The Journal of Animal & Plant Sciences, 28(1): 2018, Page: 197-207
ISSN: 1018-7081

SALICYLIC ACID-INDUCED IMPROVEMENT IN GERMINATION AND GROWTH PARAMETERS OF WHEAT UNDER SALINITY STRESS

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ABSTRACT

A pot experiment was conducted at the experimental shed of the Department of Agronomy, Sher-e-Bangla Agricultural University, Bangladesh during in winter season (2013-2014) with a view to find out the regulatory roles of exogenous salicylic acid (SA) in germination and growth of wheat under salt stress condition. The experiment was carried out with two varieties i.e. BARI Gom 21 and BARI Gom 25 and ten salt stress treatments viz. control (without salt), SA (1 mM salicylic acid), S50 (50 mM NaCl), S50+SA (50 mM NaCl with 1 mM SA), S100 (100 mM NaCl), S100+SA (100 mM NaCl with 1 mM SA), S150 (150 mM NaCl), S150+SA (150 mM NaCl with 1 mM SA), S200 (200 mM NaCl) and S200+SA (200 mM NaCl with 1 mM SA). Seed germination percentage, normal seedling percentage, length of shoot and root, fresh weight of shoot and root and dry weight were decreased under the stress condition but the abnormal seedling percentage increased. Salt stresses significantly reduced the plant height, tillers hill^{-1}, fresh weight and dry weight of both varieties at all growth duration. Exogenous SA application with salt stress improved germination and crop growth parameters in both cultivars where BARI Gom 25 showed better tolerance. But, SA application could not improve germination and crop growth parameters at extreme level of salt stress (200 mM NaCl).

Key words: Abiotic stress, Phytohormones, Salinity, Seed germination

INTRODUCTION

Among the abiotic stresses, one of the major environmental determinants of plant growth and productivity is salinity. Various physiological and biochemical processes of plants are adversely affected by the accumulation of salt whether in soil or water. At higher levels of salinity causes both hyperionic and hyperosmotic stress and can lead to plant collapse. As a result, these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leading to plant death (Mahajan and Tuteja, 2005; Hasanuzzaman *et al*., 2012). Furthermore, plant growth reduced due to either water relations or the toxic effects of Na^+ and Cl^- ions on the metabolism. Na^+ concentration uplifts into the cytoplasm due to Na^+ influx into the root cells and causes toxicity symptoms (Rashad and Hussien, 2014). This implies that osmotic effects induced due to salt stress which limits the growth predominantly, power of ion compartmentalization and energy cost in plant cells (Hasegawa *et al*., 2000). Therefore, to ensure global food security, as well as for water and land conservation it is important to increase the salt tolerance of crop plants. Salt susceptible cultivars absorb higher amount of toxic ions compared to salt tolerant one. Under salt stress condition, plants can adapt by altering their cellular metabolism and invoking various defense mechanisms (Ghosh *et al*., 2011). Plants need some abilities to perceive the stimulus, generate and transmit a signal, and initiate various physiological and biochemical changes to survive under this condition (Tanou *et al*., 2009a; El-Shabrawi *et al*., 2010).

Wheat is the most important cereal crop for the majority of world's populations. It is the most important staple food of about two billion people (35% of the world population) (Jing and Chang, 2003). Wheat ranks third in the world's grain production (FAOStat, 2013) and accounts for more than 20% of the food calories consumed by human (USDA, 2014).

Some exogenous protectant such as plant hormone antioxidants, signaling molecules, polyamines, trace elements etc. have been found effective to mitigate the salt induced damage in plant recently (Hasanuzzaman *et al*., 2011a, b; 2013; 2014). Under salinity environment different protectants showed the capacity to enhance the plants growth, yield as well as stress tolerance. A potential endogenous plant hormone and a common plant-produced phenolic compound that plays an important role in plant growth and development is salicylic acid (SA) (Khan *et al*., 2012; Alam *et al*., 2013; Hasanuzzaman *et al*., 2014). Under different abiotic stresses, the role of SA has widely been studied in the recent years (Alam *et al*., 2013; Hasanuzzaman *et al*., 2014; Li *et al*., 2014). A number of physiological events taking place in the plant regulates by SA which is one such plant growth regulators (Dolatabadian *et al*., 2008; Ashraf *et al*., 2010). Some key plant functions such as stomatal functioning (Aldesuquy *et al*., 1998), ion uptake and transport (kaydan *et al*., 2007), photosynthesis (Noreen and Ashraf, 2008; Li *et al*., 2014), water relations (Barkosky and Einhelling, 1993; Hayat *et al*., 2010), production rate and content of anthocyanin and chlorophyll (Khurana and Maheshwari, 1980), growth increment (Arfan *et al*., 2007; Ashraf *et al*., 2010) and up-regulates antioxidative system (Erdal *et al*., 2011; Hasanuzzaman *et al*., 2014) by the SA. Under saline environment, these all functions have a significant role in plant tolerance (Abreu and Munne-bosch, 2009; Ashraf *et al*., 2010).

