Journal of Agricultural Science; Vol. 6, No. 10; 2014
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Effect of K^+ and Salicylic Acid on Broccoli (*Brassica oleraceae* var. *Italica*) Plants Grown Under Saline Water Irrigation

Zohair Mahmoud Mirdad[1]

[1] Department of Arid Land Agriculture, Faculty of Meteorology, Environment, and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia

Correspondence: Zohair Mahmoud Mirdad, Department of Arid Land Agriculture, Faculty of Meteorology, Environment, and Arid Land Agriculture, King Abdulaziz University, P. O. Box 6551, Jeddah 21452, Saudi Arabia. Fax: 966-12-688-5612. E-mail: zmirdad1@yahoo.com

Received: June 3, 2014 Accepted: July 23, 2014 Online Published: September 15, 2014

doi:10.5539/jas.v6n10p57 URL: http://dx.doi.org/10.5539/jas.v6n10p57

Abstract

High salinity affects plant growth and productivity of most vegetable crops through osmotic effects which inhibition of water uptake by roots or specific ion effects and causes toxicity of salt ions, as well as changes in soil physical and chemical properties causing a decrease in the growth of the roots and plants. This research conducted to improve the agricultural practices of broccoli production by using the K^+ and salicylic acid (SA); which will contribute to overcome the deleterious effect of salinity stress. The results of this study showed that broccoli plants grown under saline water that receiving K^+ at concentration 1000 mg l^{-1} as foliar application were recorded minimum the deleterious impacts of salinity stress and achieved maximum plant height, number of leaves and branches, leaf area per plant, the main, secondary and total curd yield (t ha^{-1}) and water use efficiency (WUE) over control treatment. Furthermore, the curd diameter (of main and secondary), curd weight (of main, secondary and plant) dry matter percentage of the curds and the leaf and curd mineral contents (N, P and K%) were improved with foliar application of K up to 1000 mg l^{-1}. Moreover, the vegetative growth, cruds yield and its quality, WUE and leaf and crud mineral contents of broccoli plants irrigated with saline water increased significantly and successively as the SA concentration was increased up to 200 mg l^{-1}. The combined foliar application of 1000 mg l^{-1} K^+ with salicylic acid at 200 mg l^{-1} as a dernch and foliar application is the most efficient combination treatment, which gave the best results to alleviate the deleterious impact of salinity stress on the vegetative growth, curd yield and its quality characters, leaf and curds chemical contents of broccoli plants irrigated with saline water.

Keywords: curd yield of broccoli, growth, potassium, salicylic acid, saline water, water use efficiency

1. Introduction

Broccoli (*Brassica oleraceae* var. *Italica*) is grown for its edible curd, which has become a popular item in the kitchen because of its high nutritive and medicinal values (Feher, 1986). Where, it is a good source of vitamins (A, B_1, B_2, B_5, B_6, C, E and folic acid), minerals (Ca, Mg, Zn, and Fe), carotenoids, fiber, and antioxidant substances, which prevent the formation of cancer causing agents (Beecher, 1994; Michaud et al., 2002). Eating more than one serving of broccoli a week reduces the risk of prostate cancer by up to 45% (Gad & Abd El-Moez, 2011). Therefore, it is fast becoming an important fresh market and processing vegetable crops in many parts of the world (Morelock et al., 1982).

In Saudi Arabia, high temperatures, low quality of irrigation water and soil salinity are major limiting factors in sustaining and increasing vegetable productivity. Whereas, hot and dry environment, high evapotranspiration results in substantial water loss, thus leaving salt around the plant roots which interfere with the plant's ability to uptake water particularly with the drip irrigation system. High salinity affects plant growth and productivity of vegetable crops through osmotic effects (Yamaguchi & Blumwald, 2005), which inhibition of water uptake by roots or specific ion effects (Yildirim et al., 2008). Addition, salinity imposes causes toxicity of salt ions, and changes in soil physical and chemical properties (Keren, 2004), as well as causing an imbalance of nutritional cations in plant tissues resulting from altered K^+/Na^+ ratios (Gad, 2005) and leads to a buildup in Na^+ and Cl^- concentrations that are detrimental to plants (Yamaguchi & Blumwald 2005). Where, salinity has been shown to affect the directly nutrient uptake as Na^+ reducing K^+ and Ca^{2+} uptake (Yildirim et al., 2006) or by Cl^- a reducing

$NO3^-$ uptake (Halperin et al., 2003). One of the effective practices to mitigate the deleterious effects of salinity stresses and inducing salt tolerance in many crops under arid region conditions is the use of salicylic acid (El-Tayeb, 2005; Gunes et al., 2005; Stevens et al., 2006) and potassium (Yildirim et al., 2009; Khan et al., 2013) as a foliar application through their contribution in alleviating Na^+ and Cl^- injury.

