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Effect of Drought Stress and its Interaction with Salicylic Acid on Black Cumin (*Nigella sativa*) Germination and Seedling Growth

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Abstract: To evaluate the effects of salicylic acid pretreatment on enhancement of seed germination of *Nigella sativa* under drought stress a factorial experiment based on completely randomized design was employed. Treatments were the combination of five levels of drought stress induced by PEG (0, -0.1, -0.2, -0.3 and -0.4 MPa) and four concentrations of salicylic acid (0, 0.25, 0.5, 0.75 and 1 mM) with three replications. Results indicated that an increase in drought stress reduced germination components such as germination percentage and rate, total biomass, seed vigor index, root length, root fresh and dry weight, shoot length, shoot fresh and dry weight. Salicylic acid improved germination; therefore, the average time necessary for germination decreased under drought conditions. The seeds treated by salicylic acid, produced a higher root and shoot length, root and shoot fresh and dry weight, total biomass and seed vigor index. Salicylic acid ameliorated the negative effects of drought stress on black cumin germination and seedling's growth. Higher concentrations of SA were more effective than the lower ones. It seems that SA can enhance the tolerant ability of the seeds to germination under drought stress.

Key words: Drought stress · Germination · *Nigella sativa* · Salicylic acid

INTRODUCTION

Drought is one of the most serious world-wide problems for agriculture, which determines the success or failure of plant's establishment [1]. The effects of water deficiency depend on several factors such as its intensity, duration, phonological phase of growth and genetic resistance capacity of plants. Water stress affects different aspects of plant growth (morphology, physiology and anatomy) and causes many changes such as decrease or delay in germination, aerial organ growth reduction, decrease in dry biomass and in rate of growth [2]. The determined metabolically and physiological responses of agricultural plants to the drought stress condition were studied, but for the pharmaceutical and aromatic plants under the lack of humidity are not known. Seed germination is mostly an issue in medicinal plant seed's emergence [3]. Among the plant growth stages, seed germination and seedling emergence and establishment are key processes in the survival and growth of plants [4]. Taylor *et al.* [5] demonstrated that the seed germination and emergence are reduced at a low negative osmotic potential. At the germination stage, drought could decrease shoot and root length [6]; at the vegetative period, it would decrease shoot growth [7] and cause dehydration on cell and osmotic imbalance [8]. Jalali Honarmand [9] reported that germination percentage in wheat seed was decreased under drought conditions. Furthermore, other studies indicated that stem length is more sensitive to drought stress than root length [10]. Heikal *et al.* [11] investigated the effect of different osmotic stresses obtained with polyethylene glycol 6000 solutions on the germination of flax, sesame and onion seeds. The rate of seed germination and the final germination percentages as well as the amount of water absorbed by the seeds were considerably lowered with the rise of osmotic stress levels. Seed priming treatments 1such as osmopriming, hydro priming and hormonal priming have been employed to accelerate the germination, seedling growth and yield in most of the crops under normal ad stress conditions [12]. Although, the mechanism of seed priming treatments is not fully understood, it has been observed that physiological and biochemical changes take place during the seed

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treatments [13]. The benefits of seed priming to have been reported, including improving stand establishment at semi-arid condition [14] and at drought stress [15], enhancing seed with low vigor [16], improving dormancy breakdown [17], or increasing productivity [18]. Seed priming accelerates seed germination and seedling establishment under both normal and stressful environments [19].

Salicylic acid (SA) is an endogenous growth regulator from group phenol compounds that influence many physiological processes such as germination [20], seedling's growth [21, 22], stomatal closure [23], membrane permeability [24], the control over ion intake to roots and stomatal conductivity [25], the content of photosynthetic pigments [26] and the rate of photosynthesis [27]. Salicylic acid is a conservative compound of some biological stresses and it is an important molecular signal for adjustment plant's reaction to environmental stresses [28]. The inclusion of SA at 0.5 mM in the germination medium was associated with increase germination percentage of tomato [29].

Nigella sativa L. is an annual herbaceous plant belonging to the Ranuculacea family and is a crop which is being focused on by farmers because of its multiple uses. For example, the potential uses of black cumin seeds are as sources of oil and protein. In particular, the seed oil is used as a semi-drying vegetable oil in the surface coating industry and in the production of many oleochemicals (i.e. fatty acid methyl esters, fatty alcohols, alkanolamides and sucrose esters). Seeds of black cumin (*Nigella sativa* L.) are used as a spice in cooking and in a wide traditional medicinal use, the seed volatile oil and its main active constituent, thymoquinone, are extensively reported to exhibit protective effects against many diseases depending on its high antioxidant activity [30].

