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Protective Role of Salicylic Acid on Salt Affected Broccoli Plants

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Authors' contributions

This work was carried out in collaboration between the two authors. Both authors KP and MNH designed the study, wrote the protocol, wrote the first draft of the manuscript, managed the literature searches and analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Salicylic acid (SA), an endogenous plant growth regulator has been found to generate a wide range of metabolic and physiological responses in plants thereby affecting their growth and development. Broccoli plant was grown under saline condition with foliar application of SA as alleviating agent for salt toxicity. Plants were treated with 0, 4 and 8 dS m^{-1} concentration of NaCl solution along with three levels of foliar application of SA such as 0, 0.25 and 0.50 mM. Growth and development of broccoli was gradually decreased under increasing level of salinity and mostly hampered at 8 dS m^{-1}. Plant height, leaf size, foliage coverage as well as curd size and weight were also reduced at 8 dS m^{-1} of salinity. SA worked against the induced toxicity by salinity through improving growth behavior, yield component and yield. The improvement of plant height, leaf size (leaf length and breadth), foliage coverage, stem diameter, curd length, breadth and weight were enhanced with

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increasing concentration of SA where 0.50 mM of SA showed the better result. This study concludes that exogenous foliar spray of SA mitigates the salt toxicity in broccoli cultivation by improving morphology and yield contribution.

Keywords: Brassica oleracea var. italica L.; curd formation; foliage coverage; salinity; salt mitigation.

1. INTRODUCTION

Salinity stress is one of the major contributors decreasing plant productivity. Major physiological processes are altered and hampered by salt stress. Salt stress results in decreased water uptake, ionic and nutrients homeostasis, photosynthesis, enzymatic inhibition, metabolic dysfunction which are responsible for decreased growth and productivity of plants [1,2]. Creating osmotic stress and ionic toxicity salt stress creates water deficit stress and obstacles germination metabolism which reduce germination percentage and maturity [3,4]. Salt reduces water uptake and thus hamper cell division, differentiation and expansion which ultimately reduce plant growth and development [5,6]. Salt stress beyond the tolerance level causes growth inhibition, chlorosis, senescence, and death [7]. Like other abiotic stresses, salinity put forth more severe effect on reproductive stage, compared to vegetative stage [8]. Salt stress (250 mM NaCl) decreased yield of different cultivars of *Vigna radiata* cv. BARI mung-2, BARI mung-5 and BARI mung-6 was reduced by 77%, 73% and 66%, respectively in contrast to control. Decreased number of pods plant^{-1}, seeds pod^{-1} and seed weight were responsible for yield reduction [9]. Yield reduction due to salt stress (per 1 dS m^{-1} increase in soil electrical conductivity) was 8.9 ± 1.2% in *Vitis vinifera* L. [10]. Broccoli (*Brassica oleracea* var. *italica* L.) is one of the major vegetable crops grown worldwide [11] that contributes to the vitamin and mineral components of the human diet, but also beneficial effect on human health [12]. It is a moderately salt sensitive crop with 2.8 dS m^{-1} level of salinity where a slope of 9.2% for every one unit increases in salinity [13]. So, if it can be cultivated under saline affected area or with irrigation by saline water, then it will be possible to supply required broccoli to our over increased world population.

Salicylic acid (SA) is a plant-produced phenolic compound and plant hormone. SA has being important with the discovery of different important roles of it in plant developmental processes [14]. El Tayeb [15] demonstrated that SA application in barley induced adaptive response that made barley plant tolerant to salt stress. Application of SA increased biosynthesis of chlorophyll (chl) *a,* chl *b* and carotenoid, and maintained membrane integrity. SA-pretreated plants accumulated more K^+ and soluble sugars in roots. Improvement of these physiological features leaded to improved plant growth [15]. SA application decreased leaf Na^+, Cl^-, and H_2O_2 content and improved phtosynthetic performance in salt affected mungbean plants [16]. *Lycopersicon esculentum* showed increased photosynthetic rates after SA supplementation under salt stress [17,18]. Electrolyte leakage had been decreased by the supplementation of SA under salt stress [19]. Keeping in view the diverse physiological roles of SA in plants, the present study was undertaken to investigate the roles of different doses of SA to mitigate the damage effects of different levels of salt stress in broccoli plant.