Potassium is one of the essential elements in the nutrition of the plant. However, under the salinity stress, metabolic toxicity of Na is largely due to its ability to compete with K for binding site essential for cellular function (Bhandal & Malik, 1988). Many studies have revealed that K^+ alleviates the adverse effects of salinity on plant growth by regulating the desirable K/Na ratio (Marschner, 1995). Whereas, a K^+ foliar application improved nutrient status causing increases in salt tolerance of different plants (El-Fouly et al., 2002; Safaa et al., 2013) by enhancing the biosynthesis of organic metabolites and improving nutritional status (Fathy et al., 2009). Yildirim et al. (2009) reported that the highest alleviation effect of foliar nutrient application at 40 mM salinity stress was observed for 10 mM KNO_3; resulting in an increase in plant root dry weight (50%), shoot dry weight (50%) of strawberry plants. Potassium in plants is necessary to increase the efficiency of photosynthesis and use of water (Rose, 2001). Moreover, K^+ plays an important role in the synthesis of amino acid and protein as well as translocation of sugars and assimilates within the plant and the accumulation of high molecular carbohydrates (Yagodin 1982; Archer, 1985). In addition, it has activate the enzymes involved in biosynthesis of organic acids (Evans & Sorger, 1996), as well as accelerating translocation of carbohydrate necessary for fruit formation and development (Marschner, 1986) which leads to increase plant growth and yield.

Using salicylic acid (SA) can as an active practice to facilitate the plant growth (Yildirim et al., 2008), where it play an important role in alleviating the deleterious effects of several environmental stresses on plants and which ones high temperature, drought (Singh & Usha, 2003; Shi et al., 2006) and salinity (Yildirim et al., 2008) stresses. Raskin et al. (1990) reported that SA is synthesized by many plants and accumulated in the plant tissues under the impact of unfavorable abiotic factors and contributing to the increase of plant resistance to salinization (Kang & Saltveit, 2002). Where, SA is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plants (Karlidag et al., 2009). Many researchers clarified several beneficial effects of SA under abiotic stress conditions such as; can it play a significant role in plant water relations (Barkosky & Einhelling, 1993), photosynthesis, growth rate and stomatal regulation (Khan et al., 2003; Arfan et al., 2007), as well as ion uptake and transport (Gunes et al., 2005) and membrane permeability (Barkosky & Einhellig, 1993). Where, Farahbakhsh and Shamsaddin Saiid (2011) concluded that the positive reaction of the SA application under saline conditions on plant growth may be due to the chemical changes in plants throughout avoiding the uptake of toxic ions Na^+ and Cl^- and enhancing the uptakes of NO_3^-, Mg^{2+}, Fe^{2+}, Mn^{2+}, and Cu^{2+}. Because of multiple roles of SA, it can greatly benefit plant growth under some environmental stresses including high temperature and drought on cucumber, bean, tomato and wheat (Singh & Usha, 2003; Senaratna et al., 2000; Shi et al., 2006), as well as salinity on tomato, maize and violet (Stevens et al., 2006; Farahbakhsh & Shamsaddin Saiid, 2011; Hussain et al., 2011). However, Salehi et al. (2011) stated that the effects of SA on physiological processes of plants depend on its concentration, type of plant, the stage of plant growth and environmental conditions.

This work conducted to minimize the deleterious impacts of salinity stress on broccoli (cv. Emperor) plants grown under saline water by using foliar application of salicylic acid and potassium.

2. Materials and Methods

This study was carried out at Agricultural Experiment Station, Hada-Alsham, King Abdulaziz University, Saudi Arabia, during the agriculture season of 2012/2013. The experiment included 9 treatments and repeated three times, which were the combinations concentrations of three potassium (K^+) and three salicylic acid (SA; 2-hydroxybenzoic acid).

