recording 125.11, 119.28, 128.84 cm height, respectively, compared with the (Shami + salinity 9 dS/ m^{-1}), (Shami + silicon 0 mg L^{-1}) and (silicon 0 mg L^{-1} + salinity 9 dS/ m^{-1}) treatments which gave 86.08, 100.98, 83.22 cm, respectively. While the triple-interaction treatment between (Bashiki +silicon 100 mg L^{-1} + salinity 3 dS/ m^{-1}) recorded the highest average of this trait (134.34 cm) compared with the (Shami +silicon 0 mg L^{-1} + salinity 9 dS/ m^{-1}) treatment, which gave the lowest average (80.99 cm). The superiority of Bashiki cultivar over Shami cv. may be because of differences in the genetic factors of each cultivar. While silicon had a positive role in increasing this trait and reducing salinity damage because of its contribution to the increase of anti-oxidative enzymes and the effectiveness of the root by reducing the speed of transpiration and increasing the hormones of the plant, promoting the absorption of nutrients such as Ca, K, reducing the concentration of ions Cl^-, Na^+ and increasing the proportion of K^+: Na^+ (Epstein, 2001). The salinity has a harmful effect on the height of the seedling because of the low turgor pressure of the cells and the impact of the physiological

Table 1. Some chemical and physical properties of the experiment soil.

K	P	N	O. M.	EC	pH	Texture	Sand	Silt	Clay
34.98 mg L^{-1}	1.36%	4.11%	3.31%	2.41	7.6	Sandy soil	51.3	26.2	22.5

Table 2. The chemical properties of irrigation water

EC	pH	Na^+	K^+	Cl^-	HCO_3^-	SO_4^{2-}
1.6	7.33	9.87	7.99	12.98	1.70	16.01
3	7.49	18.17	9.65	15.77	1.76	37.98
6	7.69	33.92	12.45	20. 09	2.67	65.87
9	7.92	76.48	16.01	48.89	4.98	68.87

Table 3. Effect of cultivars , silicon, salinity level and their interaction on seedling height (cm)

Cultivar	Salinity dS / m^{-1}	Silicon (mg L^{-1})			Cultivars × Salinity
		0	50	100	
Bashiki	1.6	114.85	120.99	130.11	121.98
	3	115.34	125.65	134.34	125.11
	6	98.45	113.54	119.34	110.44
	9	85.45	89.45	93.32	89.41
Shami	1.6	112.45	119.69	125.34	119.16
	3	112.98	118.11	123.34	118.14
	6	97.45	100.21	106.56	101.41
	9	80.99	83.23	83.99	82.74
L S D $_{0.05}$			4.89		3.45
Silicon Spray Medium		102.31	108.86	114.54	
L S D $_{0.05}$			1.47		Cultivars Medium
Cultivars × silicon	Bashiki	103.52	112.45	119.28	111.75
	Shami	100.98	105.31	109.81	105.37
L S D $_{0.05}$			1.99		1.73
					Salinity Medium
Salinity× silicon	1.6	113.65	120.34	127.73	120.57
	3	114.16	121.88	128.84	121.62
	6	97.95	106.88	112.95	105.93
	9	83.22	86.34	88.67	86.08
L S D $_{0.05}$			3.56		2.74

processes through the imbalance of ions and impedes the elongation and growth of seedlings and the rise of chloride causes the death of the tops of seedlings (Mass and Gratten, 1999; Jana *et al.,* 2019).

Number of leaves (leaf/seedling)