2. MATERIALS AND METHODS

A pot experiment was placed under venyl house which was made by bamboo with polythene roof at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh situated at 23°74′N latitude and 90°35′E longitude at an altitude of 8.6 meter above the sea level during the period from October 2014 to March 2015. The soil of the experimental site was silt loam in texture (sand 20.84%, silt 57.46% and clay 21.7%) with pH 6.9, organic matter 0.86%, available potassium 25 mg kg^{-1} and available sodium 70 mg kg^{-1}. The climate of this area is subtropical humid climatic conditions with a monthly average rainfall, relative humidity, maximum and minimum temperature was 2.67 mm, 69.5%, 26.6°C and 15.9°C, respectively. Seedlings of 30 days of broccoli variety named as "Early green" were used as planting material in this experiment. Three levels of salinity induced by sodium (Na^+) *viz.,* 0, 4, 8 dS m^{-1} and three levels of SA *viz.,* 0, 0.25, 0.50 mM were used as treatment variables. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each pot was 35 cm in diameter and 30 cm in height. Each pot treated as a replication where one plant was transplanted. Broccoli plants were treated with 0, 4 and 8 dS m^{-1} salinity levels which were maintained by adding 0, 27 and 58 g of sodium chloride (NaCl) respectively per pot containing 10 kg of soil. These total amounts of salts were applied through irrigation water in three splits at 25, 40 and 55 days after transplanting (DAT) at afternoon. As a mitigation agent of Na^+ stress, SA was used as foliar spray in the same days after application of salt using a mini hand sprayer, to the canopy of plants each until incipient runoff (approx. 10 mL aqueous solution per plant). The control plants were sprayed with the same amount of water. Different morphological (plant height, number of leaves plant^{-1}, average leaf length and breadth, foliage coverage plant^{-1}, stem diameter) and reproductive parameter as well as yield (curd length, breadth and weight) was recorded to evaluate the response of broccoli under saline condition and also the mitigating behavior of SA to salt toxicity. Plant height, leaf length and breadth, foliage coverage, curd length and curd breadth were measured with measuring scale where number of leaves were counted, stem diameter was measured with slide calipers and curd weight was taken by using weight machine.

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using MSTAT-C [20] program and the mean differences were compared by least significant difference (LSD) test at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Plant height varied significantly by different levels of salinity stress at different DAT of broccoli (Table 1). Plant height decreased with increasing salt stress upto 8 dS m^{-1} irrespective of all sampling date. Similar results were found by Parvin et al. [21] in tomato, they stated that plant height of tomato drastically decreased mostly under at 6 and 8 dS m^{-1} levels of salinity. These results were confirmed by Jafari [22]; Nawaz [23] in sorghum, Milne [24] in lettuce, Ewase et al. [25] in coriander. The reduction of plant height may be due to inhibitory behavior of salt stress on cell division and cell expansion [26]. So, plant growth reduction is a common feature under saline condition [27-29]. SA is not successful to harmful effect of salinity on plant height of broccoli at different age stages. From this experiment it was found that, the highest plant height was recorded from control plant and lowest one from SA treated plant. Combined effect between salinity stress and SA as mitigation agent on plant height was significant at different DAT (Table 1). At 35 DAT, the highest plant height (28.00 cm) was obtained from combination of 4 dS m^{-1} salt stress and 0.50 mM SA. At 45, 55, 65 and 75 DAT, the highest plant height (35.00, 37.67, 43.33 and 44.67 cm, respectively) was recorded from without salinity and 0.50 mM SA combination. Increasing the salinity in soil without application of SA decreased the plant height of broccoli at different growth period.