2.1 Soil and Irrigation Water Analysis

Before the beginning of the trial, physical and chemical properties of the experimental site soil (0 – 30 cm) were estimated according to the published procedures by (Page et al., 1982). The soil texture is sandy (92.1% sand, 5.9% silt and 2.0% clay) with pH = 8.1, EC = 3.72 dS m^{-1} and organic matter = 0.03%. Available soil N, P and K were 19, 8 and 17 mg/kg, respectively. Chemical properties of irrigation water, which obtained from a local well, were measured (Page et al., 1982). The irrigation water had an EC value of 4.23 dS m^{-1}, and contained Na = 0.49, Mg = 0.32, Ca = 6.18, HCO_3 = 0.69, Cl = 1.48 and SO_4 = 6.63 meq l^{-1}.

2.2 Experimental Design

The experimental design used was the split-plot system in randomized complete blocks design with three replications. The potassium concentrations were, randomly, arranged in the main plots, while three SA concentrations were, randomly, distributed in the sub-plots. Each sub-plot contained two rows having an area of 16 m^2. Broccoli (cv. Emperor) seedlings were transplanted into the soil on 14 December 2012. The row spacing was 50 cm between the seedlings and 120 cm between the rows. Each sub-plot contained 32 plants. SA solutions at rates; 0, 100, 200 mg l^{-1} and K^+ (potassium sulphate; K_2SO_4) solutions at rate; 0, 500 and 1000 mg l^{-1}, were sprayed on the shoots of broccoli plant at three times, starting from 3th week after transplanting, during late afternoon hours with 10 days intervals using a hand-held sprayer until dripping, with a held atomizer. Moreover, the same concentrations of SA solutions were applied three times, at 10-day intervals, as a drench to the plant root area at rate 0.1 l per plant, starting from the 2nd week after transplanting (Senaratna et al., 2000; Stevens et al., 2006). The control plants were treated with tap water.

2.3 Irrigation and Fertilization

The actual evapotranspiration of broccoli plant (ET_c), under Hada-Alsham region conditions, was calculated and adjusted at the beginning of each growth stage (Table 1) by multiplying reference evapotranspiration (ET_0) for different months of the growing season (November, 2012 – May, 2013) by a crop coefficient (K_C), $ET_c = ET_0 \times K_C$, as indicated in Allen et al. (1998). The drip irrigation system consisted of laterals GR of 16 mm in diameter with drippers at 0.5 m distance. The drippers had a discharge rate 4 l h^{-1}. Irrigation water was applied every alternate day, to maintain soil moisture above 50% soil moisture depletion, according to Qassim and Ashcroft (2002), which is the optimum level of broccoli plants.

Table 1. Length of the growth stages, crop coefficients (K_c), reference evapotranspiration (ET_0) and water requirements of broccoli crop (ET_c), at Hada-Alsham region conditions, Saudi Arabia

Growth stages	Initiation	Vegetative	Curds formation
Number of days per stage	25	40	55
Crop Coefficients (K_C)	0.7	0.82	1.0
Reference evapotranspiration (ET_0) mm day^{-1}	4.6	5.8	6.1
Water requirements of broccoli crop (ET_c) mm day^{-1}	3.22	4.76	6.1
Total water requirements per growth stage	80.5	190.2	335.5

The urea (46%) at rate 120 kg N ha^{-1}, phosphoric acid (85%) at rate 100 kg P_2O_5 ha^{-1} and potassium sulphate (48.5%) at rate 100 kg K_2O ha^{-1} biweekly fertigated in 24 equal doses, started in 2nd week and continued until 14th week .The fertilizers were injected directly into the irrigation water using a venture - type injector.

All agricultural practices were done as commonly followed in the commercial production of broccoli in the drip irrigation system. The average temperature and relative air humidity throughout broccoli growth stages at Hada-Alsham region conditions, Saudi Arabia are shown in Table 2.