Table 4 shows significant differences between the treatments in the effect on the leaves number. The treatment of the Bashiki cv., silicon spray (100 mg L^{-1}) and salinity (1.6 dS/ m^{-1}) significantly excelled by giving 409.61, 425.20, 497.19 leaf/seedling, respectively, compared with the Shami cv., silicon 0 mg L^{-1} and salinity (9 dS/ m^{-1}) treatments which gave 398.28, 381.39, 290.16 leaf /seedling values, respectively. Bi-interaction treatment between (Bashiki + salinity 1.6 dS/ m^{-1}), (Bashiki + silicon 100 mg L^{-1}) and (salinity 1.6 dS/ m^{-1} + silicon 100 mg L^{-1}) significantly excelled by recording 503.08, 429.71, 525.66 leaf /seedling, respectively in comparison with the (Shami + salinity 9 dS/ m^{-1}), (Shami+ silicon 0 mg L^{-1}) and (salinity 9 dS/ m^{-1} +silicon 0 mg L^{-1}) treatments which gave 277.58, 375.36, 285.49 leaf/seedling), respectively. While the triple-interaction treatment between (Bashiki +silicon 100 mg L^{-1} + salinity 1.6 dS/ m^{-1}) recorded the highest average of this trait (540.44 leaf/seedling) compared with the (Shami+ silicon 100 mg L^{-1} + salinity 9 dS/m^{-1}) treatment, which gave the lowest average (271.89 leaf /seedling).

The superiority of Bashikii on Shami in the leaves number may be because of its superiority in height (Table 2). Using highly saline irrigation water led to the inhibition of the leaves number because the increase of salinity in the growth media has negative effects on the growth and development of the plant and the reduction of the value of water stress, leading to a lack of expansion of cells, and the stomata closure . It is also accompanied by a decline in the efficiency of photosynthesis process and salts lead to an imbalance in ionic and hormonal balance as lower levels of plant hormones (Srivastav, 2002).

Leaf area (cm^2/leaf)

The effect of cultivars was significant in case of the leaf area (Table 5). The maximum leaf area (116.57 cm^2) was obtained with Bashiki cultivar, while the lowest value was obtained with Shami cultivar (114.72 cm$^{2)}$.

However, the silicon treatment (50 mg L^{-1}) significantly increased in the leaf area (119.68 cm^2) compared to the treatment of control (108.51 cm^2), This can be ascribed to the role of silicon in photosynthesis by increasing the chlorophyll (a, b), photosynthesis rate,

Table 4. Effect of cultivars, silicon, salinity level and their interaction on leaves number(leaf/seedling)

Cultivar	Salinity dS / m^{-1}	Silicon(mg/l)			Cultivar × Salinity
		0	50	100	
Bashiki	1.6	468.45	500.34	540.44	503.08
	3	400.98	450.45	460.77	437.38
	6	389.73	394.28	401.76	395.26
	9	290.43	301.89	315.87	302.73
Shami	1.6	469.45	493.55	510.87	491.29
	3	390.67	440.44	500.99	444.03
	6	360.87	380.88	399.01	380.25
	9	280.54	280.32	271.89	277.58
L S D $_{0.05}$			13.64		9.78
Silicon Spray Medium		381.39	405.27	425.20	
L S D $_{0.05}$			3.99		
					Cultivars Medium
Cultivars ×silicon	Bashiki	387.39	411.74	429.71	409.61
	Shami	375.36	398.79	420.69	398.28
L S D $_{0.05}$			5.77		4.11
					Salinity Medium
Salinity× silicon	1.6	468.95	496.95	525.66	497.19
	3	395.83	445.45	480.88	440.72
	6	375.30	387.58	400.43	387.77
	9	285.49	291.11	293.88	290.16
L S D $_{0.05}$			9.71		6.98

stomatal behavior and decreasing the transpiration rate in the leaves. This means increasing photosynthesis efficiency. The angle of the leaf in a way that makes it upright and increases its objection to light, and thus the positive impact on the leaf area (Xie *et al.,* 2014), while salinity treatment 9 dS/ m^{-1} caused significant decreases in the leaf area (91.49 cm^2) compared to the treatment of salinity 1.6 dS/ m^{-1}, which was 133.18 cm^2. The bi- interactions treatment between (Shami + salinity 1.6 dS/ m^{-1}), (Shami + silicon 50 mg L^{-1}) and (salinity 1.6 dS/ m^{-1} + silicon 50 mg L^{-1}) gives 140.74, 123.80, 146.66 cm^2 compared with the (Bashiki + Salinity 9dS/ m^{-1}), (Shami + silicon 0 mg L^{-1}) and (salinity 9dS/ m^{-1} + silicon 0 mg L^{-1}) treatments which gave 88.22, 108.11, 86.28 cm^2, respectively. While the triple-interaction treatment between (Shami +silicon 50 mg L^{-1} + salinity 1.6 dS/ m^{-1}) recorded the highest average of this trait (167.76 cm^2) compared with the (Bashiki +silicon 0 mg L^{-1}+ salinity 9 dS/ m^{-1}) treatment, which gave the lowest average (80.67 cm^2). The decrease in leaf area because of high salinity levels is because of the effect of salinity on the plant's vital activities, some plant hormones, and the lack of cell filling because of the low water stress, which reduces cell filling, affects cell division and elongation (Weisman *et al.,* 2004).