Polyethylene Glycol (PEG) compound has been used to simulate osmotic stress effects in Petri dish (in vitro) for plants to maintain uniform water potential throughout the experimental period [31].

Therefore, the aim of this study was to investigate the effect of drought stress on seed germination and seedling growth of black cumin (*Nigella sativa* L.) and to test whether seed priming with salicylic acid (SA) could mitigate the adverse effects of drought stress.

MATERIALS AND METHODS

This study was carried out at the Faculty of Agriculture, Shahid Bahonar university of Kerman, Iran, in 2011.

Germination and seedling growth was studied during 14 days under control and drought stress conditions. For implementation of drought stress, four different concentrations of PEG (-0.1, -0.2, -0.3 and -0.4 MPa) were used. Distilled water was used as control. Homogenous seeds of *Nigella sativa* were surface sterilized using 5% sodium hypochlorite solution for 5 min to eliminate possible Seed-borne microorganisms and then rinsed three times with sterile distilled water. The seeds of black cumin were subjected to seed priming; the first group was hydroprimed [soaked in distilled water] and while the second group was osmoprimed [soaked in 0.25, 0.5, 0.75 and 1 mM salicylic acid (SA)] for 24 hour, (these concentrations was suggested after some preliminary experiment). After soaking period the seeds were air dried.

Germination test was conducted by three replications of 20 seeds from every treatment in 9 centimeters Petri dishes. Top of Whatman paper No.2 was moistened with 10 ml different concentrations of PEG solution or distilled water (as a control). In order to avoid water losses, Petri dishes were tightly sealed with impermeable colorless paraffin and then placed in a germination chamber at 21±1°C with 70% relative humidity. All Petri dishes and filter papers were disinfected in 120 °C for 2 hours. Radicle length of 2 mm was scored as germination [32]. Length of radical and shoot measured by millimetric ruler and for measuring of fresh and dry weight of radical and shoot a balance were used to milligram (Sartorius model: LIBROR AEL- 40 SM). Germination percentage was recorded every day during the study period.

After 14 days, germination percentage (GP), germination rate (GR) (seeds day^{-1}), Root Length (mm), Shoot Length (mm), Root fresh and dry weight (mg plant^{-1}), Shoot fresh and dry weights (mg plant^{-1}) were determined. Rate of germination (seeds day $^{-1}$) was estimated using Maguire's equation [33].

$$GR = \Sigma\ Si/Di$$

Where GR is germination rate (the number of germinated seeds per day), Si is the number of germinated seeds at each counting and Di is number of days until the nth count. Dry weights of root and shoot (mg plant^{-1}) were measured after drying samples at 70°C for 48 h in an oven [6]. Germination was expressed as the Final Percentage of Germination was calculated according to the method of Maguire's equation [33]:

$$GP = (n/N) \times 100$$

GP = Percent of Germination.
N = Number of total seeds.
n = number of germinated seeds.

Total Biomass = Root Dry Weight + Shoot Dry Weight

The seed vigor index (SVI) of the seed was estimated as suggested by Abdul-Baki and Anderson [34] as follows:

SVI = [germination percentage × mean (radicle length + plumule length)] / 100

Statistical Analysis: The experiment was conducted in a factorial arrangement based on completely randomized design with 25 treatments and three replications. Static assays were carried out by one-way ANOVA using LSD test to evaluate whether the means were significantly different, taking $p<0.05$ as significant. Computations and statistical analysis were done using SAS and MSTATC.

RESULTS AND DISCUSSION

Drought stress induced by Polyethylene glycol (PEG_{6000}) caused a significant reduction in all the measured traits, including germination percentage and rate, total biomass, seed vigor index, root length, root fresh and dry weight, shoot length, shoot fresh and dry weight (Table 1). Pretreatment with salicylic acid (SA) markedly alleviated the effects of water stress and also ameliorated all the measured parameters significantly. Salicylic acid applied through seed soaking was more effective within the range of 0.5–1 mM in protecting *Nigella sativa* seedlings against drought stress.