Table 2. Average temperatures and humidity during the growing season of broccoli crop at Hada-Alsham region conditions, Saudi Arabia

Month	Temperature			Humidity		
	Min.	Max.	Mean	Min.	Max.	Mean
December	18.7	30.5	24.4	50.9	90.1	68.2
January	16.2	27.1	21.6	57.9	93.7	73.0
February	19.0	31.0	24.8	35.7	83.3	59.0
March	18.4	31.5	24.8	29.9	73.1	50.5
April	21.7	36.3	28.9	24.2	69.2	44.6

2.4 Data Recorded

In each sub-plot, the first row was allocated to measuring the vegetative growth characters that included plant height, number of branches and leaves, and leaf area (cm^2), with initiation of main curd of 25% broccoli plants.

The second row was saved to determine the main, secondary and total curds yield and its quality characters; curd diameter, curd weight and curd dry matter percentage. The leaf and curds contents of N, P and K were estimated as described in Cottenie (1980). Water-use efficiency (WUE kg m^{-3}) was calculated by dividing total curds yield (kg ha^{-1}) of broccoli by total irrigation water applied (6060.2 m^3 ha^{-1}) throughout the growing season.

2.5 Statistical Analysis

All obtained data of the present study were individually subjected to the analysis of variance techniques according to the design used by the MSTAT–C computer software program (Freed & Scott, 1989). The comparisons among means of the different treatments were carried out by using the revised LSD test at ($P<0.05$).

3. Results

3.1 Vegetative Growth

Broccoli plants grown under saline water that receiving K^+ at concentration 1000 mg l^{-1} as foliar application were recorded minimum the deleterious impacts of salinity stress and achieved maximum plant height, number of leaves and branches, and leaf area per plant followed by plants receiving 500 mg l^{-1} K^+ and control treatments, respectively (Table 3).

Increasing the salicylic acid (SA) level up to 200 mg l^{-1} that was supplied as foliar and drench application lead to a significant progressive increasing in plant height, number of leaves and branches, and leaf area per plant over control treatment of broccoli plants irrigated with saline water.

The interaction effects of K^+ and SA concentrations on the vegetative growth traits of broccoli were significant (Table 3). Increasing the SA concentration up to 200 mg l^{-1} within any K+ rate, generally, increased plant height, number of leaves and branches, and leaf area per plant. Spraying broccoli plants grown under salinity stress with K^+ at rate 1000 mg l^{-1} + SA at rate 200 mg l^{-1} can be considered the best combined treatment, where achieved higher values of all studied vegetative growth characters.

Table 3. Effect of potassium and salicylic acid (SA) concentration and its interaction on the plant height, number of leaves and branches and leaf area of broccoli plants grown under saline water

Treatments		Plant height (cm)	No. leaves/plant	No. branches/plant	Leaf area (cm^2)
K_2O (mg/l)	SA (mg/l)				
0		33.4C*	20.1C	6.9C	455.41C
500		36.1B	36.1B	8.2B	532.84B
1000		39.7A	39.7A	9.4A	579.73A
	0	32.7C	16.9B	7.1C	461.50C
	100	36.1B	19.1A	8.2B	541.22B
	200	40.3A	21.7A	9.2A	565.26A
	0	31.5e	15.3g	6.3e	367.86i
0	100	33.7cd	21.3f	7.2de	477.84h
	200	34.9c	23.7e	7.3cde	520.53f
	0	32.9de	21.2f	7.5cde	480.40g
500	100	34.8c	25.4cd	8.1bcd	551.80d
	200	40.6b	26.1bc	8.9bc	566.31c
	0	33.8cd	24.2de	7.6b-e	536.24e
1000	100	39.8b	27.4ab	9.2b	594.02b
	200	45.4a	28.1a	11.3a	608.94a

*Values having the same alphabetical letter in common do not significantly differ at $P<0.05$.

3.2 Curds Yield and Water Use Efficiency (WUE)

Data of Table 4 illustrated that, increasing the spraying rate of K^+ up to 1000 mg l^{-1} significantly increased the main, secondary and total curds yield (t ha^{-1}) by 59.7, 202.4 and 109.8%, respectively, over the broccoli plants irrigated with saline water only (Table 4). Moreover, broccoli plants that treated with 1000 mg l^{-1} of K^+ achieved significantly higher WUS (109.8%) over control treatment.