3.2 Number of Leaves Plant^{-1}

Different doses of salt stress showed non-significant effect on leaves number of broccoli plant except 35 and 65 DAT (Table 2). Salinity reduced the number of leaves plant^{-1} of broccoli. At 35 and 65 DAT, the highest leaves number (7.89, 10.44, respectively) was obtained from without salt stress plant. Saberi et al. [30] also obtained reduced leaves number plant^{-1} under salinity stress. Salinity mostly at 6 and 8 dS m^{-1} decreased the leaf production plant^{-1} in tomato [21]. SA significantly reduced the saline toxicity on leaves number by increasing the number under different level of saline treatment (Table 2). At 45, 55, 65 and 75 DAT, the highest leaves number (9.00, 10.00, 11.67 and 13.67, respectively) was recorded from the maximum level of SA (0.50 mM) and lowest (7.67, 8.89, 6.56 and 10.89, respectively) was counted from without foliar application of SA. Due to combination of salinity and SA on leaves number of broccoli plant showed significant (Table 2) at different DAT. From this study it was found that, salinity reduced the total leaf initiation and SA also increased the leaf production plant^{-1} at different DAT.

3.3 Average Leaf Length and Breadth Plant^{-1} (cm)

Salinity significantly affected the average leaf length and breadth plant^{-1} at different DAT of broccoli (Table 3). At 45 DAT, the highest value of average leaf length (27.22 cm) and breadth (13.56 cm) were found from 4 dS m^{-1} salinity. At 55, 65 and 75 DAT, the highest average leaf length (29.33, 33.00 and 36.44 cm) and breadth (14.44, 10.89 and 15.22 cm, respectively) was recorded from no salt treated plant. Lowest value of both average leaf length and breadth at different DAT was found from highest salinity level (8 dS m^{-1}). So, it can be summarized that increasing level of salinity gradually decreased the leaf size which may also be responsible for lower photosynthesis. Foliar application of SA showed significant effect on average leaf length and breadth plant^{-1} of broccoli (Table 3). The highest leaf length plant^{-1} (28.22, 27.33, 29.33, 33.78 cm) and breadth (13.78, 13.11, 11.78, 14.89 cm) at different DAT was recorded from highest level of SA concentration (0.50 mM), where lowest values were found from without SA treated plant. Combined effect of salinity and SA on average leaf length and breadth plant^{-1} was significantly ($p\leq0.01$) reflected at different stages of broccoli (Table 3). The foliar spray of SA increased the leaf size under salinity.

3.4 Foliage Coverage Plant^{-1} (cm)

Foliage coverage plant^{-1} of broccoli decreased with increasing level of salinity (Table 4). At 55, 65 and 75 DAT, the highest foliage coverage (46.00, 56.11, 59.44 cm, respectively) was recorded from 0 dS m^{-1} treatment whereas, the lowest (42.22, 43.00 and 45.22 cm, respectively) was obtained from 8 dS m^{-1} salinity. Decreasing the foliage coverage may be due to the reduction of leaf number and leaf size under saline condition. SA gradually improved the foliage coverage compare to without SA treated plant at different DAT of broccoli (Table 4). At 45, 55, 65 and 75 DAT, the highest foliage coverage (45.78, 48.11, 53.56 and 56.89 cm, respectively) was calculated from maximum (0.50 mM) SA application and the lowest (31.56, 39.44, 44.44 and 45.44 cm, respectively) was found from without SA treated plants. Combined effect of salinity and SA on foliage coverage exhibited significant effect (Table 4). At 45 and 55 DAT, the highest foliage coverage (47.67 and 53.33 cm, respectively) was recorded from combination of 0.50 mM SA with 4 dS m^{-1} salinity treated plant. At 65 and 75 DAT, the highest foliage coverage (60.33, 69.33, respectively) was measured from without salinity and 0.50 mM SA treatment combination.

