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EFFECTS OF SEEDS PRIMING WITH PLANT GROWTH REGULATORS ON GERMINATION AND SEEDLING GROWTH OF HARGEL (*SOLENOSTEMMA ARGEL* (DEL.) HAYNE) UNDER SALINITY STRESS

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Abstract

Salt stress is a wide-reaching problem, and new strategies are required to alleviate this problem. This study was designed to define whether seed treated with plant hormones can reduce the negative impacts of salt stress on Hargel (*Solenostemma argel* (Del.) Hayne) during seeds germination and seedling growth. Hargel seeds were presoaked with plant hormones at the rate of 0.0 mM without hormone (CK), 0.144, 0.288 mM of gibberellic acid (GA_3), 0.362, 0.724 mM of salicylic acid (SA), and 0.285, 0.571 mM of indole acetic acid (IAA). Seeds were treated with salinized water at 0, 25, 50, 75 and 100 mM NaCl. The research was designed in CRD as a factorial experiment while each treatment was replicated thrice. The interaction between salinity and growth hormones significantly influenced water uptake at 24 h, shoot length, root length and root fresh weight. At 100 mM NaCl, the dose of 0.288 mM GA_3 increased root length by 19%; in addition, the dose of 0.724 mM SA increased shoot length by 57.5% and root length by 19.0%. However, the dose of 0.285 mM IAA increased by 139.2%, while the dose of 0.571 mM IAA increased water uptake after 24 h by 31.0% compared to 0.0 mM without hormone at 100 mM NaCl. These findings suggest that using 0.288 mM GA_3, 0.724 mM SA, and 0.285 mM IAA in proper concentration might reduce inhibitory effects of salinity stress on Hargel.

Key words: Abiotic stress, Medicinal plant, Phyto-hormones, Early seedlings growth.

Introduction

Salinity is abiotic stress that affects plants' growth and production (Chrysargyris *et al*., 2018). The ionic and osmotic pressure in plant cells due to salt stress degrade crop development by affecting physiological processes (Nasri *et al*., 2017), elevating the production of reactive oxygen species (ROS), increasing the lipid peroxidation, membrane leakage, ion imbalance (Amanifar *et al*., 2019), limiting seeds germination, early plant establishment, and consequently the development of plant growth (Ali *et al*., 2019; Ibrahim *et al*., 2019).

Plant hormones are molecules produced in very low concentrations that can act near to/or transport to other parts from their synthesis sites to mediate physiological, biochemical, and/or molecular responses of plants under optimal or stressful conditions (Peleg & Blumwald, 2011). The growth and development of plants is organized in a coordinated manner through the stimulation of various plant hormones that play an essential role in regulating various physiological as well as biochemical processes (Iqbal *et al*., 2014).

Seed germination is an essential and sensitive stage of plant growth because this phase's duration determines seedling establishment and future plant growth (*Hakim et al*., 2010; Gupta & Huang, 2014). Thus, the study for the interaction of plant growth with salt stress at germination and the young seedling stage is necessary for developing salt-tolerant plants.

Pre-soaking treatment may be used to mitigate the impact of many stresses on seed germination. Seed treatment with plant growth regulators (PGR) is sometimes an easy and low-cost approach to alleviate the detrimental effects of stresses (Talat Rashad, 2019). Seeds treated with salicylic acid (SA) and gibberellin can improve plants growth and enhance their responses to abiotic stresses (salinity, temperature, and drought stresses) and oxidative damage (El-Tayeb, 2005). The effects of SA for mitigating the impacts of salt stress have been reported in various crops such as faba bean (*Vicia faba L*) (Anaya *et al*., 2018), french marigold seeds (*Tagetes patula* L) (Afzal *et al*., 2017), rice (*Oryza sativa* L) (Jini & Joseph, 2017), wheat (*Triticum aestivum* L.) (Fardus *et al*., 2018), and sea lavender (*Limonium bicolor*) seeds (Liu *et al*., 2019). It has already been reported that IAA has an essential role in developing and adapting plants under environmental stresses (Kazan, 2013; Iqbal *et al*., 2014; Fahad *et al*., 2015). Some investigations revealed that wheat seeds treated with IAA decreased the harmful effects of salt stress (Afzal *et al*., 2005; Ashraf & Foolad, 2005).

Hargel (*Solenostemma argel* (Del.) Hayne) is one of the majority of the traditional medicinal plants used as a drug worldwide (Shayoub *et al.*, 2013). It treats many diseases, including jaundice, cystitis, abdominal cramps (Ibrahim *et al*., 2015), diabetes mellitus, cough, cold, hypercholesterolemia, and measles (El-Kamali & Khalid, 1998). After thorough of literature, it came to our knowledge that little attention has been paid to the responses of seed germination of hargel under salinity stress. Although this medicinal plant is widely cultivated under, marginal soils that face different abiotic stresses such as salinity.

The hypothesis of this study is that the harmful impacts of salt stress on the Hargel plant could be mitigated by growth regulators such as GA_3, SA, and IAA at different levels as well as these hormones can strengthen the germination of seed and seedling growth of hargel plant. Therefore, the objective of this study was to assess the impacts of seeds priming with different concentrations of GA_3, SA, and IAA for alleviating the inhibitory impacts of salt stress on seed germination and young seedlings characteristics of the hargel plant.