The highest and lowest germination percentage was recorded for control and -0.4 MPa treatments respectively (Table 2). This treatment reduced the germination percentage by 91.9% compared to control. Increasing the drought stress from 0 to -0.4 MPa led to a reduction in germination rate. Highest level of osmotic potential caused a reduction of 96.7% in germination rate compared to control (Table 2).

SA affected germination percentage and rate (Table 3). The highest and lowest value of these traits belonged to 0.5 mM SA and control respectively. The concentration of 0.5 mM SA caused an increasing of 21.9% and 26.9% in germination percentage and rate compared to control respectively.

The response of germination percentage to the interaction of SA concentrations and drought levels were different, so that no germination observed at the 0.25 and 0.5 mM SA at -0.4 MPa treatments while 0.75 and 1 mM SA led to germination at the mentioned level of drought (Table 4). Based on these results, it seems that higher concentrations of SA ameliorate germination. Drought stress adversely affected GP in non-primed seeds. The highest reduction of GP was recorded for -0.3 MPa treat ments, meantime no germination occurred at the -0.4 MPa treatment. The difference in GP was not statistically significant between -0.1 Mpa and control treatments, while both were significantly higher than the other two treatments. Applying SA caused an increase in GP at all levels of drought compared to 0 mM SA. The highest and lowest germination rate belonged to -0.1 and -0.3 MPa treatments under stress conditions at 0.25 and 0.5 mM levels of SA. No Germination rate was recorded for hydroprimming and primed treatments with 0.25 and 0.5 mM at -0.4 MPa treatments, while its value for 0.75 and 1 mM were 0.32 and 0.28 respectively (Table 4).

The effect of osmotic potential on total biomass and seed vigor index of Black cumin were shown on Table 2. On the basis of these results, increasing drought levels caused remarkably decrease in total biomass and seed vigor index (Table 2). All the levels of drought stress were significantly different with each other. So that, the highest of total biomass (1.84) and seed vigor index (75.6) were recorded for control treatment, they decreased by increasing osmotic potential and reached to 0.68 and 11.9 respectively.

SA had a significant effect on total biomass and seed vigor index of black cumin (Table 3). The difference in these traits was statistically significant between control and all concentrations of SA. The highest concentration of SA caused an increment of 39.7% and 39.5% in a total biomass and seed vigor index compared to control respectively.

The interaction of drought and SA showed that treatment of *Nigella* with SA through seed soaking could prevent the decrease in total biomass and seed vigor index caused by drought stress. Moreover, seedling pretreatment with 0.5 and 1 mM SA had the highest of these traits under normal and stress condition (Table 4).

Root length was also reduced by increasing drought stress and all the treatments were significantly different from control (Table 2). Root length reduced from 62.1mm at normal condition to 20.9 mm at the highest osmotic potential.

As shown in table 2, the effect of drought levels on root fresh and dry weight was similar and with the increasing drought levels, both traits reduced significantly. The highest value of both traits belonged to control, but the lowest of these traits belonged to -0.3 MPa treatment (Table 2).

The effect of SA pretreatment on root length, root fresh and dry weight was significant. Increasing concentration of SA caused remarkably increase in the mentioned traits (Table 3). The greatest increase in root

length, root fresh and dry weight was observed in the concentration of 1 mM SA as 37%, 38.9% and 37.5% compared to non-primed seedlings respectively.

Table 1: Mean squares for germination percentage and rate, total biomass, seed vigor index, root length, root fresh and dry weight, shoot length, shoot fresh and dry weight of *Nigella sativa*.

		MS									
SOV	DF	Germination percentage	Germination rate	Total biomass	Seed vigor index	Root length	Root fresh weight	Root dry weight	Shoot length	Shoot fresh weight	Shoot dry weight
SA	4	375.5*	0.431^{ns}	0.54**	596.84**	503.21**	16.22**	0.05**	176.9**	21.54**	0.3**
Drought	4	13815.5**	30.41**	7.62**	13859.73**	8313.3**	251.95**	0.77**	2448.1**	370.95**	3.56**
SA ×Drought	16	106.3^{ns}	0.113^{ns}	0.06**	82.31^{ns}	138.5**	2.18*	0.008*	17.4^{ns}	1.83^{ns}	0.04**
Error	50	112.3	0.27	0.023	65.96	49.9	1.03	0.004	19.6	1.5	0.01

**, * and ns denote significant differences at 0.01, 0.05 % levels and not significant respectively.

Table 2: The effect of drought stress on germination percentage and rate, total biomass, seed vigor index, root length, root fresh and dry weight, shoot length, shoot fresh and dry weight of *Nigella sativa*.