3.5 Stem Diameter (cm)

Increased level of salinity gradually decreased the stem diameter of broccoli (Table 5). The highest diameter (3.63 cm) was recorded from no salt treated plant and the lowest (2.90 cm) was found from 8 dS m^{-1} salinity. SA increased the stem diameter of broccoli plant under saline condition (Table 5). The highest stem diameter (3.36 cm) was recorded from 0.50 mM concentrated SA which was statistically similar with 0.25 mM SA and the lowest (2.99) was found from without SA treated plant. Combination

Table 1. Effect of salinity and/or SA on plant height at different DAT of broccoli

Treatment		Plant height (cm) at				
		35 DAT	**45 DAT**	**55 DAT**	**65 DAT**	**75 DAT**
Salinity level						
0 dS m^{-1}		25.89 a	33.78 a	36.44 a	40.00 a	42.78 a
4 dS m^{-1}		24.11 b	30.78 b	34.67 a	37.78 b	40.78 b
8 dS m^{-1}		22.22 c	28.67 b	29.78 b	29.89 c	33.33 c
$LSD_{(0.05)}$		0.751	2.453	1.765	0.882	1.402
Level of significance		**	*	**	**	**
SA level						
0 mM		25.22 a	33.22 a	33.78 a	37.22 a	39.11 a
0.25 mM		24.89 a	33.33 a	34.11 a	34.56 b	38.78 a
0.50 mM		22.11 b	29.22 b	30.56 b	35.78 b	39.00 a
$LSD_{(0.05)}$		0.751	2.453	1.765	0.882	1.402
Level of significance		**	*	**	**	ns
Salinity × SA						
	×0 mM	25.33 bc	33.00 ab	30.67 c	35.67 d	41.33 bcd
0 dS m^{-1}	×0.25 mM	26.00 b	32.33 ab	33.33 bc	41.00 b	42.33 abc
	×0.50 mM	26.33 b	35.00 a	37.67 a	43.33 a	44.67 a
	×0 mM	19.00 e	28.00 ab	30.33 cd	36.67 cd	39.00 d
4 dS m^{-1}	×0.25 mM	25.33 bc	29.33 ab	33.00 bc	38.00 c	40.33 cd
	×0.50 mM	28.00 a	32.67 ab	35.00 ab	40.00 b	43.00 ab
	×0 mM	19.67 e	27.33 b	24.00 e	28.00 f	31.00 f
8 dS m^{-1}	×0.25 mM	22.67 d	30.33 ab	27.33 d	30.00 e	33.67 e
	×0.50 mM	24.33 c	28.67 ab	31.33 c	31.33 e	35.33 e
$LSD_{(0.05)}$		1.301	7.280	3.057	1.527	2.428
Level of significance		**	*	**	**	**

***: significant at p≤0.01, *: significant at p≤0.05, ns: non-significant.*
Values followed by the same letters do not differ at 5% level of significance

Table 2. Effect of salinity and/or SA on number of leaves plant^{-1} at different DAT of Broccoli

Treatment		Number of leaves plant^{-1} at				
		35 DAT	**45 DAT**	**55 DAT**	**65 DAT**	**75 DAT**
Salinity level						
0 dS m^{-1}		7.89 a	8.78 a	9.78 a	10.44 a	12.56 a
4 dS m^{-1}		7.67 ab	8.44 a	9.33 a	8.33 b	11.44 a
8 dS m^{-1}		6.89 b	8.33 a	9.56 a	9.78 a	11.56 a
$LSD_{(0.05)}$		0.822	0.652	0.904	1.199	1.164
Level of significance		**	ns	ns	**	ns
SA level						
0 mM		7.56 a	7.67 b	8.89 b	6.56 c	10.89 b
0.25 mM		7.78 a	8.89 a	9.78 ab	10.33 b	11.00 b
0.50 mM		7.11 a	9.00 a	10.00 a	11.67 a	13.67 a
$LSD_{(0.05)}$		0.822	0.652	0.904	1.199	1.164
Level of significance		ns	**	*	**	**
Salinity × SA						
0 dS m^{-1}	×0 mM	7.67 ab	8.33 bc	10.33 ab	5.67 d	12.00 bc
	×0.25 mM	8.33 a	9.67 a	11.33 a	11.67 b	11.33 bc
	×0.50 mM	7.67 ab	8.33 bc	7.67 cd	14.00 a	14.33 a
4 dS m^{-1}	×0 mM	8.33 a	7.67 cd	9.00 bc	5.00 d	10.33 c
	×0.25 mM	7.33 ab	8.33 bc	8.00 cd	8.67 c	10.67 c
	×0.50 mM	7.33 ab	9.33 ab	11.00 a	11.33 b	13.33 ab
8 dS m^{-1}	×0 mM	6.67 b	7.00 d	7.33 d	9.00 c	10.33 c
	×0.25 mM	7.67 ab	8.67 abc	10.00 ab	10.67 bc	11.00 c
	×0.50 mM	6.33 b	9.33 ab	11.33 a	9.67 bc	13.33 ab
$LSD_{(0.05)}$		1.423	1.130	1.566	2.077	2.016
Level of significance		*	*	**	**	*