However, the response of plants to salt stress varies among the crop varieties and the concentration and duration of stress. In addition, the role of exogenous protectants is also variable in such conditions. Although there are many studies on the effect of salt stress on wheat but there is hardly any study regarding the role of exogenous protectants in mitigating salt stress in wheat. This study was designed to understand the physiological mechanisms of salt stress tolerance mediated by exogenous SA on two high yielding wheat varieties such as BARI Gom 21 and a tolerant variety BARI Gom 25 which were grown in saline condition in Bangladesh.

MATERIALS AND METHODS

Plant Materials and Stress Treatments: Seed of a salt tolerant (BARI Gom 25) and salt sensitive (BARI Gom 21) variety of wheat were collected from Bangladesh Agriculture Research Institute, Joydebpur, Gazipur, Bangladesh, respectively. A pot experiment was conducted at the experimental shed of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka (90°77′ E longitude and 23°77′ N latitude) during the period from November 2013 to March 2014. Empty earthen pots with 18 inch depth were used for the experiment. Twelve kilogram sun-dried soils were put in each pot.

The soils and fertilizers were mixed well before placing the soils in the pots. Fertilizers used in the experimental pots were urea, triple super phosphate, muriate of potash and gypsum @ 4.6, 4.1, 2.7 and 1.2 g/pot. One-third of urea and the whole amount of other fertilizers were incorporated with soil at final pot preparation before sowing. Rest of the nitrogen were applied in two equal splits one at 30 days after sowing (DAS) and the other at 60 DAS. Fifteen healthy seeds of each variety were sown in each pot. After germination 9-10 plants were allowed to grow in each pot. There were five salinity levels including control where developed by adding respected amount commercial NaCl salt to the soil/pot as water dissolved solution. The salinity levels were C (control), S50 (50 mM NaCl), S100 (100 mM NaCl), S150 (150 mM NaCl) and S200 (200 mM NaCl). The salinity treatments were applied on 28, 35, 42, 49, 56 and 63 DAS (days after sowing). Salicylic acid (SA) was used as a protectant. The concentration of SA was 1mM and applied as spray solution under non-saline (SA) and saline (S50, S100, S150 and S200) condition. The experiment was laid out in a Randomized Completely Block Design (RCBD) with three replications.

Germination test: Germination test was performed before sowing the seeds in the pot. For laboratory test, petridishes were used. Filter paper was placed on petridishes. Firstly seeds were soaked in 10ml of 70% alcohol for 10 minutes. Then half amounts of seeds were soaked in SA solution for 1 hr. The filter paper soaked with 10ml water for Control and 10ml of 50 mM, 100 mM, 150 mM and 200 mM NaCl solution. Seeds were placed in petridishes randomly. Data were collected five days after placement of seed. For each variety data was taken three times after placing the seeds in petridish for three times after and after.

Germination (%): Germination (%) was measured by the following formula-

$$\text{Germination (\%)} = \frac{\text{N o g s}}{\text{N o s p}} \times 100$$

Normal and abnormal seedlings (%): The normal seedlings and abnormal seedlings were classified according to the prescribed rules given by ISTA (1999)**.**

Shoot and root length (cm): Shoot and root length was measured from five seedlings randomly.

Fresh weight of shoot and root (g) seedling^{-1}: Five sample seedlings were given for taking fresh weight. Then seedlings shoot and root were weighed in balance and averaged them to take fresh weight seedling^{-1}

Dry weight (g) seedling^{-1}: After weighing the fresh weight, seedlings were then kept in an electric oven maintaining 60^0c for 24 hours. Then it was weighed in balance to take dry weight and then averaged them.

Plant height (cm): The height of the wheat plants was recorded from 30 days after sowing (DAS) at 15 days interval up to 60 DAS, beginning from the ground level up to tip of the leaf was counted as height of the plant. The average height of five plants was considered as the height of the plant for each pot.

Tiller hill^{-1}: Total tiller number was taken from 30 DAS at 15 days interval up to 60 DAS. The average number of tillers of five plants was considered as the total tillers plant^{-1}.

Fresh weight plant^{-1} (g): Three sample plants uprooted from each pot and wash them in water. Then the plants were weighed in a balance and averaged them to have fresh weight plant^{-1} and taken from 30 DAS at 15 days interval up to 60 DAS.

Dry weight plant^{-1} (g): Three sample plants after weighing for fresh weight was dried them in an electric oven maintaining 60^{0}c for 48 hours. Then the plants were weighed in an electric balance and averaged them to have dry weight plant^{-1}. The data were collected from 30 to 60 DAS at an interval of 15 days.