Materials and Methods

Plant materials: The hargel seeds were collected from Sudan. Seeds approximately the same in size, shape, and colour were selected, disinfected with 1% NaOCl (Sodium hypochloride) for three minutes, washed with distilled water, and air-dried at room temperature for 24 hours.

Experimental design: The study was conducted in a controlled environment in a growth chamber at the Joint International Research Laboratory of Agriculture and Agri-Product Safety (JILAR) of Ministry of Education of China, Yangzhou University (32°39′ N, 119°41′E), Jiangsu Province, China. The experimental design was a factorial (salinity and hormones) arranged in a completely randomized design (CRD) with three replications. The salinity levels included 0, 25, 50, 75 and 100 mM NaCl (sodium chloride). The exogenous hormonal levels included 0.0 mM without hormone designated as CK (control), GA_3 (0.144, and 0.288 mM), SA (0.362 and 0.724 mM), and IAA (0.285, and 0.571mM). Seeds of each treatment (3 g) were soaked in the various concentration of hormonal solution for 12 hours at room temperature in the dark; thereafter, the solutions were thrown away and the seeds were air-dried under shade for two days (Afzal *et al*., 2005). Ten seeds were placed in a 9 cm Petri dish with two layers of filter paper moistened with distilled water or saline water (5 mL NaCl solutions at the different salinity levels). All the Petri dishes were covered with lids to reduce evaporation. Finally, the seeds were incubated at 35°C and 28°C (day- night temperature) and 16/8 h day/ night under photoactive radiation (PAR) of 500 W/ m^2, while relative humidity (RH) was set at 40% - 55% during the experiment.

Measurements

Seed water uptake (SWU): The SWU uptake at 12 and 24 h was determined using the following formula (Ibrahim *et al*., 2016).

$$Seed\ Water\ Uptake\ (\%) = \frac{(\text{Seed}\ final\ weight - Seed\ initial\ weight)}{(\text{Seed}\ initial\ weight)} \times 100$$

Seeds germination percentage (SG %): The SG% was calculated by the following formula:

$$SG\% = Gs/Ts \times 100$$

Where is:

SG% = Seed germination percentage; Gs = Number of germinated seed; Ts = Total number of seeds.

Germination rate (GR): GR was calculated using the following formulae (Anon., 1983):

$$Germination\ rate = \frac{Number\ of\ \ germinated\ seed}{Day\ of\ the\ first\ count} + (\ldots) + \frac{Number\ of\ \ germinated\ seed}{Day\ of\ the\ final\ \ count.}$$

Seedling vigour index (SVI): SVI was calculated using the following formula (Abdul-Baki & Anderson, 1970), to

$$Seedling\ vigour\ index\ = \frac{Germinaton\ percentage\ (\%) \times The\ average\ seedling\ length\ (cm)}{100}$$

Growth parameters: After 10 d of seeding, three seedlings were selected at random from each Petri dish, separated into shoots and roots, and the following measurements were taken; SL (shoots length), RL (roots length), roots fresh and dry weight and, shoots fresh and dry weight.

Data analysis: Analysis of Variance (ANOVA) was computed using the statistical package of MSTAT-C (Abdelgadir *et al*., 2010). 'F' values were cautiously taken into consideration, while means were separated by LSD (least significant difference) test ($p \leq 0.05$).

Results

Seed water uptake (SWU): Salinity, hormone and their interactions exhibited significant ($p \leq 0.05$) effected at various salinity and PGR levels (Table 1). At 100 mM NaCl level of salinity, SWU reduced by 28.2% compared with 0 mM NaCl (control). However, when seeds were treated with 0.288 mM GA_3 and 0.571 mM IAA at 100 mM NaCl, SWU was increased by 23.9% and 31.0%, respectively as compared with 0.0 mM without hormone (Table 2).

Table 1. The ANOVA table for seed water uptake (SWU), germination rate (GR), seed germination percentage (SG%), shoot length (SL), root length (RL), shoot fresh weight (SFW), root fresh weight (RFW), shoot dry weight (SDW), root dry weight (RDW) and seedling vigor index (SVI) of hargel as influenced by salinity and the exogenous hormones.

Source	F value		
	Salinity	Hormone	Salinity × Hormone
SWU after 12 h	8.09^{**}	1.09^{ns}	0.76^{ns}
SWU after 24 h	23.81^{***}	9.32^{***}	2.32^{**}
GR	137.14^{***}	9.65^{***}	1.10^{ns}
SG%	122.31^{***}	6.80^{***}	0.78^{ns}
SL	1362.47^{***}	9.20^{***}	4.73^{***}
RL	37.84^{***}	3.60^{**}	2.90^{***}
SFW	76.35^{***}	7.03^{***}	1.51^{ns}
RFW	53.12^{***}	3.59^{**}	2.04^{*}
SDW	18.18^{***}	6.15^{***}	0.76^{ns}
RDW	46.18^{***}	2.69^{*}	0.90^{ns}
SVI	1724.58^{***}	5.28^{***}	0.32^{ns}

Ns = Insignificant difference; * = Significant difference at $p \leq 0.05$; ** = Significant difference at $p \leq 0.01$; *** significance different at $p \leq 0.001$

Germination characteristics

Germination rate (GR): Salinity and growth hormones at different levels have significantly affected the germination rate (Table 1). The high salinity level of 100 mM NaCl reduced germination rate by 65.9% compared with 0 mM NaCl (Fig. 1a). Regarding the different levels of GA_3, the highest germination rate was observed at the dose of 0.144 mM GA_3 (4.63), followed by the dose of 0.288 mM GA_3 (4.33). While the dose of 0.362 mM SA and the dose of 0.285 mM IAA increased germination rate by 47.4% and 48.7%, respectively, compared to 0.0 mM without hormone (Fig. 1b).