Drought levels (MPa)	Germination percentage	Germination Rate (Seed/day)	Total biomass (mg/plant)	Seed vigor index	Root length (mm)	Root fresh weight (mg/plant)	Root dry weight (mg/plant)	Shoot length (mm)	Shoot fresh weight (mg/plant)	Shoot dry weight (mg/plant)
0	82. 67a	3.65a	1.84a	75.6a	62.1a	10.6a	0.6a	32.3a	12.98a	1.24a
-0.1	69b	2b	1.47b	50.5b	44.6b	8.3b	0.44b	28b	10.5b	1.03b
-0.2	46c	0.9c	1.1c	26.7c	33.9c	6.1c	0.33c	23.4c	8.65c	0.77c
-0.3	29.667d	0.5d	0.68d	11.9d	20.9d	3.8d	0.21d	14.9d	5.91d	0.46d
-0.4	6.67e	0.12d	0	0	0	0	0	0	0	0

Means followed by the same letter(s) in each column are not significantly different at the 5% level.

Table 3: The effect of salicylic acid (SA) on germination percentage and rate, total biomass, seed vigor index, root length, root fresh and dry weight, shoot length, shoot fresh and dry weight of *Nigella sativa*.

SA levels (mM)	Germination percentage	Germination Rate (Seed/day)	Total biomass (mg/plant)	Seed vigor index	Root length (mm)	Root fresh weight (mg/plant)	Root dry weight (mg/plant)	Shoot length (mm)	Shoot fresh weight (mg/plant)	Shoot dry weight (mg/plant)
0	39.3b	1.18b	0.73c	23.6c	25.3b	4.41d	0.25d	14.2c	5.6c	0.48c
0.25	44ab	1.35ab	0.99b	31.1b	29.7b	5.63bc	0.31bc	19.2b	7.5b	0.68b
0.5	50.3a	1.59a	1.17a	38.6a	36a	6.21b	0.34b	22.5a	8.4ab	0.84a
0.75	51a	1.55ab	0.98b	32.5b	30.4b	5.35c	0.29cd	20.1ab	7.9ab	0.7b
1	49.3a	1.5ab	1.2a	39a	40.1a	7.2a	0.4a	22.6a	8.6a	0.81a

Means followed by the same letter(s) in each column are not significantly different at the 5% level.

Table 4: The effect of salicylic acid (SA) pretreatment on germination percentage (GP) and rate (GR), total biomass (TB), seed vigor index (SVI), root length (RL), root fresh (RFW) and dry (RDW) weight, shoot length (SL), shoot fresh (SFW) and dry (SDW) weight of *Nigella* under different levels of drought stress.

SA × Drought	GR	GP (seed/day)	TB (mg/plant)	SVI
0 mM SA				
Control	78.333 ab	3.2767 ab	1.41fg	60.961 bc
-0.1 MPa	58.333 cde	1.4067 def	1.0933 h	34.212 ef
-0.2 MPa	41.667efgh	0.7967 fgh	0.7148 jk	17.326 gh
-0.3 MPa	18.333ij	0.4 gh	0.4156 l	5.556 hi
-0.4 MPa	0 k	0 h	0	0
0.25 mM SA				
Control	85 a	3.5233 a	1.8278 bc	77.817 a
-0.1 MPa	61.667 bcd	1.81 cde	1.5222 def	44.478 de
-0.2 MPa	48.33 defg	1.01efg	1.1133 h	25.594 fg
-0.3 MPa	25 hij	0.4167 gh	0.5222 kl	7.65 hi
-0.4 MPa	0 k	0 h	0	0
0.5 mM SA				
Control	86.667 a	4.0567 a	2.2767 a	86.339 a
-0.1 MPa	80 a	2.43 bc	1.5822 cdef	60.933 bc
-0.2 MPa	53.333 def	1.0233 efg	1.2178 gh	33.289 ef
-0.3 MPa	31.667ghij	0.4533 gh	0.7811ij	12.5 ghi
-0.4 MPa	0 k	0 h	0	0