***: significant at p≤0.01, *: significant at p≤0.05, ns: non-significant*
Values followed by the same letters do not differ at 5% level of significance

of salinity and SA increased the stem diameter plant^{-1} of broccoli (Table 5). The highest stem diameter (3.80 cm) was found from 0 dS m^{-1} and 0.50 mM SA treatment combination whereas the lowest (2.70 cm) was measured from combination of 8 dS m^{-1} salinity with 0 mM SA.

3.6 Curd Length (cm)

Salinity significantly reduced the curd length of broccoli (Table 5). The lowest curd length (9.94 cm) was recorded from 4 dS m^{-1} salinity treated plant and highest length (15.22 cm) was found from 8 dS m^{-1} which is identical with control treatment. Curd length of broccoli increased with foliar application of SA (Table 5). Highest level of SA application (0.50 mM) gave the highest curd length (14.11 cm) compared to control (without SA) treatment (12.00 cm). Combined effect of salinity and salicylic acid on curd length is significant (Table 5). The highest curd length (16.67 cm) was observed from 8 dS m^{-1} salinity with 0.50 mM SA combination which was statistically at par with 8 dS m^{-1} salinity with 0.25 mM and 0 dS m^{-1} salinity with 0.50 mM SA combinations. Mirdad [31] also reported that SA increased curd quality characteristic under saline condition.

3.7 Curd Breadth (cm)

Increased level of salinity reduced the curd breadth of broccoli (Table 5). The highest curd breadth (13.39 cm) was recorded from salt stress free plant and the lowest (10.67 cm) was found from highest level of salinity (8 dS m^{-1}). SA increased the curd breadth by reducing the saline toxicity on broccoli (Table 5). The maximum curd breadth (12.94 cm) was measured from 0.50 mM SA and the lowest (10.56 cm) was found from without SA treated treatment which was statistically similar with 0.25 mM SA. Mirdad [31] also found the similar result in broccoli plants, who stated that SA spray increased the curd diameter over the control treatment. Combination of salinity and SA showed significant result on curd breadth of broccoli (Table 5). The maximum curd breadth (15.17 cm) was found from salt free treated plant with 0.50 mM SA combination and the lowest (9.67 cm) was obtained from combination of 8 dS m^{-1} salinity with 0 mM SA.

Table 3. Effect of salinity and/or SA on average leaf length and breadth $plant^{-1}$ at different DAT of broccoli