Chlorophyll content in leaves (SPAD unit)

As we can see from Table 6 that Bashiki cv. caused a significant increase in chlorophyll content (74.66 SPAD unit) compared to Shami cv. (73.21 SPAD unit). The treatment of the silicon spray (100 mg L^{-1}) and salinity (1.6 dS/m^{-1}) significantly excelled by giving 79.97, 81.54 SPAD unit chlorophyll values, respectively, compared to silicon (0 mg L^{-1}) and (salinity 9 dS/ m^{-1}) treatments which gave 67.29, 61.09 SPAD unit, respectively. This increase is because silicon helps to increase the size of chloroplasts and increase the number of grana units (Suriyaprabha *et al*., 2012). Bi-interaction treatment between (Shami + salinity 3 dS/ m^{-1}), (Bashiki + silicon 100 mg L^{-1}) and (salinity 1.6 + silicon 100 mg L^{-1}) significantly excelled by recording 82.39, 80.11, 88.29 SPAD unit, respectively compared with the (Shami + Salinity 9 dS/ m-1), (Bashiki + silicon 0 mg L^{-1}) and (salinity 9 dS/m^{-1}+ silicon 0 mg L^{-1}) treatment which gave 60.73, 66.77, 54.32 SPAD unit, respectively. While the triple- interaction treatment between (Bashiki + salinity 1.6 dS/ m^{-1} + silicon 100 mg L^{-1}) recorded the highest average of this trait (88.89 SPAD unit) compared to (Shami+ silicon 0 mg L^{-1}+ salinity 9 dS /m-1) treatment, which gave the lowest average (53.76 SPAD unit). The

Table 5. Effect of cultivars, silicon, salinity level and their interaction on leaf area.

Cultivar	Salinity dS / m^{-1}	Silicon mg L^{-1}			Cultivar × Salinity
		0	50	100	
Bashiki	1.6	120.77	125.65	130.54	125.65
	3	118.87	124.89	130.11	124.62
	6	115.42	120.62	125.12	120.39
	9	80.67	91.01	92.98	88.22
Shami	1.6	122.56	167.76	131.89	140.74
	3	116.98	120.90	125.52	121.13
	6	100.98	111.89	115.87	109.55
	9	91.89	94.66	97.87	94.81
L S D $_{0.05}$			11.89		11.54
Silicon Spray Medium		108.51	119.68	118.73	
L S D $_{0.05}$			4.32		Cultivars Medium
Cultivars × silicon	Bashiki	108.93	115.54	119.69	114.72
	Shami	108.11	123.80	117.79	116.57
L S D $_{0.05}$			6.91		4.29
					Salinity Medium
Salinity× silicon	1.6	121.67	146.66	131.22	133.18
	3	117.93	122.89	127.82	122.88
	6	108.20	116.23	120.56	114.99
	9	86.28	92.84	95.38	91.49
L S D $_{0.05}$			11.49		8.71

lower chlorophyll content in olive leaves with higher salinity may be because of the lower stomata action in the gas exchange process because of the closure of the stomata which leads to a lower chlorophyll manufacturing process, or because of the toxic effect of salts in reducing the levels of chlorophyll because of the increased concentration of sodium which inhibits the activity of responsible enzymes on the composition of the chlorophyll molecule (Ben-Rouina *et al*., 2006; Zhu *et al* ,.2019).