Table 4: Continue

0.75 mM SA				
Control	81.667 a	3.69 a	1.73 bcd	73.317 ab
-0.1 MPa	73.333 abc	2.26 c	1.4531efg	50.303 cd
-0.2 MPa	41.667efgh	0.8133 fgh	1.0933 h	22.889 fg
-0.3 MPa	40 fgh	0.65 fgh	0.6437 jkl	15.783 gh
-0.4 MPa	18.333 ij	0.321 gh	0	0
1 mM SA				
Control	81.667 a	3.68 a	1.9444 b	79.589 a
-0.1 MPa	71.667 abc	2.1167 cd	1.6778 cde	62.694 bc
-0.2 MPa	45 defg	0.84 fgh	1.3711fg	34.589 ef
-0.3 MPa	33.333 ghi	0.56 fgh	1.03hi	17.978 gh
-0.4 MPa	15 jk	0.28 gh	0	0

RL	RFW	RDW	SL	SFW	SDW	
SA × Drought	(mm)	(mg/plant)	(mg/plant)	(mm)	(mg/plant)	(mg/plant)
0 mM SA						
Control	49.33 cdef	9.117 cdef	0.4633 cde	28.33 abc	10.22 cd	0.9467 def
-0.1 MPa	37.44 ghij	6.778 gh	0.3822 efghi	20.89 defg	7.778 efg	0.711 gh
-0.2 MPa	26.22 jkl	4.278 ij	0.2678 jkl	14.996 fg	6.778 gh	0.447 ij
-0.3 MPa	13.556 n	1.889 k	0.1344 m	6.778 hi	3.22 i	0.281 j
-0.4 MPa	0	0	0	0	0	0
0.25 mM SA						
Control	60.22 bc	10.544 bc	0.6467 ab	31.33 ab	13.11 a	1.1811 bc
-0.1 MPa	42.889 fgh	8.44 ef	0.4211 defg	29.11ab	10.744 bc	1.101 bcd
-0.2 MPa	31.44 hijk	5.676 hi	0.31 hijk	21.44 cdef	8.33 defg	0.8033 fg
-0.3 MPa	14 mn	3.478 jk	0.1889 lm	13.889 gh	5.33 h	0.33 j
-0.4 MPa	0	0	0	0	0	0
0.5 mM SA						
Control	82.33 a	12.556 a	0.7122 a	34.44 a	14.218 a	1.5644 a
-0.1 MPa	45.667 efg	8.583 def	0.4311 defg	30.667 ab	10.889 bc	1.1511 bc
-0.2 MPa	34 hijk	6.22 gh	0.3456 fghij	27.78 abcd	9.44 cdef	0.8722 efg
-0.3 MPa	18.22 lmn	3.667 j	0.1911 lm	19.667 efg	7.44 fg	0.59 hi
-0.4 MPa	0	0	0	0	0	0
0.75 mM SA						
Control	56.89 bcde	9.739 bcde	0.5 cd	33.22 a	13.33 a	1.23 bc
-0.1 MPa	39.56 fghi	7.556 fg	0.4053 defgh	29.056 ab	10.556 bc	1.0478 cde
-0.2 MPa	30 ijk	5.33 hi	0.2889 ijkl	24.44 bcde	9.11 cdef	0.8044 fg
-0.3 MPa	25.56 klm	4.11 ij	0.2367 klm	14 gh	6.556 gh	0.407 ij
-0.4 MPa	0	0	0	0	0	0
1 mM SA						
Control	61.889 b	11.22 ab	0.66556 ab	34.333 a	14 a	1.2789 b
-0.1 MPa	57.556 bcd	10.11 bcd	0.5611bc	30.33 ab	12.44 ab	1.1167 bcd
-0.2 MPa	47.78 defg	8.75 def	0.44667 def	28.11 abcd	9.56 cde	0.9244 def
-0.3 MPa	33. 33 hijk	6 gh	0.34 ghijk	20.33 efg	7 gh	0.69 gh
-0.4 MPa	0	0	0	0	0	0

Means followed by the same letter(s) in each column are not significantly different at the 5% level.

Interaction between drought stress and SA pretreatment indicated that priming with 0.5 mM SA statistically showed the highest root length as compared to control and other concentrations of SA under non stress condition. Root fresh and dry weight also was affected the interaction of drought and SA, So that pretreatment with 1 mM SA caused an increasing of these traits at all levels of drought stress (Table 4).