Statistical analysis: The data obtained for different parameters were statistically analyzed following computer based software XLSTAT 2014 (AddinSoft, 2014) and mean separation was done by LSD at 5% level of significance.

RESULTS

Germination percentage: Germination percentage declined with increase of salinity level. However, application of SA improved germination in all cases except 200 mM NaCl (Fig. 1A). Under 200 mM NaCl stress in case of both varieties, germination percentage significantly dropped at 14 and 18%. In any case, germination percentage was always higher in BARI Gom 25 than BARI Gom 21.

Normal seedling: In case of BARI Gom 21, at 100 and 150 mM salinity stress the number of normal seedling were 33.33 and 6.67% respectively whereas BARI Gom 21 seedling treated with SA under same level of salt stresses the number of seedling were 58.33 and 31.67% (Fig. 1B). However, In case of BARI Gom 25, at 100 and 150 mM NaCl stress the number of normal seedling were 51.67 and 14.17% respectively whereas BARI Gom 25 seedling treated with SA under same level of stresses the number of seedling were 70.83 and 45.83%.

Abnormal seedling: SA treatment reduced the number of abnormal seedling under salt stress condition. In case of BARI Gom 21 the abnormal seedling was significantly higher than that of BARI Gom 25. At 150 mM NaCl level caused the highest abnormal seedling (78.97%) in case of BARI Gom 21 whereas the lowest abnormal seedling (3.35%) found when seedling treated only with SA in case of BARI Gom 25 (Fig. 1C).

Length of shoot (cm): The data (Fig. 2A) showed that salt stress significantly reduced the shoot length as compared to control conditions in BARI Gom 21 (salt sensitive) and BARI Gom 25 (salt tolerant) wheat cultivars. Extent of reduction was higher in BARI Gom 21 than BARI Gom 25. On the contrary, exogenous application of SA increased the shoot length in both the cultivars under saline and non-saline conditions.

Length of root: Salinity caused (Fig. 2B) a significant reduction ($p \leq 0.05$) in the root length of wheat plants of both cultivars compared to those in non-saline solution and magnitude of decrease was less in BARI Gom 25 as compared to BARI Gom 21. Sharp increases in root length were observed in the seedlings which were treated with SA under salt stressed condition (27, 45 and 63% for BARI Gom 21 and 8, 7 and 4% for BARI Gom 25 at SA treated 50, 100 and 150mM, respectively) than the respective controls (Fig. 2B). Moreover, both of variety did not get significant result at 200 mM and SA treated 200 mM salt stressed conditions.

Fresh weight of shoot seedling^{-1}: Fresh weight of shoot was higher in unstressed control of both varieties than salt stressed plants. As shown in Fig. 3A, salinity stress treatment decreased fresh weight of shoot by 17, 51, 65 and 93% for BARI Gom 21 and 10, 41, 77 and 86% for BARI Gom 25 at 50, 100, 150 and 200 mM NaCl stressed condition. However, SA supplementation in salt stressed plants caused increases fresh weight of shoot for both of variety. In different, 200 mM NaCl and SA treated 200 mM NaCl plant gave statistically similar result for both of variety (Fig. 3A). Control and only SA treated plant of BARI Gom 25 produced higher fresh weight of shoot which was statistically similar with control and only SA treated plant of BARI Gom 21 fresh weight result.

Fresh weight of root seedling^{-1}: Fresh weight of root was also decreased in the same way which was 19%, 49%, 62%, 84% for BARI Gom 21 and 14%, 38% 71%, 80% for BARI Gom 25 at 50, 100, 150 and 200 mM NaCl stressed conditions, respectively (Fig. 3B). Importantly, SA supplementation in salt treatment significantly increased the fresh weight of root compared to salt stressed seedlings.

Dry weight seedling^{-1}: Fig. 3C shows that seedling dry weight was decreased by adverse effect of salinity treatment when compared with control. Higher seedling dry weight was recorded in only SA treated seedlings (0.0035 g) of BARI Gom 25 which was statistically similar with control (0.0034 g) of BARI Gom 25 (Fig. 3C). On the other hand, 200 mM NaCl stressed and SA treated seedlings did not give any significant result. Among the cultivars, BARI Gom 25 (salt tolerant) showed a better performance and produced more dry weight under salt stress when compared with BARI Gom 21; however, the reverse was true under non-saline conditions.

Plant height: Sharp decreases in plant height was observed in response to salt stress, compared to the untreated control at 30, 45, 60 DAS and at harvest for both of variety (Table 1). However, SA supplementation with salt treatment increased plant height up to 100 mM NaCl stressed condition for both of variety. But after 100 mM NaCl stressed treatment plant height became statistically similar with SA treated salt treatment at 30, 45, 60 DAS and at harvest. Importantly, SA treatment with 200 mM salt stress at 30 DAS gave lower result than respective control (Table 1). But in case of BARI Gom

21, SA treatment with 200 mM NaCl stress produced similar plant height with 200 mM stress treatment.