Treatment		Average leaf length $plant^{-1}$ (cm) at				Average leaf breadth $plant^{-1}$ (cm) at			
		45 DAT	55 DAT	65 DAT	75 DAT	45 DAT	55 DAT	65 DAT	75 DAT
Salinity level									
0 dS m^{-1}		20.33 b	29.33 a	33.00 a	36.44 a	12.67 ab	14.44 a	10.89 a	15.22 a
4 dS m^{-1}		27.22 a	24.89 b	27.33 b	30.44 b	13.56 a	12.00 b	10.44 a	12.56 b
8 dS m^{-1}		25.11 a	21.44 b	22.22 c	25.33 c	10.89 b	10.89 b	9.11 b	11.00 c
$LSD_{(0.05)}$		2.184	3.966	1.846	2.640	1.861	1.452	0.962	1.341
Level of significance		**	**	**	**	*	**	**	**
SA level									
0 mM		19.00 c	22.56 b	25.00 b	28.33 b	10.67 b	11.56 b	8.33 c	11.00 c
0.25 mM		25.44 b	25.78 ab	28.22 a	30.11 b	12.67 a	12.67 ab	10.33 b	12.89 b
0.50 mM		28.22 a	27.33 a	29.33 a	33.78 a	13.78 a	13.11 a	11.78 a	14.89 a
$LSD_{(0.05)}$		2.184	3.966	1.846	2.640	1.861	1.452	0.962	1.341
Level of significance		**	*	**	**	**	*	**	**
Salinity × SA									
0 dS m^{-1}	×0 mM	12.67 e	26.00 abc	28.67 b	32.00 bc	11.67 bc	13.00 bc	8.667 de	12.67 b
	×0.25 mM	23.33 cd	30.33 a	35.00 a	36.00 b	12.00 abc	14.00 ab	11.33 ab	15.67 a
	×0.50 mM	25.00 bc	31.67 a	35.33 a	41.33 a	14.33 ab	16.33 a	12.67 a	17.33 a
4 dS m^{-1}	×0 mM	24.33 c	21.33 bc	25.33 cd	28.67 cde	11.33 bc	11.00 c	8.33 e	10.00 d
	×0.25 mM	26.00 bc	25.33 abc	27.67 bc	30.00 cd	14.33 ab	12.67 bc	10.33 bc	12.33 bc
	×0.50 mM	31.33 a	28.00 ab	29.00 b	32.67 bc	15.00 a	12.33 bc	12.67 a	15.33 a
8 dS m^{-1}	×0 mM	20.00 d	20.33 c	21.00 e	24.33 e	9.00 c	10.67 c	8.00 e	10.33 cd
	×0.25 mM	27.00 bc	21.67 bc	22.00 e	24.33 e	11.67 bc	11.33 c	9.33 cde	10.67 bcd
	×0.50 mM	28.33 ab	22.33 bc	23.67 de	27.33 de	12.00 abc	10.67 c	10.00 bcd	12.00 bcd
$LSD_{(0.05)}$		3.784	6.869	3.197	4.573	3.223	2.515	1.666	2.323
Level of significance		*	*	*	*	*	*	*	*

***: significant at p≤0.01, *: significant at p≤0.05*
Values followed by the same letters do not differ at 5% level of significance

Table 4. Effect of salinity and/or SA on foliage coverage plant^{-1} at different DAT of broccoli

Treatment		Foliage coverage plant^{-1} (cm) at			
		45 DAT	55 DAT	65 DAT	75 DAT
Salinity level					
0 dS m^{-1}		35.78 a	46.00 a	56.11 a	59.44 a
4 dS m^{-1}		39.11 a	45.22 a	46.89 b	48.11 b
8 dS m^{-1}		38.33 a	40.22 b	43.00 b	45.22 c
$LSD_{(0.05)}$		4.296	3.417	4.847	2.199
Level of significance		ns	**	**	**
SA level					
0 mM		31.56 c	39.44 c	44.44 b	45.44 c
0.25 mM		35.89 b	43.89 b	48.00 b	50.44 b
0.50 mM		45.78 a	48.11 a	53.56 a	56.89 a
$LSD_{(0.05)}$		4.296	3.417	4.847	2.199
Level of significance		**	**	**	**
Salinity × SA					
	×0 mM	31.33 d	43.67 bc	53.00 ab	51.67 cd
0 dS m^{-1}	×0.25 mM	32.67 cd	46.00 b	55.00 ab	57.33 b
	×0.50 mM	43.33 ab	48.33 ab	60.33 a	69.33 a
	×0 mM	34.00 cd	36.00 d	41.33 cd	41.67 f
4 dS m^{-1}	×0.25 mM	35.67 cd	46.33 b	47.33 bcd	48.67 de
	×0.50 mM	47.67 a	53.33 a	52.00 ab	54.00 bc
	×0 mM	29.33 d	38.67 cd	39.00 d	43.00 f
8 dS m^{-1}	×0.25 mM	39.33 bc	39.33 cd	41.67 cd	45.33 ef
	×0.50 mM	46.33 ab	42.67 bc	48.33 bc	47.33 e
$LSD_{(0.05)}$		7.441	5.918	8.396	3.809
Level of significance		*	*	*	**