Nitrogen content in leaves

Table 7 shows the significant differences between the treatments in respect of the effect on the nitrogen content in leaves. The treatments of the cultivar (Bashiki), (silicon 100 mg L^{-1}) and (salinity 1.6 dS/ m^{-1}) had significantly excelled by giving 0.84, 0.87, 0.96% nitrogen content, respectively, compared with the (Shami), silicon 0 mg L^{-1} and (salinity 9 dS/ m^{-1}) treatment which gave (0.83, 0.79, 0.65%) respectively. This increased N content belongs to an increase in nutrient absorption because of adding silicon (White, 2015). Bi-interaction treatment between (Bashiki + Salinity 1.6 dS/ m^{-1}), (Bashiki + silicon 100 mg L^{-1}) and (salinity 1.6 + silicon 100 mg L^{-1}) recorded the highest average of this trait - 0.97, 0.87, 0.99%, respectively, compared with the (Shami + Salinity 9 dS/ m-1), (Shami + silicon 0 mg L^{-1}) and (salinity 9 dS/ m^{-1}+ silicon 0 mg L^{-1}) treatment which gave 0.64, 0.77, 0.58%, respectively. While the triple-interaction treatment between (Bashiki + salinity 1.6 dS/ m^{-1} + silicon 100 mg L^{-1}) recorded the highest average of this trait (0.99%) compared to (Bashiki+ silicon 0 mg L^{-1} + salinity 9 dS / m^{-1}) treatment, which gave the lowest average (0.61%). The decrease in nitrogen percentage with salinity increases maybe due to the effect of salinity on the optional permeability of root cell membranes or chloride interaction with nitrates or lack of water absorption because of high osmotic pressure in the growth medium (Tester and Davenport, 2003).

Phosphorus content in leaves

Table 8 illustrates that the cultivars differed in their phosphorus content, Bashiqi cv. showed a significant increase in the phosphorus percentage in the leaves (0.29%) compared to the Shami cv. (0.23%), while the spray treatment with silicon (100 mg L^{-1}) showed a significant increase in the reduction of salinity effect (0.30%). The salinity of irrigation water (9 dS/ m^{-1}) significantly reduced P (0.17%) compared with the

Table 6. Effect of cultivars, silicon, salinity level and their interaction on chlorophyll (SPAD unit)

Cultivar	Salinity dS / m^{-1}	Silicon mg L^{-1}			Cultivar × Salinity
		0	50	100	
Bashiki	1.6	74.76	80.65	88.89	81.43
	3	70.54	79.76	87.78	79.30
	6	66.89	69.89	74.78	74.85
	9	54.87	60.65	68.99	61.50
Shami	1.6	75.65	81.56	87.69	81.80
	3	74.87	84.76	87.54	82.39
	6	67.00	69.65	75.87	70.84
	9	53.76	60.55	67.89	60.73
L S D $_{0.05}$			3.76		2.11
Silicon Spray Medium		67.29	73.46	79.97	
L S D $_{0.05}$			1.98		Cultivars Medium
Cultivars × silicon	Bashiki	66.77	72.74	80.11	73.21
	Shami	70.07	74.18	79.75	74.66
L S D $_{0.05}$			1.96		1.71
					Salinity Medium
Salinity× silicon	1.6	75.21	81.11	88.29	81.54
	3	72.71	82.23	83.16	79.37
	6	66.95	69.77	75.33	70.68
	9	54.32	60.60	68.44	61.09
L S D $_{0.05}$			1.78		1.87

Table 7. Effect of cultivars, silicon, salinity level and their interaction on N (%) in leaves

Cultivars	Salinity dS / m^{-1}	Silicon mg L^{-1}			Cultivars × Salinity
		0	50	100	
Bashiki	1.6	0.95	0.97	0.99	0.97
	3	0.89	0.90	0.94	0.91
	6	0.78	0.80	0.87	0.82
	9	0.61	0.66	0.68	0.65
Shami	1.6	0.93	0.95	0.98	0.95
	3	0.90	0.98	0.95	0.96
	6	0.70	0.74	0.79	0.74
	9	0.54	0.68	0.71	0.64
L S D $_{0.05}$			0.03		0.01
Silicon Spray Medium		0.79	0.84	0.87	
L S D $_{0.05}$			0.02		Cultivars Medium
Cultivars × silicon	Bashiki	0.81	0.83	0.87	0.84
	Shami	0.77	0.84	0.86	0.83
L S D $_{0.05}$			0.02		0.01
					Salinity Medium
Salinity× silicon	1.6	0.94	0.96	0.99	0.96
	3	0.90	0.94	0.95	0.93
	6	0.74	0.77	0.83	0.78
	9	0.58	0.67	0.70	0.65
L S D $_{0.05}$			0.02		0.1