Tiller hill^{-1}: The data (Table 2) showed that salinity also reduced the tiller number hill^{-1} in both cultivars of wheat. On the other hand, the magnitude of decrease was less in BARI Gom 25 as compared to BARI Gom 21. The SA treated salt-stressed seedlings had significantly higher tiller number hill^{-1} (9, 31, and 39% at 30 DAS; 7, 16 and 31% at 45 DAS; 6, 19 and 29% at 60 DAS in BARI Gom 21 and 12,15 and 26% at 30 DAS; 6, 14 and 21% at 45 DAS; 2, 13 and 23% at 60 DAS in BARI Gom 25 at SA treated 50, 100 and 150 mM NaCl stresses, respectively), compared to the seedlings subjected to salt stress without SA treatment (Table 2). At 200 mM NaCl, SA could not give any higher result compared to its respective control for both of variety.

Fresh weight plant^{-1}: As shown in Table 3, the fresh weight in wheat plants decreased significantly under salt stress compared to the control. Control and only SA treated plant of BARI Gom 25 gave significantly higher fresh weight (3.96, 4.01g at 30 DAS; 9.22, 9.46g at 45 DAS and 11.89, 12g at 60 DAS, respectively) compared to other salt stressed and SA treated stressed plants of those variety and other variety (BARI Gom 21). On the contrary, supplementation of SA under stressed condition could increase fresh weight of plant compared to its control for both of variety. But, it had limitation. Because it could not affect 200 mM stressed condition, where fresh weight would not increase or decrease.

Dry weight plant^{-1}: A significant reduction in dry weight plant^{-1} was observed in both varieties of wheat plants exposed to salt stress as compared to the untreated control (Table 4). However, addition of SA, in combination with salt stress significantly increased dry weight in both varieties, compared to addition of salt only. But, after 200 mM SA treatment could not increase dry weight of wheat plant. In BARI Gom 21, at 30, 45 and 60 DAS and in BARI Gom 25, at 45 DAS, the dry weight of wheat plant became decreased with the treatment of SA at 200 mM salt stressed condition, where in other growth duration for both varieties gave similar result with 200mM salt stressed condition. Besides, when only SA was applied, the dry weight of wheat plant was similar to that in the untreated control. The highest dry weight was found in BARI Gom 25 at all growth duration (0.71 and 0.70 g at 30 DAS, 2.56 and 2.55 g at 45 DAS and 3.48 and 3.48 g at 60 DAS at control and only SA treated plant, respectively).

Table 1. Plant height of two wheat varieties at different growth duration induced by saline, SA and their combination.

Variety	Treatment	Plant height (cm)			
		30 DAS	**45 DAS**	**60 DAS**	**At harvest**
BARI Gom 21	C	30.20ab	43.07bc	67.77c	85.10bc
	SA	29.73b	44.97b	68.17c	86.47b
	S50	24.67d	36.00e	61.07e	75.97e
	S50+SA	28.13c	40.17d	62.73de	82.00d
	S100	21.83f	33.60f	53.33g	69.00f
	S100+SA	24.53de	32.77f	58.97f	74.50e
	S150	19.67gh	27.43g	46.80h	60.73g
	S150+SA	20.17g	29.07g	47.67h	62.53g
	S200	17.77ij	22.93h	37.20j	54.87h
	S200+SA	16.47j	23.00h	34.30k	54.23h
BARI Gom 25	C	31.47a	48.83a	73.93a	91.63a
	SA	31.03ab	48.30a	74.00a	92.27a
	S50	27.20c	41.80cd	70.30b	85.33bc
	S50+SA	30.77ab	44.90b	71.77b	90.57a
	S100	24.93d	37.00e	62.70de	81.63d
	S100+SA	27.87c	36.90e	63.20d	83.80cd
	S150	23.30e	32.67f	53.63g	74.87e
	S150+SA	23.67de	33.93f	58.567f	75.87e
	S200	20.67fg	28.30g	46.73hi	68.80f
	S200+SA	18.63hi	28.33g	44.80i	68.57f
CV (%)		**3.33**	**3.46**	**2.06**	**2.10**
LSD (0.05)		**1.336**	**2.044**	**1.974**	**2.634**

Mean (±SD) was calculated from three replicates for each treatment. Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD test

Table 2. Effect of SA on tillers hill^{-1} of wheat cultivars under saline and non saline conditions at different age.