Seed germination percentage (SG%): Salinity and growth hormones at different levels have significantly affected seed germination percentage (Table 1). Salinity was reduced SG% by 5.4%, 24.0%, 38.7%, and 43.6% at 25, 50, 75, and 100 mM NaCl, respectively, compared to control (0 mM NaCl) (Fig. 2a). Among all hormones treatment the dose of 0.288 mM GA_3 had the highest SG% (89.3%). In addition, at 0.362 and, 0.724 mM SA increased SG% by 16.5%, and 6.2%, while, IAA at 0.285 mM, and 0.571Mm were increased SG% by 10.3%, and 13.4%.as compared to 0.0 mM without hormone (Fig. 2b).

Growth parameters

Shoots length (SL): Salinity, hormone and their interactions have significantly affected SL (Table 1). SL was significantly reduced when salinity levels increased. The interaction between 75 mM NaCl with 0.0 mM without hormone, and the interaction between 100 mM NaCl, with 0.0 mM without hormone, decreased SL by 50.9% and 64.0% respectively, as compared with control (0.0 mM without hormone with 0 mM NaCl). All exogenous hormones treatments increased shoot length to some extent over the control. At 50 mM NaCl, SL increased by 51.8% at 0.288 mM GA_3, 23.6% at 0.724 mM SA and 20.0% at 0.571 mM IAA compared with 0.0 mM without hormone at the same salinity level. While, at 100 mM NaCl level, SL was higher than the control by 23.8%, 58.0%, and 23.8% at, 0.288 mM GA_3, 0.724 mM SA and 0.571 mM IAA respectively, compared with 0.0 mM without hormone (Table 2).

Roots length (RL): Salinity, hormone and their interactions have significantly affected RL (Table 1). With the increase of salinity, RL was significantly decreased. At the interaction between 0 mM NaCl with 0.0 mM without hormone, root length was decreased by 26.3%, 31.7%, 40.3%, and 57.1% in 25, 50, 75, and 100 mM NaCl respectively, compared with 0 mM NaCl at 0.0 mM without hormone. All hormones treatments significantly increased root length. At 75 mM NaCl, RL increased by 25.4% at 0.144 mM GA_3, 18.8% at 0.724 mM SA and 11.7% at 0.571 mM IAA compared with 0.0 mM without hormone at the same salinity level. While, at the high salinity level of 100 mM NaCl, 0.288 mM GA_3, 0.724 mM SA, and 0.571 mM IAA increased root length by 19.0%, 19.0%, and 16.0%, respectively, compared with 0.0 mM without hormone (Table 3).

Table 2. The effect of interaction between salinity × hormones on Seed water uptake after 24 h and Shoot length (cm) of hargel seeds.

Parameters	Salinity (mM NaCl)	CK (mM)	GA_3 (mM)		SA (mM)		IAA (mM)	
		0.0	0.144	0.288	0.362	0.724	0.285	0.571
Seed water uptake after 24 h	0	71.68ef	73.47cde	76.19b	74.49bcd	71.79ef	79.04a	73.54cde
	25	61.31no	65.24jkl	63.86klm	69.49g	72.69de	68.87gh	65.36jkl
	50	56.46p	68.91gh	68.72gh	74.70bc	64.63jklm	69.47gh	63.38lm
	75	54.15q	62.66mn	60.44o	65.49ijk	66.05ij	70.22fg	66.36ij
	100	51.50r	62.69mn	63.81klm	59.95o	61.08no	55.54pq	67.45hi
Shoot length (cm)	0	3.28e	4.18b	3.98c	3.33e	3fg	3.7d5	4.45a
	25	2.45ij	3.28e	3.65d	2.81gh	2.69h	2.75h	3.15ef
	50	1.95kl	2.62hi	2.96fg	2.28j	2.41j	2.34j	2.08k
	75	1.12op	1.81lm	1.6n	1.85lm	1.7mn	1.56n	1.71mn
	100	0.80q	0.97pq	0.99pq	1.22o	1.26o	0.92pq	0.99pq

Similar alphabet in the column denote non-significant variation at $p \leq 0.05$ level