Table 8. Effect of cultivars, silicon, salinity level and their interaction on leaf P content (%)

Cultivars	Salinity dS / m^{-1}	Silicon mg L^{-1}			Cultivars × Salinity
		0	50	100	
Bashiki	1.6	0.32	0.34	0.36	0.34
	3	0.30	0.35	0.36	0.33
	6	0.27	0.28	0.30	0.29
	9	0.18	0.19	0.21	0.19
Shami	1.6	0.31	0.37	0.39	0.36
	3	0.30	0.37	0.37	0.35
	6	0.26	0.28	0.29	0.27
	9	0.10	0.14	0.16	0.13
L S D $_{0.05}$			0.09		0.04
Silicon Spray Medium		0.26	0.29	0.30	
L S D $_{0.05}$			0.05		Cultivars Medium
Cultivars × silicon	Bashiki	0.27	0.29	0.30	0.29
	Shami	0.24	0.29	0.31	0.23
L S D $_{0.05}$			0.05		0.04
					Salinity Medium
Salinity× silicon	1.6	0.32	0.36	0.38	0.35
	3	0.30	0.36	0.37	0.35
	6	0.27	0.28	0.30	0.28
	9	0.14	0.17	0.19	0.17
L S D $_{0.05}$			0.06		0.04

salinity treatment (1.6 and 3 dS/ m^{-1}) which recorded an increase of P (0.35%). However, bi-interaction treatment between (Shami + Salinity 1.6 dS/ m^{-1}), (Shami + silicon 100 mg L^{-1}) and (salinity 1.6 + silicon 100 mg L^{-1}) recorded the highest average of this trait (0.36, 0.31, 0.38%) respectively , compared with the (Shami + Salinity 9 dS/ m^{-1}), (Shami + silicon 0 mg L^{-1}) and (salinity 9 dS/ m^{-1}+ silicon 0 mg L^{-1}) treatment which gave 0.13, 0.24, 0.14%, respectively. While the triple-interaction treatment between (Shami + salinity 1.6 dS/ m^{-1} + silicon 100 mg L^{-1}) recorded the highest average of this trait(0.39%) compared to (Shami+ silicon 0 mg L^{-1} + salinity 9 dS / m^{-1}) treatment, which gave the lowest average (0.10%). The difference in the percentage of phosphorus between cultivars may be because of difference in genotypes with respect to their P leaf content, increased electrophoresis, the expulsion of harmful ions, or an effective mechanical mechanism that excludes sodium ion and chlorine in absorption by roots, role of silicon in the increase of anti-oxidative enzymes, the effectiveness of the total root and reduced speed of transpiration besides the increase of hormones and low proportion of phosphorus with the high salinity in irrigation water because of the high osmosis and the effect of ionic chloride and sodium, which obstruct the movement of elements necessary for the plant, including phosphorus. (Gratten and Grieve, 1999).

Potassium content in leaves

Table 9 shows that the treatment of the (Bashiki), (silicon 100 mg L^{-1}) and (salinity 1.6 dS/ m^{-1}) significantly excelled by giving K content of 0.61, 0.63, 0.78%, respectively, compared with (Sahmi), (silicon 0 mg L^{-1}) and (salinity 9 dS/ m^{-1}) treatment which gave 0.57, 0.55, 0.29%, respectively. This increase in K content can be due to the role of silicon in increasing the absorption of potassium by activating the potassium ion load across the plasma membrane because of increased electrical stress gradient because of increased activity of the enzyme H-ATPase (Laing *et al.,* 2006). Bi- interactions between the study factors (Bashiki + salinity 1.6 dS/ m^{-1}) (Bashiki + silicon 100 mg L^{-1}) and (salinity 1.6 + silicon 100 mg L^{-1}) recorded the highest average of this trait (0.82, 0.66, 0.84%, respectively), compared with the (Shami + Salinity 9 dS/ m^{-1}), (Shami + silicon 0 mg L^{-1}) and (salinity 9 dS/ m^{-1}+ silicon 0 mg L^{-1}) treatments which gave 0.31, 0.53, 0.26% K content, respectively. While the triple-interaction treatment between (Bashiki + silicon 100 mg L^{-1} + salinity 1.6 dS/ m^{-1}) recorded the highest average of this trait (0.86%) compared to (Shami+ silicon 0 mg L^{-1} + salinity 9 dS / m^{-1}) treatment, which gave the lowest average (0.29). The reason for the decrease in potassium can be ascribed to the competition between potassium and sodium on the absorption sites because of the ionic effect of the sodium element in the plants which are growing in the saline medium. When the Na concentration is high within the cell or because of the increase of the osmosis stress (because of the increased salinity) in the root region it inhibits the absorption of potassium (Marschner, 2012).