Variety	Treatment	Tillers hill^{-1}		
		30 DAS	45 DAS	60 DAS
BARI Gom 21	C	1.97b	2.20bcd	2.37bc
	SA	1.93b	2.23abc	2.43ab
	S50	1.63e	2.03ef	2.23de
	S50+SA	1.80cd	2.07ef	2.23de
	S100	1.33g	1.60j	1.83f
	S100+SA	1.37g	1.87gh	1.93f
	S150	1.17ij	1.43l	1.47h
	S150+SA	1.20hi	1.53jkl	1.70g
	S200	1.07jk	1.17m	1.17j
	S200+SA	1.00k	1.20m	1.03k
BARI Gom 25	C	2.23a	2.27ab	2.47ab
	SA	2.17a	2.33a	2.53a
	S50	1.93b	2.10de	2.27cd
	S50+SA	1.97b	2.13cde	2.43ab
	S100	1.70de	1.73i	2.13e
	S100+SA	1.90bc	1.97fg	2.17de
	S150	1.50f	1.57jk	1.67g
	S150+SA	1.67e	1.80hi	1.90f
	S200	1.30gh	1.43l	1.47h
	S200+SA	1.20hi	1.47kl	1.33i
CV (%)		**4.46**	**4.36**	**3.77**
LSD (0.05)		**0.118**	**0.130**	**0.120**

Mean (±SD) was calculated from three replicates for each treatment. Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD test

Table 3. Fresh weight of two wheat varieties grown on normal and saline condition at different growth durations as affected by SA application.

Variety	Treatment	Fresh weight (g) plant^{-1}		
		30 DAS	45 DAS	60 DAS
BARI Gom 21	C	3.78abc	7.62b	9.44d
	SA	3.72bc	7.67b	9.67cd
	S50	2.85de	5.67d	7.00h
	S50+SA	3.71bc	6.96c	8.85ef
	S100	2.56f	5.08e	6.67h
	S100+SA	2.78ef	5.67d	6.77h
	S150	2.11g	4.67ef	4.96i
	S150+SA	2.15g	4.78ef	5.44i
	S200	1.74h	4.04g	3.85j
	S200+SA	1.70h	3.56h	4.11j
BARI Gom 25	C	3.96ab	9.22a	11.89a
	SA	4.01a	9.46a	12.00a
	S50	3.81abc	7.00c	10.07bc
	S50+SA	3.85abc	8.00b	10.22b
	S100	3.09d	6.67c	7.72g
	S100+SA	3.67c	6.77c	9.18de
	S150	2.82ef	5.11e	6.72h
	S150+SA	2.79ef	5.68d	8.67f
	S200	1.93gh	4.74ef	5.11i
	S200+SA	1.94gh	4.60f	5.11i
CV (%)		**5.50**	**4.48**	**4.05**
LSD (0.05)		**0.268**	**0.455**	**0.513**

Mean (±SD) was calculated from three replicates for each treatment. Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD test

Table 4. Effect of SA application on dry weight of two wheat varieties under normal and salt affected condition.

Variety	Treatment	Dry weight (g) plant^{-1}		
		30 DAS	**45 DAS**	**60 DAS**
BARI Gom 21	C	0.63bc	2.20c	2.80c
	SA	0.64b	2.21c	2.71cd
	S50	0.60cd	1.93ef	2.17fg
	S50+SA	0.59d	1.93e	2.42e
	S100	0.44g	1.53gh	1.96h
	S100+SA	0.49f	1.91ef	2.21f
	S150	0.38ij	1.30i	1.53ij
	S150+SA	0.39i	1.45h	1.55h
	S200	0.30k	1.05j	1.21k
	S200+SA	0.29k	0.91k	1.40j
BARI Gom 25	C	0.71a	2.56a	3.48a
	SA	0.70a	2.55a	3.48a
	S50	0.68a	2.11cd	3.18b
	S50+SA	0.68a	2.39b	3.17b
	S100	0.50f	1.80f	2.55de
	S100+SA	0.56e	2.04de	2.88c
	S150	0.40hi	1.58g	2.01gh
	S150+SA	0.43gh	1.61g	2.47e
	S200	0.35j	1.21i	1.64i
	S200+SA	0.37ij	1.01jk	1.65i
CV (%)		**4.16**	**4.47**	**4.52**
LSD (0.05)		**0.035**	**0.130**	**0.173**

Mean (±SD) was calculated from three replicates for each treatment. Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD test