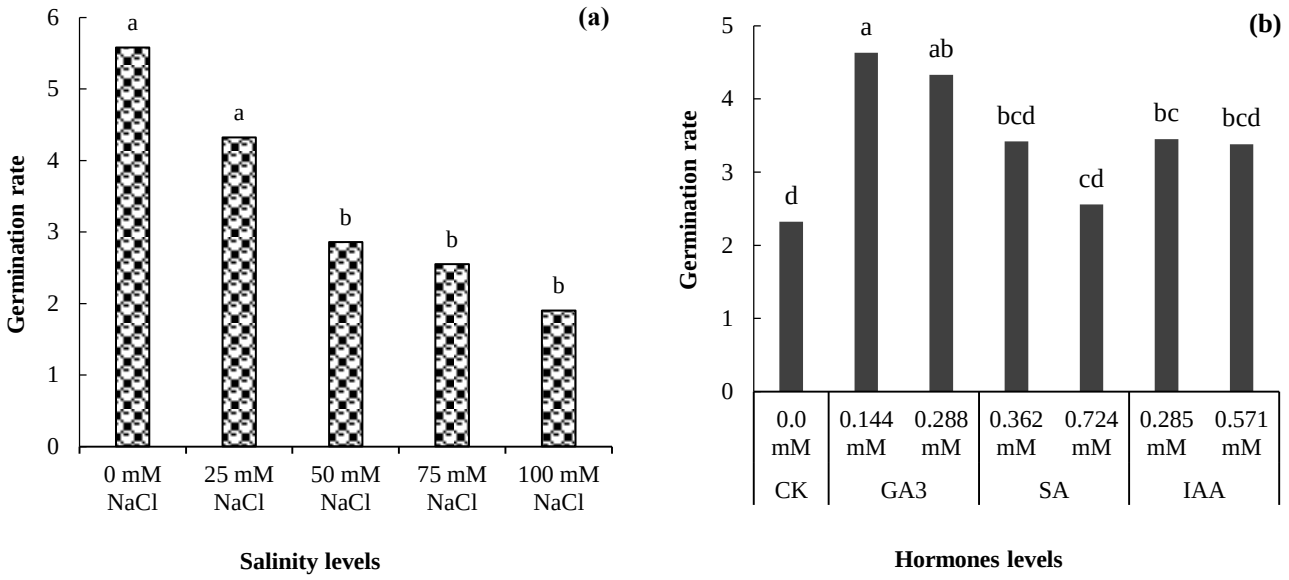

Fig. 1. The effects of (a) salinity and (b) hormones on Germination rate of hargel plant Bars have different letters, which differ statistically at a probability level of $p \leq 0.05$.

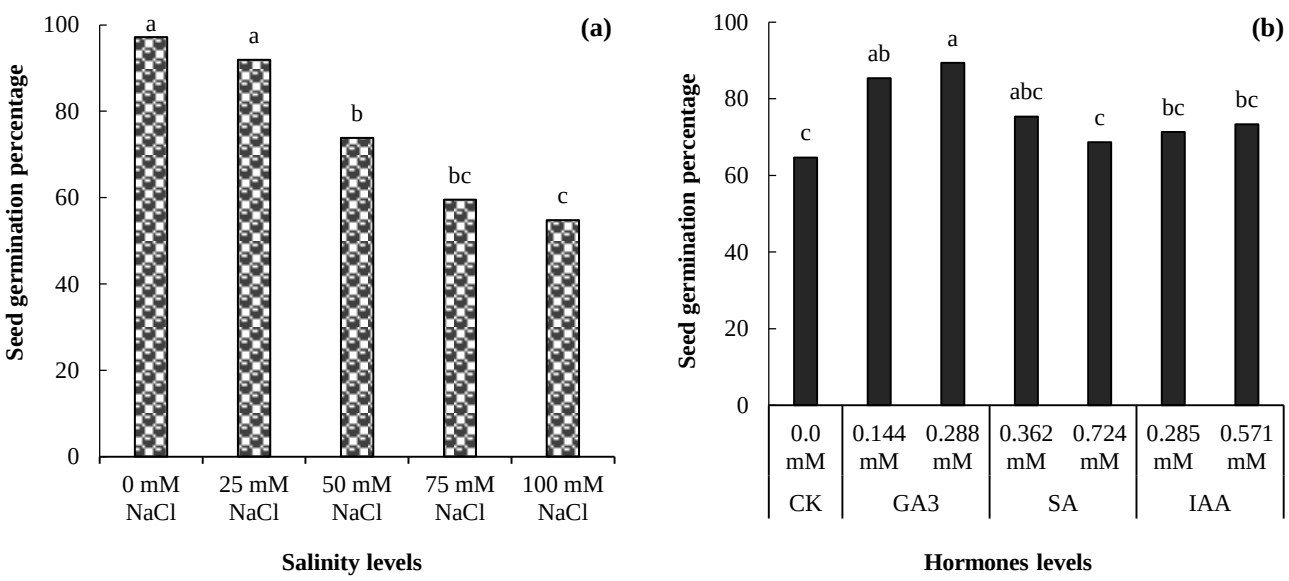

Fig. 2. The effect of (a) salinity and (b) hormones on Seed germination percentage of hargel plant. Bars have different letters, which differ statistically at a probability level of $p \leq 0.05$.

Table 3. The effects of interaction between salinity × hormones on root length (cm) and root fresh weight (mg/plant) of hargel seedling.