Sodium content in leaves

The result in Table 10 showed that Shami cv. gave highest Na content in leaves (0.49%) superior to Bashiki (0.48%), while the spray treatments (silicon 50 and 100 mg L^{-1}) gave (0.48%) less than from (control 0.51%), Silicon reduces Na absorption by roots and its transportation to leaves (Tahir *et al.,* 2006). Salinity treatment (9 dS/ m^{-1}) significantly increased Na to 0.71% in comparison with the salinity treatment of (1.6 dS/ m^{-1}) which recorded 0.31%. Bi-interactions between the study factors (Bashiki + salinity 9 dS/ m^{-1}) (Shami + silicon 0 mg L^{-1}) and (salinity 9 + silicon 0 mg L^{-1}) recorded the highest average of this trait (0.75, 0.52, 0.74%, respectively), compared with the (Bashiki + Salinity 1.6 dS/ m^{-1}), (Bashiki + silicon 100 mgL^{-1}) and (salinity 1.6 dS/ m^{-1}+ silicon 100 mg L^{-1}) treatments which gave 0.31, 0.46, 0.30% leaf Na content, respectively. While the triple-interaction treatment between (Bashiki + silicon 0 mgL^{-1} + salinity 9 dS/ m^{-1}) recorded the highest average of this trait (0.76%) compared to (Bashiki+ silicon 100 mgL^{-1}+ salinity 1.6 dS / m^{-1}) and (Shami+ silicon 100 mgL^{-1}+ salinity 1.6 dS / m^{-1}) treatment which gave the lowest average (0.30). The increase in sodium percentage in the leaves with increased concentration of salinity may be because of the increase of its concentration in irrigation water and increased flow to the roots, which led to the increase in the concentration of leaves (Amin *et al.,* 2020).

Chloride content in leaves

Table 11 illustrates that the cultivars differed in their chloride content, Bashiki cv. showed a significant increase in the chloride percentage in the leaves (2.92%) compared to the Shami cv. (2.63%), whereas the spray treatment of 100 mg L^{-1} silicon reduced chlorine to 2.58% compared to the control treatment which increased chlorine to 2.93%. Salinity (9 dS/ m^{-1}) recorded more increase in chlorine (4.19%) compared to the treatment of (control 1.6 dS/ m^{-1}) ,which had 1.44% level.

Bi-interactions between the study factors (Bashiki + salinity 9 dS/ m^{-1}) (Shami + silicon 0 mgL^{-1}) and (salinity 9 + silicon 0 mgL^{-1}) recorded the highest average of this

Table 9. Effect of cultivars, silicon, salinity level and their interaction on K% in leaves

Cultivar	Salinity dS / m^{-1}	Silicon mgL^{-1} 0	50	100	Cultivar × Salinity
Bashiki	1.6	0.78	0.81	0.86	0.82
	3	0.73	0.74	0.79	0.75
	6	0.53	0.60	0.66	0.60
	9	0.23	0.28	0.31	0.27
Shami	1.6	0.72	0.75	0.81	0.76
	3	0.69	0.75	0.79	0.74
	6	0.43	0.48	0.52	0.48
	9	0.29	0.30	0.33	0.31
L S D $_{0.05}$			0.08		0.04
Silicon Spray Medium		0.55	0.59	0.63	
L S D $_{0.05}$			0.04		Cultivars Medium
Cultivars × silicon	Bashiki	0.57	0.61	0.66	0.61
	Shami	0.53	0.57	0.61	0.57
L S D $_{0.05}$			0.04		0.04
					Salinity Medium
Salinity× silicon	1.6	0.72	0.78	0.84	0.78
	3	0.71	0.75	0.79	0.75
	6	0.32	0.54	0.59	0.48
	9	0.26	0.29	0.32	0.29
L S D $_{0.05}$			0.04		0.04