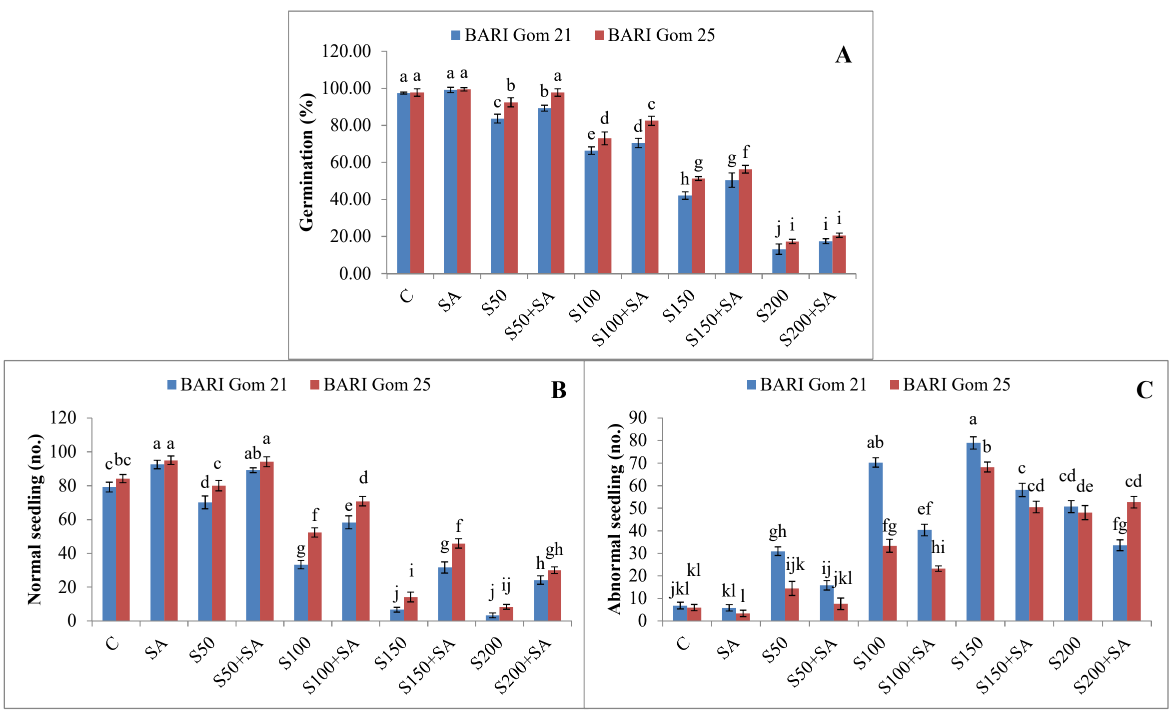

Fig 1. (A) Germination (%), (B) Normal seedling and (C) Abnormal seedling in salt sensitive and salt tolerant wheat plants induced by exogenous salicylic acid under salt stress. S50, S100, S150 and S200 indicate 50 mM, 100 mM, 150 mM NaCl and 200 mM NaCl, respectively. SA indicates 1 mM salicylic acid spray, respectively. Mean (±SD) was calculated from three replicates for each treatment. Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD test.

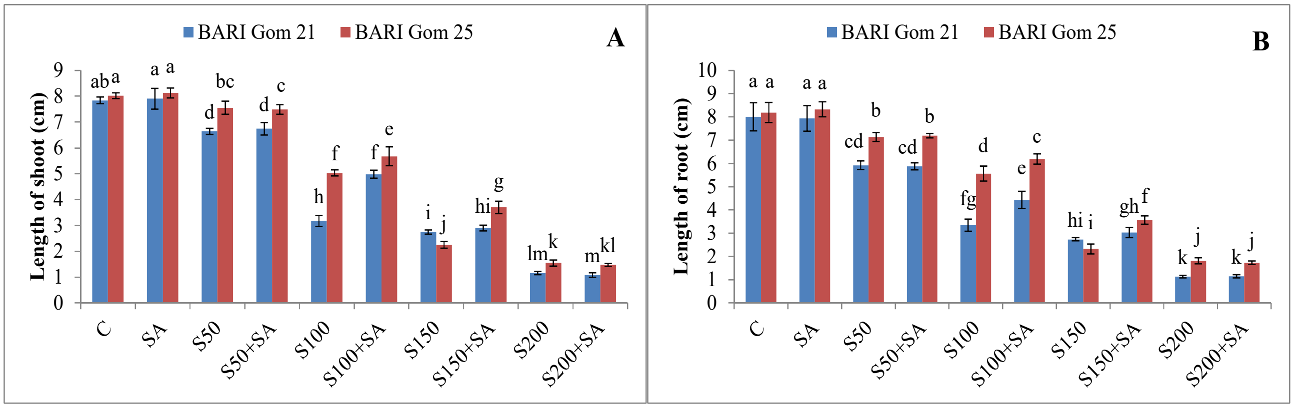

Fig 2. (A) Length of shoot and (B) Length of root in salt sensitive and salt tolerant wheat plants induced by exogenous salicylic acid under salt stress. S50, S100, S150 and S200 indicate 50 mM, 100 mM, 150 mM NaCl and 200 mM NaCl, respectively. SA indicates 1 mM salicylic acid spray, respectively. Mean (±SD) was calculated from three replicates for each treatment. Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD test.