Various shoot lengths were obtained at the different osmotic potentials (Table 2). The decreasing of osmotic potential reduced shoot length compared to control. The highest reduction in shoot length (53.9 %) belonged to the -0.3 MPa treatment compared to control. The shoot fresh and dry weight was negatively affected by drought stress. Drought caused a greater reduction in fresh and dry weight of shoot at higher concentrations compared to control condition (Table 2)

All the concentrations of SA were different from control significantly (Table 3). At the concentration of 1 mM SA, the shoot length, shoot fresh and dry weight were increased by approximately 37.2%, 34.9% and 40% when they were compared with their control treatments respectively.

Maximum shoot length and shoot fresh weight was achieved in seeds primed with 0.5 mM SA, which was statistically similar to all the remaining treatments under normal condition; while this concentration of SA was significantly different from the other levels of SA in shoot dry weight under control condition. But, considering the latter trait, under stress conditions, the level of 1 mM SA was much better than the others (Table 4).

Drought is an important factor influencing the growth and physiological characteristics of plants [35]. The responses of plants to drought stress depend on the species and genotype, the length and severity of water deficit and the age and stage of development [36]. Severe stresses reduced germination percentage and rate, seedling emersion and vigor [37].

Drought stress induced by PEG decreased germination percentage and also delayed germination time at the highest concentrations due to lower water uptake by seed resulting in decreases of germination. The decrease in water potential gradient between seeds and their surrounding media by the effects of PEG_{6000} adversely affects seed germination. Lower germination due to limited water uptake by the seeds was also reported by Dodd and Donovan [38].

Drought stress reduced germination percentage and rate (Table 2). These results were in agreement with the findings of Yadavi *et al* [39], Gholami *et al* [40], Basu *et al* [41] and Jatai and Afzal [42]. Germination rate was more sensitive than germination percentage; this is correlated well with the results of AL-Taisan [43] who reported that osmotic potential decreased germination rate more than germination percentage. Root length is one of the most important characters for drought stress due to it contacts with soil and absorbing water. For this reason, root length plays an important role in the response of plants to drought stress [44]. The reduction of enzyme's activity and hormones sprinkle and disorder in photosynthesis and growth in seedlings, which were subjected to drought stress, was probably the reasons of decreasing in shoot length [45]. Gamze *et al* [1], Alam *et al* [46] and Baalbaki *et al* [47] showed that drought stress caused a reduction in seedling growth, root and shoot length, fresh and dry weight of root and shoot.

In this study, the interactive effect of salicylic acid (SA) and drought on *Nigella sativa* was investigated. Drought stress induced by PEG reduced germination percentage and rate, total biomass, seed vigor index, root length, root fresh and dry weight, shoot length and shoot fresh and dry weight of black cumin, while SA alleviated drought stress damages and increased all the mentioned traits under normal and stress conditions. SA is a compound that able to decrease harmful effects of drought stress on germination, root and shoot length, root fresh and dry weight and shoot fresh and dry weight [48]. Applying of SA stimulated germination due to scavenging of ROS. Baalbaki *et al* [47] reported that seed priming with SA caused the reduction of oxidative damages and increased antioxidant enzymes activity during germination. The obtained results on winter wheat [49], sunflower [32] and rice [50] showed that SA is a moderate stimulant for germination. Singh and Usha [51] and Hayat and Ahmad [52] suggested that increase in germination and dry mass of water stressed plants in response to SA may be related to the induction antioxidant responses that protect the plants from damage. Senaratna *et al* [53] have suggested a similar mechanism to be responsible for SA induced multiple stress tolerance in bean and tomato plants. Similar results were also reported by Sakhabutdinova *et al* [54] who found that SA changed the plant hormone's balance and seeds which were treated with SA caused a sharp accumulation of abscisic acid (ABA) and prevented the decrease in indole-3-acetic acid (IAA) and cytokinin content, which reduced inhibitory effects of water and salinity stresses on plant growth. Zhang *et al.* [55] reported that SA has an inhibitor role in the ethylene biosynthesis. Furthermore, it was reported that SA regulate cell extension, division and death and in fact, it created a balance between growth and senescence [55]. AL-Hakimi and Hamada [56] have shown that the treatment of wheat plants with SA through seed soaking could ameliorate the inhibitory effect of drought and stimulate grown by enhancing photosynthetic rate and reducing dark respiration. Several reports proved that seed priming with SA caused an increasing of seedling length, seedling fresh and dry weight, total biomass and seed vigor index [16, 57, 58].

In conclusion, the application of exogenous protection compound (such as salicylic acid) could increase the antioxidant capacity of plant against stress condition.

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