Table 10. Effect of cultivars, silicon, salinity level and their interaction on Na (%) in leaves

Cultivars	Salinity dS / m^{-1}	Silicon mgL^{-1}			Cultivars × Salinity
		0	50	100	
Bashiki	1.6	0.32	0.31	0.30	0.31
	3	0.39	0.38	0.34	0.37
	6	0.54	0.50	0.47	0.50
	9	0.76	0.74	0.74	0.75
Shami	1.6	0.33	0.31	0.30	0.31
	3	0.48	0.44	0.43	0.45
	6	0.56	0.51	0.50	0.52
	9	0.72	0.65	0.63	0.67
L S D $_{0.05}$			0.10		0.04
Silicon Spray Medium		0.51	0.48	0.48	
L S D $_{0.05}$			0.04		Cultivars Medium
Cultivars × silicon	Bashiki	0.50	0.48	0.46	0.48
	Shami	0.52	0.48	0.47	0.49
L S D $_{0.05}$			0.08		0.04
					Salinity Medium
Salinity× silicon	1.6	0.33	0.31	0.30	0.31
	3	0.44	0.41	0.39	0.41
	6	0.55	0.51	0.49	0.52
	9	0.74	0.70	0.69	0.71
L S D $_{0.05}$			0.08		0.04

Table 11. Effect of cultivars, silicon, salinity level and their interaction on Cl (%) in leaves

Cultivar	Salinity dS / m^{-1}	Silicon mgL^{-1}			Cultivar × Salinity
		0	50	100	
Bashiki	1.6	1.16	1.16	1.01	1.11
	3	2.11	2.00	1.99	2.03
	6	3.45	2.89	2.65	2.99
	9	4.58	4.56	3.99	4.38
Shami	1.6	1.89	1.77	1.65	1.77
	3	2.77	2.70	2.59	2.69
	6	3.33	3.30	2.98	3.20
	9	4.12	4.10	3.78	4.00
L S D $_{0.05}$			0.11		0.05
Silicon Spray Medium		2.93	2.81	2.58	
L S D $_{0.05}$			0.05		Cultivars Medium
Cultivars × Silicon	Bashiki	2.83	2.65	2.41	2.63
	Shami	3.03	2.97	2.75	2.92
L S D $_{0.05}$			0.04		0.05
					Salinity Medium
Salinity× silicon	1.6	1.53	1.47	1.33	1.44
	3	2.44	2.35	2.29	2.36
	6	3.11	3.10	2.82	3.01
	9	4.35	4.33	3.89	4.19
L S D $_{0.05}$			0.04		0.05

trait (4.38, 3.03, 4.35%, respectively) , compared with the (Bashiki + Salinity 1.6 dS/ m^{-1}) , (Bashiki + silicon 100 mgL^{-1}) and (salinity 1.6 dS/ m^{-1}+ silicon 100 mgL^{-1}) treatments (1.11, 2.411.33%, respectively) . While the triple-interaction treatment between (Bashiki + silicon 0 mgL^{-1} + salinity 9 dS/ m^{-1}) recorded the highest average of this trait (4.58%) compared to (Shami+ silicon 100 mg L^{-1} + salinity 1.6 dS / m^{-1}) treatment which gave the lowest average (1.01%). The increase in chlorine with the increase in salinity levels may be due to increased salinity in the growth medium, which leads to absorption and accumulation in the leaves. Saline conditions lead to increased concentration of chlorine in the root area, which causes a decrease in nutrient absorption and low permeability (Tattini *et al*., 1995).