Table 4. Effect of potassium and salicylic acid (SA) concentration and its interaction on the number of main, secondary and total curds yield per hectare as well as the water use efficiency of broccoli plants grown under saline water

Treatments		Main curds yield (t/ha)	Relative value	Secondary curds yield (t/ha)	Relative value	Total curds yield (t/ha)	Relative value	Water use efficiency (kg/m^3)	Relative value
K_2O (mg/l)	SA (mg/l)								
0		4.62C*	100.00	2.51C	100.00	7.13C	100.00	1.18C	100.0
500		6.67B	144.37	4.63B	184.46	11.30B	158.49	1.86B	157.6
1000		7.38A	159.74	7.59A	302.39	14.96A	209.82	2.47A	209.3
	0	5.07B	100.00	2.72C	100.00	7.79C	100.00	1.29C	100.0
	100	6.53A	128.80	5.17B	190.07	11.70B	150.19	1.93B	149.6
	200	7.07A	139.45	6.44A	236.76	13.50A	173.30	2.23A	172.9
	0	4.23cd	100.00	1.39f	100.00	5.61g	100.00	0.93g	100.0
0	100	4.70c	111.11	3.03e	217.99	7.74f	137.97	1.28f	137.6
	200	4.93c	116.55	3.34e	240.29	8.27f	147.42	1.36f	146.2
	0	4.89c	115.60	3.12e	224.46	8.00f	142.60	1.32f	141.9
500	100	7.30ab	172.58	4.95cd	356.12	12.26d	218.54	2.02d	217.2
	200	7.82a	184.87	5.93c	426.62	13.75c	245.10	2.27c	244.1
	0	6.10bc	144.21	3.98de	286.33	10.08e	179.68	1.66e	178.5
1000	100	7.58a	179.20	8.14b	585.61	15.72b	280.21	2.59b	278.5
	200	8.45a	199.76	11.11a	799.28	19.55a	348.48	3.23a	347.3

*Values having the same alphabetical letter in common do not significantly differ at $P<0.05$.

Broccoli plants receiving SA at rate 200 mg l^{-1} recorded significantly higher the main, secondary and total curds yield (t ha^{-1}) as well as WUE (kg m^{-3}) with an increase of 39.5, 136.8, 73.3 and 73.3 %, respectively, over the broccoli plants irrigated with saline only.

The interaction effects of the K^+ and SA concentrations on curds yield ha^{-1} and WUE of broccoli plants grown under salinity stress, showed much significantly variation (Table 4). Broccoli plants that sprayed with any K^+ concentration, increasing foliar and drench application level of SA up to 200 mg l^{-1}, led to increase the main, secondary and total curds yield (t ha^{-1}) as well as WUE (kg m^{-3}). Broccoli plants receiving K^+ (1000 mg l^{-1}) + 200 mg l^{-1} of SA, gave the highest main, secondary and total curds yield (t ha^{-1}) as well as WUE. The increases in main, secondary and total curds yield (t ha^{-1}) as well as WUE were 99.7, 699.3, 248.5 and 247.3%, respectively, over the control treatment.

3.3 The Number of Curds and Curds Quality

Foliar application of K^+ had a significant effect on the number of curds per plant and all recorded curds quality characteristics; curd diameter (of main and secondary), curd weight (of main, secondary and plant) and dry matter percentage of curds (Table 5). Increasing the concentration of K^+ up to 1000 mg l^{-1} was accompanied with corresponding significant increases in the number of curds per plant, curd diameter (of main and secondary), curd weight (of main, secondary and plant) and dry matter percentage of curds.

Table 5. Effect of potassium and salicylic acid (SA) concentrations and its interaction on the number of curds per plant and curd quality characters of broccoli plants grown under saline water