***: significant at $p \le 0.01$, *: significant at $p \le 0.05$, ns: non-significant*
Values followed by the same letters do not differ at 5% level of significance

Table 5. Effect of salinity and/or SA on Stem diameter, curd length, breadth and weight plant^{-1} of broccoli

Treatment		Stem diameter (cm)	Curd length (cm)	Curd breadth (cm)	Curd weight (g)
Salinity level					
0 dS m^{-1}		3.63 a	14.33 a	13.39 a	235.20 a
4 dS m^{-1}		3.00 b	9.94 b	11.11 b	161.10 b
8 dS m^{-1}		2.90 b	15.22 a	10.67 b	130.10 c
$LSD_{(0.05)}$		0.363	1.201	1.227	3.111
Level of significance		**	**	**	**
SA level					
0 mM		2.99 b	12.00 b	10.56 b	151.00 c
0.25 mM		3.19 ab	13.39 a	11.67 b	156.40 b
0.50 mM		3.36 a	14.11 a	12.94 a	219.00 a
$LSD_{(0.05)}$		0.363	1.201	1.227	3.111
Level of significance		*	**	**	**
Salinity × SA					
	×0 mM	3.50 abc	13.33 cd	12.00 bc	205.30 c
0 dS m^{-1}	×0.25 mM	3.60 ab	14.33 bcd	13.00 b	213.30 b
	×0.50 mM	3.80 a	15.33 abc	15.17 a	287.00 a
	×0 mM	2.77 d	10.00 e	10.00 cd	138.00 e
4 dS m^{-1}	×0.25 mM	3.03 bcd	9.500 e	11.33 bcd	140.30 e
	×0.50 mM	3.20 abcd	10.33 e	12.00 bc	205.00 c
	×0 mM	2.70 d	12.67 d	9.67 d	109.70 g
8 dS m^{-1}	×0.25 mM	2.93 cd	16.33 ab	10.67 cd	115.70 f
	×0.50 mM	3.07 bcd	16.67 a	11.67 bcd	165.00 d
$LSD_{(0.05)}$		0.629	2.080	2.125	5.388
Level of significance		*	*	**	*

***: significant at $p \le 0.01$, *: significant at $p \le 0.05$*
Values followed by the same letters do not differ at 5% level of significance

3.8 Curd Weight (g)

Increased level of salinity decreased the curd weight of broccoli (Table 5). The highest curd weight (235.20 g) was recorded from salt free plant and the lowest weight (130.10 g) was found from highest level of salinity (8 dS m^{-1}) treated plant. Salinity highly reduced the yield of tomato [19]. SA increased the curd weight of broccoli by reducing salt toxicity (Table 5). The highest curd weight (219.00 g) was recorded from the foliar application of 0.50 mM SA and the lowest (151.00 g) was weighted from without SA treatment. Exogenous application of SA significantly increased the total curd weight of broccoli [31]. Combined effect between salinity and SA on curd weight of broccoli is significant (Table 5). The highest curd weight (287.00 g) was recorded from combination of 0.50 mM SA and salt free treated plant and the smallest (109.70 g) curd was measured from 8 dS m^{-1} with no SA combination. SA significantly increased yield of soybean [32], cucumber and tomato fruit [33], maize [34] and wheat plants [35]. The effects of salinity stress are similar to the effects of drought stress [36-38]. For this reason this results can be used for drought stress.

4. CONCLUSION

It may be concluded that, salinity negatively affected the broccoli growth and development and as well as its yield by reducing diameter, length and weight of curd. Both 4 and 8 dS m^{-1} level of salinity are harmful for its production by reducing upto 44.69%. In contrast, foliar application of lower concentrated SA successfully increased upto 45.03% of its production. Application of 0.50 mM SA is very responsive for salinity mitigation and also its normal growth and development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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