Root parameters	Salinity (mM NaCl)	CK (mM)	GA_3 (mM)		SA (mM)		IAA (mM)	
		0.0	**0.144**	**0.288**	**0.362**	**0.724**	**0.285**	**0.571**
Root length (cm)	0	3.57e	4.54c	5.50a	4.50c	4.16d	4.20d	4.37cd
	25	2.63gh	4.84b	3.07f	2.63gh	3.27f	3.20f	4.36cd
	50	2.44ghi	2.67g	3.31ef	2.42ghi	2.54ghi	2.54ghi	2.63gh
	75	2.13lm	2.67g	2.39ghi	2.29ij	2.53ghi	2.26jkl	2.38hij
	100	1.53p	1.73nop	1.82no	1.59op	1.82no	1.77nop	1.75nop
Root fresh weight (mg/plant)	0	22.41de	24.12d	32.82bc	34.11ab	23.01d	35.72a	30.98c
	25	16.41j	22.81d	17.03ij	18.43hi	15.29j	20.55efg	20.74ef
	50	7.93mn	19.48fgh	18.66ghi	12.46k	10.93kl	12.13k	8.63mn
	75	8.38mno	12.07k	7.27mn	9l.0m	6.7mn	8.34mn	5.41mno
	100	2.37u	3.43qu	4.27p	3.22qu	3.33qu	5.67o	3.17q

Similar alphabet in the column denote non-significant variation at $p \leq 0.05$ level

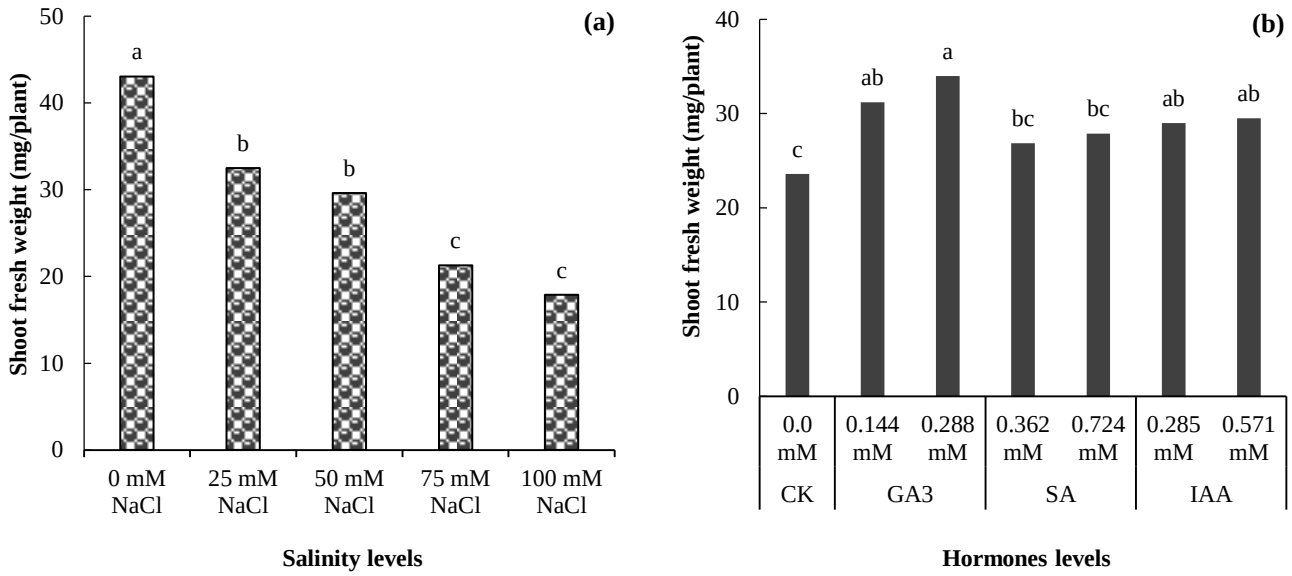

Fig. 3. The effect of (a) salinity and (b) hormones on Shoot fresh weight (mg/plant) of hargel seedlings. Bars have different letters, which differ statistically at a probability level of $p \leq 0.05$.