Proline content in leaves (µg /g f.wt)

Table 12 shows that the treatments of the (Shami cv.) , (silicon 0 mgL^{-1}) and (salinity 9 dS/ m^{-1}) performed significantly better by giving proline content values of 0.59 , 0.65 , 1.24 µg /g f.wt, respectively, compared with the Bashiki , (silicon 100 mgL^{-1}) and (salinity 1.6 dS/ m^{-1}) treatment which gave 0.54, 0.50, 0.10 µg /g f.wt , respectively .The reason for the decrease in proline with silicon addition can be due to the role of silicon in increasing the enzymatic and non-enzymatic antioxidants, which reduce the impact of damage caused by the increase of oxygenated compounds (ROS), and less proline is accumulated when silicon is added to treatments (Carloset *et al.,* 2009; Yue *et al.*,2019).

Bi-interaction treatment between (Bashiki + salinity 9 dS/ m^{-1}) ,(Shami+ silicon 0 mgL^{-1}) and (Salinity 9 dS/ m^{-1} +silicon 0 mgL^{-1}) was significantly better (1.44, 0.66, 1.57 µg /g f.wt) respectively, compared with the (Bashiki + salinity 1.6 dS/ m^{-1}) ,(Bashiki+ silicon 100 mgL^{-1}) and (salinity 1.6 dS/ m^{-1} +silicon 50 mgL^{-1}) treatments which gave 0.10, 0.47, 0.05 µg /g f. wt proline levels, respectively . While the triple- interaction treatment between (Bashiki +silicon 0 mgL^{-1}+ salinity 9 dS/ m^{-1}) recorded the highest average of proline (1.59 µg /g f.wt) compared with the (Bashiki+ silicon 100 mgL^{-1}+ salinity 1.6 ds/ m^{-1}) treatment which gave the lowest average (0.07 µg /g f. wt). The increase of proline by increasing salinity can be due to the speed of construction and lack of use, which increases the speed of accumulation as well as inhibits the effectiveness of enzymes oxidation of the proline and increases the demolition and transition of protein to amino acids. Proline regulates the oxidation of the plant tissues or cells and reduces the ionic effect resulting from the salt stress and contributes to the restriction of the toxic elements absorbed under saline conditions and the accumulation of proline in the plant (Ashraf and Foolad, 2007; Hong-Bo *et al* ., 2006).

Table 12. Effect of cultivars, silicon, salinity level and their interaction on Proline(µg /g f.wt) in leaves

Cultivar	Salinity dS / m^{-1}	Silicon mgL^{-1}			Cultivar × Salinity
		0	50	100	
Bashiki	1.6	0.15	0.09	0.07	0.10
	3	0.21	0.11	0.10	0.14
	6	0.59	0.44	0.43	0.49
	9	1.59	1.43	1.29	1.44
Shami	1.6	0.14	0.13	0.12	0.13
	3	0.32	0.31	0.29	0.31
	6	0.62	0.53	0.45	0.53
	9	1.54	1.44	1.22	1.40
L S D $_{0.05}$			0.03		0.02
Silicon Spray Medium		0.65	0.56	0.50	
L S D $_{0.05}$			0.02		Cultivars Medium
Cultivars × silicon	Bashiki	0.64	0.52	0.47	0.54
	Shami	0.66	0.60	0.52	0.59
L S D $_{0.05}$			0.01		0.02
					Salinity Medium
Salinity× silicon	1.6	0.15	0.05	0.10	0.10
	3	0.27	0.21	0.20	0.23
	6	0.61	0.49	0.44	0.51
	9	1.57	1.44	0.71	1.24
L S D $_{0.05}$			0.01		0.02

Overall, the results showed that Bashiki cv. is more resistant to salinity than Shami cv. because of genetic differences. Salinity of irrigation water 9 dS/ m^{-1} has a negative role in influencing the growth indicators because of the salinity of the soil or irrigation water. The foliar application with silicon (100 mg L^{-1}) reduced the negative effects of salinity because of its contribution to the increase of anti-oxidative enzymes, increasing the effectiveness of the root mass and reducing the speed of transpiration and increased plant hormones which promote the absorption of nutrients. We conclude from the study that the olive plant is a medium tolerant of salinity.

Authors' contribution

Conceptualization of research work and designing of experiments (HHA,IMR; Execution of field/lab experiments and data collection (HHA,IMR) ; Analysis of data and interpretation (IMR,HHA (; Preparation of manuscript (HHA)

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