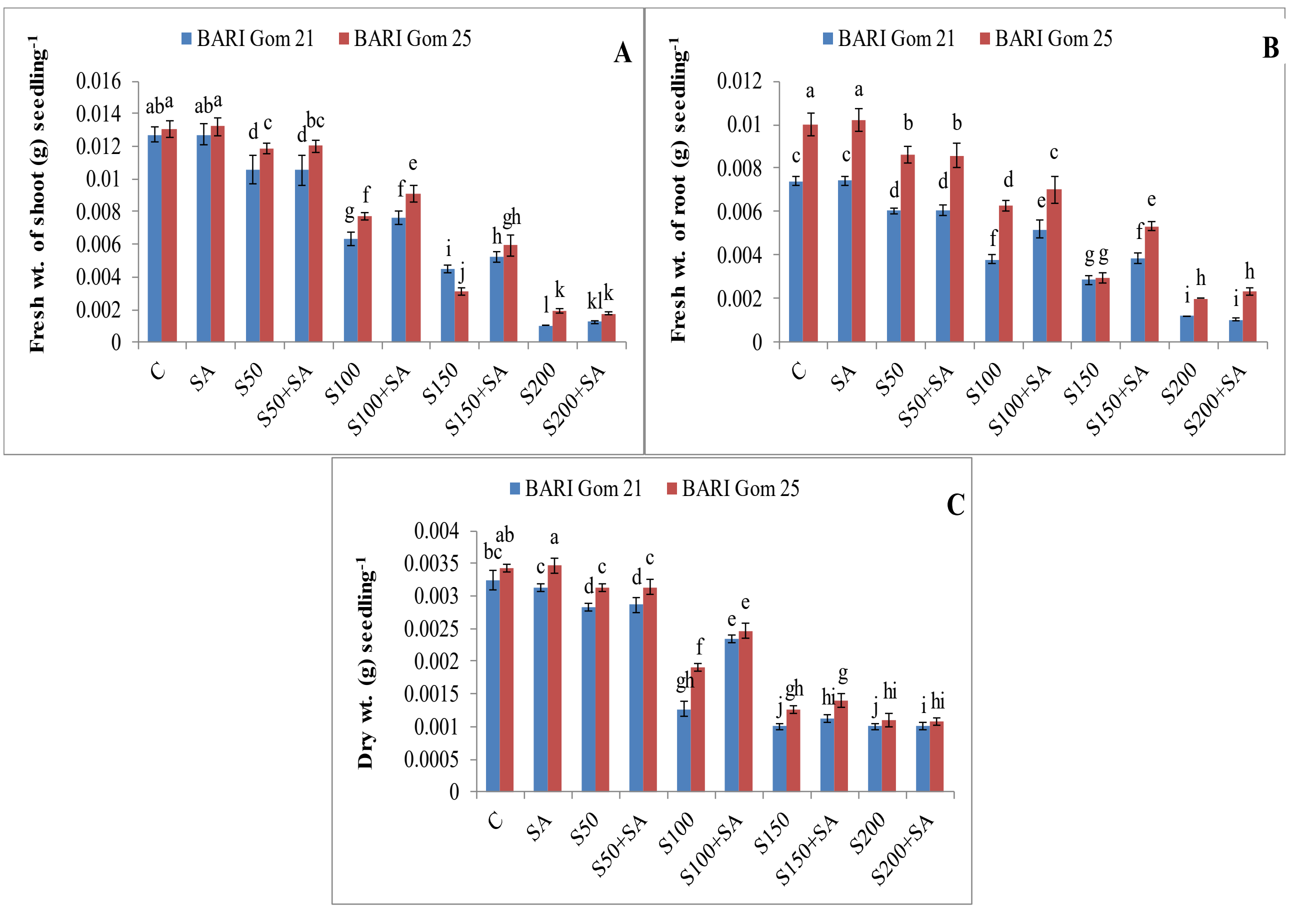

Fig 3. (A) Fresh weight of shoot seedling^{-1}, (B) Fresh weight of root seedling^{-1} and (C) Dry weight seedling^{-1}in salt sensitive and salt tolerant wheat plants induced by exogenous salicylic acid under salt stress. S50, S100, S150 and S200 indicate 50 mM, 100 mM, 150 mM NaCl and 200 mM NaCl, respectively. SA indicates 1 mM salicylic acid spray, respectively. Mean (±SD) was calculated from three replicates for each treatment. Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD test.

DISCUSSION

In this study, we observed that germination percentage delayed and decreased with increasing NaCl concentration and drastically reduced at 200 mM NaCl (Fig. 1A). Salinity also reduced the number of normal seedling and increased number of abnormal seedling (Fig. 1B, 1C). Osmotic stresses reduce germination percentage (Cornelia *et al*., 2008; Maghsoudi and Arvin, 2010). The seeds pre-treated with SA solutions exhibited higher germination percentage. These results are consistent with those of Maghsoudi *et al*., (2010) in wheat, Dolatabadian *et al*., (2009) in wheat and Anaya *et al*., (2015) in *Vicia faba L.* . Promotion in seed germination with SA may be due to increased uptake of oxygen and α-amylase activity. As a result, nutrient mobilized efficiently from cotyledons to the embryonic axis and soluble sugar contents, free amino acids and proteins become increased. This may indicate that, SA pre-treated wheat seeds exhibited an increase in salt tolerance (Zhang *et al*., 1999). We used BARI Gom 25 as a tolerant variety, but it could not tolerate the extreme condition of salinity compared to normal and other saline environment after pretreating with SA (Fig. 1).