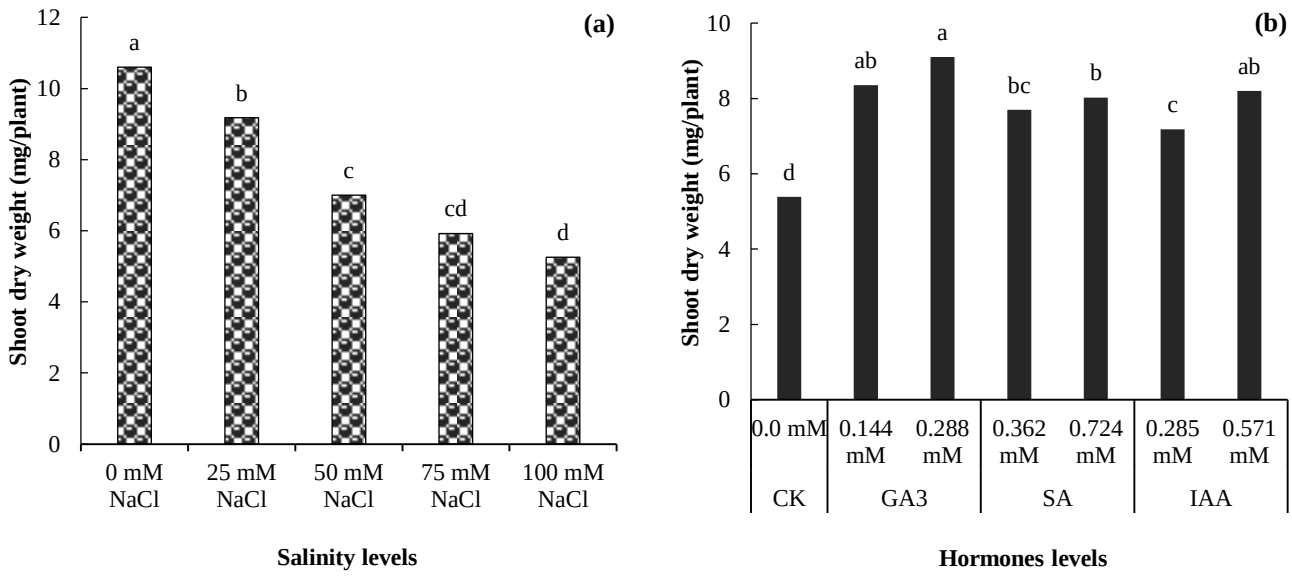

Fig. 4. Effects of (a) salinity and (b) hormones on Shoot dry weigh (mg/plant) of hargel seedlings. Bars have different letters, which differ statistically at a probability level of $p \leq 0.05$.

Shoots fresh weight (SFW): Salinity, hormones at different levels have significantly affected SFW (Table 1). SFW was significantly decreased by 24.5%, 31.2%, 50.6%, and 58.5% at 25, 50, 75, and100 mM NaCl respectively, compared with control of salinity (Fig. 3a). Among the different hormones, the highest values of shoot fresh weight were 34.0 mg/plant, 28.0 mg/plant, and 29.5 mg/ plant recorded at 0.288 mM GA_3, 0.724 mM SA and, 0.571mM IAA respectively (Fig. 3b).

Roots fresh weight (RFW): RFW was significantly affected by Salinity, hormone and their interactions (Table 1). Increased salinity levels were significantly decreased the RFW. However, all hormonal treatments with salinity levels have increased the RFW. At the control of hormone (0.0 mM), the level of 100 mM NaCl decreased RFW by 89.4% compared with 0 mM NaCl. At the high salinity level (100 mM NaCl), the highest values of RFW were 4.3 mg/plant and 5.67 mg/plant, recorded at 0.288 mM GA_3 and 0.285 mM IAA respectively, while the lowest value was 2.37 mg/plant, recorded at 0.0 mM without hormone (Table 3).

Shoots dry weight (SDW): Salinity and hormones at different levels had significantly affected SDW (Table 1). SDW was decreased by 44.2% and 48.9 % at 75 and 100 mM NaCl levels, respectively, compared with 0 mM NaCl (Fig. 4a). The SDW of hormonally treated seeds were significantly increased. The dose of 0.288 mM GA_3, 0.724 mM SA and 0.571 mM IAA, were increased the SDW by 69.0%, 48.8%, and 52.1% respectively, compared with 0.0 mM without hormone (Fig 4b).

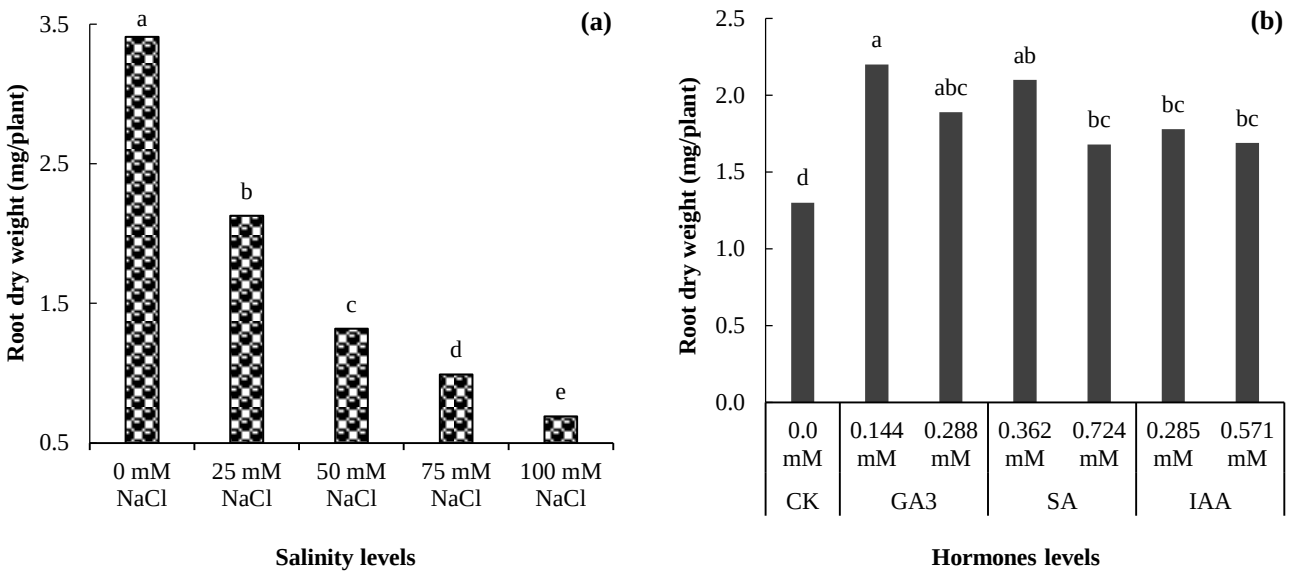

Fig. 5. The effect of (a) salinity and: (b) hormones on root dry weight (mg/plant) of hargel seedlings. Bars have different letters, which differ statistically at a probability level of $p \leq 0.05$.