Treatments		No. curds/plant	Curd diameter (cm)		Curd weight (g)			Curd dry matter (%)
K_2O (mg/l)	SA (mg/l)		Main	Second	Main	Second	/plant	
0		4.2C*	16.2C	8.9C	230.9C	39.6C	356.3C	9.93C
500		5.4B	19.9B	9.4B	333.6B	53.0B	564.9B	11.35B
1000		6.8A	24.0A	13.7A	368.8A	65.8A	748.1A	12.48A
	0	3.9C	16.7C	9.3B	253.6C	47.4C	389.4C	9.91C
	100	5.8B	20.5B	10.8A	326.4B	53.8B	584.8B	11.46B
	200	6.6A	22.9A	11.8A	353.3A	57.1A	675.1A	12.39A
	0	3.2e	12.4g	7.6d	211.3h	31.5i	280.6i	7.52g
0	100	4.6cde	17.1f	9.3cd	235.2g	42.1h	386.8h	10.44f
	200	4.7cde	19.2de	9.7c	246.3f	45.2g	413.5f	11.82cd
	0	4.1de	17.7ef	8.2cd	244.3f	50.3f	400.2g	10.47f
500	100	5.7bcd	19.7d	9.9c	365.2d	52.7e	612.9d	11.53e
	200	6.3bc	22.3c	10.1c	391.2b	55.9d	687.5c	12.05c
	0	4.3de	20.1d	12.1b	305.2e	60.3c	504.2e	11.75de
1000	100	7.1ab	24.8b	13.2b	378.9c	66.7b	785.8b	12.39b
	200	8.9a	27.2a	15.7a	422.3a	70.3a	977.7a	13.30a

*Values having the same alphabetical letter in common do not significantly differ at $P<0.05$.

Results in Table 5 indicated that SA could increase the number of curds and its quality characters of broccoli plants irrigated with saline water. Broccoli plants that sprayed and drenched by 200 mg l^{-1} SA showed significantly increased the number of curds per plant, curd diameter (of main and secondary), curd weight (of main, secondary and plant) and dry matter percentage of curds by 69.2, 37.1, 26.9, 39.3, 20.5, 73.4 and 25.2 % over the control treatment, respectively.

The comparisons among the means of the various combined treatments, presented in Table 5, clearly, demonstrated some significant interaction effects between K^+ and SA concentrations. Foliar application of K^+ at rate1000 mg l^{-1} + 200 mg l^{-1} of SA achieved the best results in lessening the injurious effects of salinity stress on broccoli plants. As these treatment has given the highest number of curds per plant (178.1%), main and secondary curd diameter (119.4 and 106.6%), curd weight of main, secondary and plant (99.8, 123.1 and 248.4%) and curds dry matter percentage (76.9%) of over control treatment.

3.4 Leaf and Curd Mineral Contents

Data in Table 6 showed that increase the foliar application of K^+ concentration up to 1000 mg l^{-1} was associated with a significant increase in the leaf and curd mineral contents (N, P and K%) of broccoli plants compared with control plants irrigated with saline water only.

The leaf and curd mineral contents were significantly affected by application of SA (Table 6). The N, P and K percentages of broccoli leaf and curd grown under salinity stress tended to increased consistently and significantly with increase in the used SA concentration up to 200 mg l^{-1}.

Table 6. Effect of potassium and salicylic acid (SA) concentration and its interaction on leaf and curd mineral contents (N, P, K) of broccoli plants grown under saline water

Treatments		N (%)		P (%)		K (%)	
K_2O (mg/l)	SA (mg/l)	Leaf	Curd	Leaf	Curd	Leaf	Curd
0		3.01B	4.89B	1.00B	2.11C	2.60B	2.08B
500		3.15A	5.14A	1.20A	2.55B	2.70B	2.34A
1000		3.27A	5.21A	1.30A	2.81A	2.90A	2.50A
	0	2.60B	4.66C	0.63B	1.46C	2.15B	1.88B
	100	3.37A	5.09B	1.35A	2.81B	2.98A	2.30A
	200	3.47A	5.49A	1.49A	3.20A	3.15A	2.74A
	0	2.59d	4.66c	0.51e	0.57d	1.73d	1.69e
0	100	3.21c	4.67c	1.18d	2.67b	3.02a	2.02d
	200	3.23c	5.33b	1.28cd	3.08a	3.07a	2.54b
	0	2.59d	4.66c	0.67e	1.80c	2.22c	1.97d
500	100	3.36bc	5.25b	1.33bcd	2.67b	2.86ab	2.30c
	200	3.50abc	5.51ab	1.49abc	3.18a	3.15a	2.74ab
	0	2.61d	4.67c	0.72e	2.01c	2.50bc	1.97d
1000	100	3.53ab	5.34b	1.54ab	3.08a	3.07a	2.58b
	200	3.68a	5.62a	1.69a	3.34a	3.23a	2.94a

*Values having the same alphabetical letter in common do not significantly differ at $P < 0.05$.