The growth parameters (fresh and dry mass of roots and shoots, their lengths) decreased progressively with the rise of stress level, compared with the control (Fig. 2A, B;, 3A-C). Salinity caused a dramatic decrease especially in 200 mM NaCl in root and shoot lengths and fresh-dry weights in 5 days old seedlings, but SA treatments ameliorated this adverse effect (Fig. 2A, B). Moreover, the roots were insensitive than shoots. The other researcher reported similar results (Akbarimoghaddam *et al*., 2011; Sajid *et al*., 2016). Shakirova *et al.*, (2003) reported that SA increased indole acetic acid content and cell division and extense root cell under saline environment to diminish the destructive action of salinity stress. Another researcher was also reported that SA triggers root formation in some crops under stress condition (Khan *et al*., 2003).

Shoot and root fresh weight and dry weight antagonistically affected after increasing NaCl concentration. Fresh weight and dry weight reduction relatively depends on shoot or root length. These results are in agreement with those of Ghoulam *et al*. (2002) and Akbarimoghaddam *et al*., (2011). The plants subjected to NaCl and subsequently treated with SA, possessed higher fresh and dry mass compared to those grown without SA treatment (Fig. 3A-C). Exogenous application of SA through the rooting medium had an ameliorative effect as well as growth promoting effect under non-saline and saline conditions (Arfan *et al*., 2007; Afzal *et al*., 2006; Karlıdag *et al*., 2009; Azooz, 2009; Erdal *et al*., 2011; Turkyilmaz, 2012; Habibi and Abdoli, 2013). These results were similiar to earlier studies which showed that exogenous application of SA promotes growth and counteracts the stress-induced growth inhibition in some crop species (Singh and Usha, 2003; Dolatabadian *et al*., 2009). This result was consistent with the report of Kaydan *et al*. (2007), who found that a pre-sowing soaking treatment of the seeds that were treated with SA positively affected the shoot and root dry mass in wheat seedlings under both saline and control conditions. Gunes *et al*., (2005) also reported that, SA increases fresh and dry matter of salt stressed plant because it may be activated antioxidant response and defense mechanism of membrane to tolerate under saline environment.

In this experiment, we observed that, plant height reduced with increasing salinity (Table 1) which was similar with the report of Khan *et al*., (2007); Turki *et al*., (2014) and Kalhoro *et al*., (2016) in wheat. Under saline environment, number of tillers also reduced (Table 2) which was previously reported by El-Hendawy (2005) and Goudarzi *et al*. (2008). The most important assessment of salt tolerance in wheat is shoot fresh and dry weight because a positive correlation existed between these traits and yield related parameters. Singh *et al*. (1994) who found that salt stress reduces leaf area photosynthetic ability and dry matter accumulation. The similar result found by Turki *et al*., 2014 and Kalhoro *et al*., 2016. SA plays key roles in the regulation of plant growth, development, the interaction with other organisms, and the responses to environmental stresses (Senaratna *et al*., 2000 and Hayat *et al*., 2010). Therefore, in the present study, the effect of exogenously treated SA on growth rate of wheat plants growing under different salt stress when compared with their corresponding non-SA applied plants (Table 1-4). Singh and Usha (2003) reported that SA counteracted growth inhibition caused by water stress, one of the major factors caused by salinity stress in plants when it was applied with foliar spray. This is not consistent with the reports of Idrees *et al*. (2011) where it was shown that SA treatment ameliorated the adverse effects of salt stress in terms of growth parameters in *Catharanthus roseus*. Similarly, SA treatment enhanced the growth of maize (Khodary, 2004), mustard (Yusuf *et al*., 2008) and barley (El Tayeb, 2005) under NaCl stress. Increase in growth of wheat under non-saline or saline conditions from which SA treatment resulted, can be attributed to an increase in photosynthesizing tissue, that is, the leaves (Dhaliwal *et al*., 1997; Arfan *et al*., 2007), which is in agreement with the results obtained also. These results are in agreement with those obtained by Ali and Adel (2013) and Erdal *et al*., (2011).

Conclusion: Based on our results we conclude that under salt stress condition accumulation of Na^+ in the seeds may have an adverse effect on seed germination resulting in delaying germination time and decreasing germination percentage in wheat. Plant growth also decreased due to salt stress. Especially, the exact mechanism of mode of action of SA is still poorly understood, because it differs with different species and also depends on environment. Moreover, the role of SA as well as detailed protective mechanisms would be helpful for developing stress tolerance in plants.

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