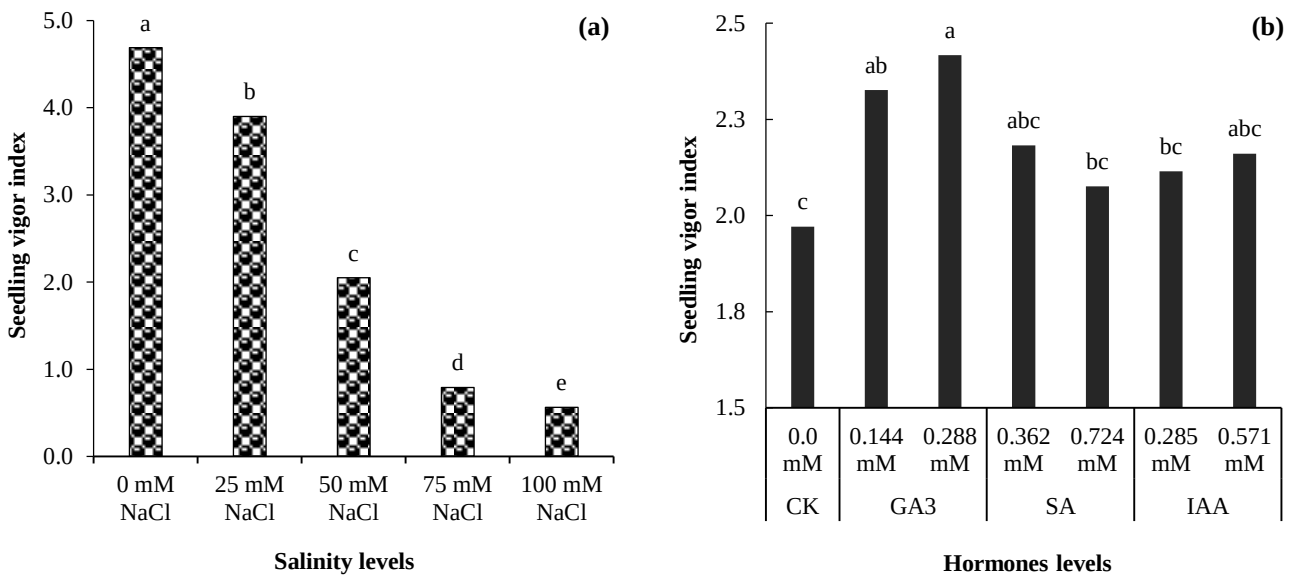

Fig. 6. The effect of (a) salinity and (b) hormones on seedling vigor index of hargel seedlings. Bars have different letters, which differ statistically at a probability level of $p \leq 0.05$.

Roots dry weight (RDW): Salinity and hormones at different levels had significantly affected RDW (Table 1). The highest value of RDW was 2.14 mg/plant and 2.02 mg/plant, recorded at the dose of 0.144 mM GA_3 and 0.362 mM SA, respectively (Fig. 5b). RDW was significantly reduced when salinity levels increased. RDW decreased by 71.0%, 65.8%, 61.3%, and 37.6% at different salinity level of 100, 75, 50 and 25 mM NaCl respectively, compared to control of salinity (0 mM NaCl) (Fig. 5a).

Seedling vigour index (SVI): SVI had significantly affected by different levels of salinity and hormones (Table 1). Compared to control of salinity (0 mM NaCl), both high salinity levels of 75 mM NaCl and100 mM NaCl reduced the seedling vigour index by 83.2% and 88.1% (Fig. 6a). All hormonal treatments increased seedling vigour index. The dose of 0.288 mM GA_3, 0.724 mM SA and 0.571 mM IAA, increased seedling vigor index by 22.8%, 10.7%, and 9.6% respectively, compared to 0.0 mM without hormone (Fig. 6b).

Discussion

The seed germination stage is an essential and important for plant growth and is subject to various harmful environmental factors, such as salt stress that hardly hinders the germination of seeds, seedlings growth, and plant production (Sun et al., 2018). Plant growth regulators have an essential part in integrating the responses expressed by the plants under stressful conditions (Amzallag *et al*., 1990). Exogenous application of suitable hormones such as GA_3, SA, and IAA at appropriate levels can improve abiotic stresses (salt, water, heat stress and waterlogging).

In this study, 100 mM NaCl was used as the highest salinity level to test the germination of Hargel seeds and observed that high salinity level significantly decreased all the parameters tested (SWU, SG%, GR), and seedling growth characteristics such as shoots length, roots length, roots fresh and dry weight, shoots fresh and dry weight, and seedling vigour index). The reductions in seed germination were due to decreased water absorption and enzymic activity induced by salinity. A decrease in water uptake was observed by increasing salt concentration (Atak *et al*., 2006). Furthermore, the decrease in germination might be caused by the low water potential that prevented water uptake and nutrients available for seed germination (Moreno *et al*., 2018). Also, the high salt concentration in solution may cause toxicity to the embryo (Kaymakanova, 2009). Germination could also be inhibited by reduced α-amylase activity due to salinity via reduced bioactive gibberellin content (Liu *et al*., 2018). It has been associated with the suppression of ethylene production during imbibition (Chang *et al*., 2010). Our results are in line with earlier studies reported by Chauhan *et al*., (2019) in oats, Shaikh-abol-hasani & Roshandel (2019) in Moldavian balm (*Dracocephalum moldavica* L.), and Ibrahim *et al*., (2019) in wheat. The reduction in the elongation of the seedlings roots can be interpreted by an unavailability of the necessary nutrient amount and the toxic effect of Na^+ and Cl^- (Akman, 2009). Our results are in good agreement with those of Nimir *et al*., (2014) and Khan, *et al*., (2015).