The comparisons, presented in Table (6), illustrated the presence of some significant interaction effects, between K^+ and SA concentrations, on the leaf and curd mineral contents of broccoli plants grown under salinity stress. Generally, it was noticed that the highest leaf and curd mineral contents of broccoli plants were obtained from the treatment combination involving the with the foliar spraying with K+ at rate 1000 mg+200 mg l^{-1} of SA .

4. Dissection

The use of saline water in the irrigation vegetable crops under arid region conditions led to the gradual increase of salinity in roots zone of plants. The salinity suppresses the phosphorus (P) uptake and reduces available P (Grattan & Grieve, 1999) as well as K^+ and Ca^{2+} (Yildirim et al., 2006), causing a decrease in growth of the roots and plants, improving the management agricultural practices of broccoli production by using the K^+ as foliar application and salicylic acid (SA) as a drench and foliar application; will contribute to overcome the deleterious effect of salinity stress. Where, using K^+ as a foliar application led to regulating the desirable K/Na ratio (Marschner, 1995). Moreover, SA is regulated of phenolic nature, which participates in the regulation of physiological processes in plants (Karlidag et al., 2009).

The results of this study showed that broccoli plants grown under saline water that receiving K^+ at concentration 1000 mg l^{-1} as foliar application were recorded minimum the deleterious impacts of salinity stress and achieved maximum plant height, number of leaves and branches, leaf area per plant, the main, secondary and total curd yield (t ha^{-1}) and water use efficiency over control treatment. Furthermore, the curd diameter (of main and secondary), curd weight (of main, secondary and plant) dry matter percentage of the curds and the leaf and curd mineral contents (N, P and K%) were improved with foliar application of K up to 1000 mg l^{-1}. This can be explained based on K is an essential nutrient for plant growth and plays an important role in many metabolic processes (Khan & Aziz, 2013) such as photosynthesis, use of water (Rose, 2001) and synthesis of amino acid and protein as well as translocation of sugars and assimilates within the plant and the accumulation of high molecular carbohydrates (Yagodin, 1982; Archer, 1985) necessary for fruit formation and development (Marschner, 1986) which leads to increase plant growth and yield. These results are in accordance with Yildirim et al. (2009) and Safaa et al. (2013). Hussein et al. (2012) they reported that foliar application of potassium mono phos-phate at 200 ppm concentration increased the plant growth, biomass production, and fruit yield of pepper plants.

The vegetative growth, cruds yield and its quality, WUE and leaf and crud mineral contents of broccoli plants irrigated with saline water increased significantly and successively as the SA concentration was increased up to 200 mg l^{-1}. This situation can be explained based on soil and foliar application of SA may be play a significant role in plant water relations (Barkosky & Einhelling, 1993), photosynthesis, growth rate and stomatal regulation (Khan et al., 2003; Arfan et al., 2007), as well as ion uptake and transport (Gunes et al., 2005), membrane permeability (Barkosky and Einhellig, 1993), raising indoleacetic acid content and enhancing of cell division and extension of root cells (Shakirova et al., 2003). Gunes et al. (2006) illistrated that the increase in dry matter of salt stressed plants in response to SA might be related to the induction of antioxidant response and protective role of membranes that increase the tolerance of plant to damage or may be attributed to the increased mineral uptake by stressed plant with SA treatment (Yildirim et al., 2008). Similar results were reported by Yildirim et al. (2006) with cucumber, Lian et al. (2000) with soybean, Senaratna et al. (2000) and Stevens et al. (2006) with bean and tomato, where SA applications positively affected shoot and root growth parameters. Yildirim et al. (2008) reported that treated cucumber plants with SA as foliar applications resulted in greater shoot fresh weight, shoot dry weight, root fresh weight, and root dry weight as well as higher plants under salt stress.

5. Conclusion

The data obtained from the present study suggest that the combined foliar application of 1000 mg l^{-1} K+ with salicylic acid at 200 mg l^{-1} as a dernch and foliar application is the most efficient combination treatment, which gave the best results to alleviate the deleterious impact of salinity stress on the vegetative growth, curd yield and its quality characters, leaf and curds chemical contents of broccoli plants irrigated with saline water.

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