The present research showed that the decrease in fresh and dry roots and shoots fresh and dry weight under salinity might be due to the lowest water absorption caused by physiological drought (Chauhan *et al*., 2019). Ibrahim *et al*., (2016) reported that there was a negative association between growth characteristics (SL, RL, roots fresh and dry weight and shoots fresh and dry weight) and salinity stress (The growth parameters decreased with increasing concentration of NaCl). The decline in SVI is most likely due to decreased availability of moisture, which leads to a reduction in the activity of enzyme and inactive moves of endosperm reserves used to develop the embryonic axes (Nimir *et al*., 2014).

In this study, utilization of exogenous SA, IAA, and GA_3 significantly enhanced water uptake, SG%, GR, seedling growth parameters, and seedling vigour index in NaCl-stressed hargel seed. The application of GA_3 was useful in mitigating salt impacts on germination of different crops by lowering the level of abscisic acid (ABA) in seeds through their activation of catabolism enzymes and increased cell wall plasticity (Chauhan *et al*., 2016). The earlier germination of primed seeds is due to the much earlier commencement of metabolic activities compared to non-primed ones (Shaikh-abol-hasani & Roshandel, 2019). Exogenous GA_3 improved seed respiration rate and enhanced starch degradation along with increased amylase activity (Khalid & Aftab, 2020). Similar results of increased SG%, SL, and RL triggered by GA_3 were reported by Shaddad *et al*., (2013) and Chauhan *et al*., (2019). However, our results were different from Chen *et al*., (2014), who mentioned that GA_3 had an adverse influence on the shoot and root length in the soybean (*Glycine max*) and wheat plants. The difference between these two studies probably lies in the difference in crop species and the levels of GA_3.

The findings of Escobar *et al*., (2010) and Anaya *et al*., (2018) indicated that seeds treated with SA lead to increase osmotic adjustment at the imbibition stage, which increased water uptake. Other suggestions declared SA-induced acidification of the cytosol resulted in aquaporin activation and faster seed imbibition (Shaikh-abol-hasani & Roshandel, 2019). Also, SA increased the activation of reserve metabolites' mobilization (Nonogaki *et al*., 2010) and enhanced the synthesis of proteins for embryo growth at the second stage of germination (Rajjou *et al*., 2006). In this study, the application of SA improved seedling growth under saline conditions, and this might be due to increased oxygen, nutrient absorption, and activity of α-amylase. These findings are in line with Farooq *et al*., (2007), who mentioned that improved fresh weight and dry weight of the SA-primed salinized seedlings could be due to motivation of cell division at the apical meristem of seedling shoots and seedling roots, which caused an increase in seedlings growth. It is proposed that the utilization of exogenous SA leads to enhance cell division in the apical meristematic tissues by preventing decreased levels of cytokinin and IAA in salt-stressed plants (Shaikh-abol-hasani & Roshandel, 2019).

In this investigation, the application of IAA improved germination, germination rate, seedling growth characteristics under saline conditions. Similar results were observed by Balki & Padole (1982) and Akbari *et al*., (2007), they reported that when seeds primed with IAA, naphthalene acetic acid and gibberellic acid improved germination and seedling growth parameters compared with control grown under saline conditions. These results are in contrast with Akbari *et al*., (2007), who reported that IAA reduced roots dry weight. The improvement in seed germination and early seedling's growth is possibly due to regulation of ionic balance and auxin-induced biosynthesis of free salicylic acid in the leaves (Iqbal & Ashraf, 2007). Furthermore, the improvement in seed germination and seedling vigour index by exgenous hormones might be due to the reserve mobilization of food material, activation, and re-synthesis of some enzymes during seed priming (Buriro *et al*., 2011). In this study, when hargel seeds were treated with exogenous hormones, they well germinated even at a high salinity level (100 mM NaCl).

Conclusion

Salt stress decreased SWU, SG%, GR, SVI, and seedling growth characteristics of hargel. However, the seeds treated with GA_3, SA, and IAA at different concentrations promoted germination traits and seedling's growth under various levels of salinity. Seed priming decreased the inhibitory impact of salt on germination and young seedling growth parameters under investigation. The concentrations of 0.288 mM GA_3, 0.724 mM SA, and 0.285 mM IAA were more effective in mitigating salinity stress on hargel traits at the germination and young seeding growth stage. Nevertheless, these results done in controlled laboratory conditions need to be further confirmed in the field environment due to the differences in soil and NaCl water solutions.

Author contributions

Ebtehal Gabralla Ibrahim; methodology, take measurement, visualization, software, and writing- original draft preparation. Ali Mahmoud Muddathir: Conceptualization, Software. Irshad Ahmad, Adam Yousif Adam Ali and Muhi Eldeen Hussien Ibrahim; take measurement, data curation and investigation. Nimir Eltyb Ahmed, Guanglong Zhu; Xiurong Jiao and Tianyao Meng; review the manuscript. Guisheng Zhou; writing review and editing, visualization, supervision, project administration and funding acquisition. All authors have read and agreed to the published version of the manuscript.

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