

Seeds priming with β -aminobutyric acid alleviated salinity stress of chickpea at germination and early seedling growth

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ABSTRACT

Salinity stress is one of the most prevalent environmental factors that severely affect seed germination, early growth stages, and crop production. The present study was carried out to evaluate the protective role of β -aminobutyric acid (BABA) in alleviating salt stress in chickpea (*Cicer arietinum* L.) varieties (Jabel Marra, Porgeg and Shendi) under four concentrations of NaCl solutions (0, 50, 100, and 150 mM NaCl). Three levels of β -aminobutyric acid (0, 0.25, and 0.50 mM) were applied. Germination and seedling attributes were measured. A high level of salinity (150 mM NaCl) increased mean germination time by 10.0% and decreased the coefficient velocity of germination and root dry weight by 12.1% and 96.2%, respectively, compared with the control. ‘Jabel Marra’ significantly surpassed other studied varieties in germination characters, while at seedling growth, ‘Shendi’ outperformed other varieties in root and shoot length, fresh, and dry weights. Seeds treated with 0.25 mM BABA caused increment on water uptake by 18.1% compared with 0.0 mM BABA. At 150 mM NaCl, seeds primed with 0.50 mM BABA increased the germination percentage of ‘Jabel Marra’ and ‘Porgeg’ by 6.3% and 11.9% as compared with 0.0 mM BABA. Under 50 mM NaCl and 0.50 mM BABA, root length, shoot length, shoot fresh weight, and root dry weight were increased by 170.6%, 44.8%, 80%, and 49.3%, respectively, relative to 0.0 mM BABA. The present study results suggested that seed priming by BABA could be useful to alleviate the salinity stress of chickpea at germination and early seedling growth.

Key words: β -Aminobutyric acid, chickpea, germination, salinity stress, seedling growth.

INTRODUCTION

Salinity is one of the main environmental factors that lead to the degeneration of agricultural land and a decrease in crop productivity worldwide (Ali et al., 2018; Rahnema et al., 2019), especially in arid and semi-arid areas. It is expected that by 2050 salinity will affect 50% of the world’s arable areas (Machado and Serralheiro, 2017). The effect of salinity in arid and semiarid areas is more serious, which influences seed germination, early growth stages and consequently crop production (Ali et al., 2018; Rahnema et al., 2019). Salinity is known to have multiple effects on plant growth through osmotic impact on plant water imbibition and/or specific ion toxicities (Hirich et al., 2014). Salt stress limits plant development by reducing processes involving cell division as a result of an increase in energy utilization functions such as osmoregulation and active transport of ions caused by excess salts in the plant (dos Santos et al., 2021). Generally,

germination and seedling development stages are critical for crop establishment and are recognized as the most sensitive growth stages significantly influenced by salinity stress in most plants species (Hussien et al., 2016). The availability of soil water to the plant is usually decreased by reducing the osmotic potential of the soil solutions around plant roots. This is mainly due to the decrease in total soil water potential (Hirich et al., 2014). Increased in salinity level reduced osmotic potential, which has been declared to have a negative effect on water and nutrient uptake of chickpea (Arif et al., 2020).

Chickpea (*Cicer arietinum* L.) is the third most important food legume grown in the world (Hirich et al., 2014). Its production increased to 14.7 million metric ton in the world (Sofi et al., 2020). The importance of chickpea is based on its high values of seed nutritional content that approximately contains 48.2%-67.6% carbohydrate, 12.4%-31.5% protein, 2.1%-3.2% fiber, 4.5%-6.6% lipid, and 2.9%-4.0% ash (Jukanti et al., 2012; Alghamdi et al., 2020). Hence it was consumed almost everywhere in the world. Moreover, it has a significant contribution to agricultural sustainability through N₂-fixation and as a rotation crop allowing the diversification of agricultural production systems, thus improving soil fertility and reducing fertilizer costs. The effects of salinity on chickpea widely ranges, which varies from germination to vegetative stage and tolerance of chickpea for salinity differs from genotype to another (Habtamu et al., 2013). Moreover, during germination chickpea cultivars had significant differences against salt tolerance.

Stand establishment and yield potential of crop are determined through seed germination and early seedling growth. Germination and early seedling growth are the most vulnerable stages of a plant's life cycle, and germination is critical for seedling establishment and eventual crop production (Zhu et al., 2019).

In addition to conventional breeding methods and molecular mechanisms, new various strategies have been developed to improve plant performance against environmental stresses. One of these strategies is seed priming with different chemical compounds like hormones, antioxidants, vitamins, and osmoprotectants. Seed priming is easy and low in cost and risk for enhancing the growth and development of plants, especially under unfavorable environmental conditions (Jisha and Puthur, 2016). In this regard, prior researches indicated that the β -aminobutyric acid (BABA) plays some role in plant defense responses (Ma et al., 2020). It is reported that BABA successfully increased the resistance of plants to different stresses, including acid rain in *Arabidopsis*, Cd stress in soybean, drought in potato, and salt stress in barley (Liu et al., 2011; Hossain et al., 2012; Sós-Hegedűs et al., 2014; Mostek et al., 2016). Furthermore, seeds primed with BABA enhanced the trunk diameter increment, root volume, root dry weight, total dry weight of sweet cherry (*Prunus avium* (L.) L.) under water stress (Javadi et al., 2017).

There has been little known about the role of BABA in abiotic stresses. The details of BABA's physiological and metabolic mechanisms in chickpea in salinity stress still need to be explained. The aim of this study was to examine the effects of BABA application as a possible plant growth regulator to enhance germination and early seedling growth of chickpea cultivars under saline conditions.

MATERIALS AND METHODS

The study was carried out in the controlled environment in the Joint International Research Laboratory of Agriculture and Agri-Product Safety of the Ministry of Education of China, Yangzhou University (32°30' N, 119°43' E), China, from June to July 2020. Three varieties of chickpea (*Cicer arietinum* L.), namely Jabel Marra, Porgeg, and Shendi, were obtained from Agricultural Research Cooperation (ARC) in Sudan. Twenty-five seeds of each replicate from each treatment were surface-sterilized with 1% sodium hypochlorite solution for 3 min, thoroughly washed three times with deionized water to prevent fungal contamination. The experiment was laid out in a randomized complete design as a factorial experiment with three replicates. Three levels of β -aminobutyric acid (BABA) concentrations (0, 0.25, and 0.50 mM) and four salinity levels (0, 50, 100, and 150 mM NaCl) were applied in this study. Therefore, the experimental treatments were the combinations of three chickpea varieties, four salinity levels, and three BABA levels.

The seeds of each variety were soaked with target solution of BABA for 12 h at room temperature, and then re-dried back for 48 h to near their original weight. After seed priming, 25 seeds of each variety of each treatment were placed in a sterilized Petri dish (15 cm in diameter) with two layers of filter paper saturated with distilled water for control treatment or with the corresponding saline solution depending on treatment combinations. During the study period the addition of distilled and saline water was monitored daily. Eventually, the petri dishes were covered with a cover lid to avoid the loss of moisture through evaporation. The petri dishes were then incubated for 10 d in growth chambers set to 25 °C, 60% to 70% relative humidity, and 500 W m⁻² photoactive radiation (12/12 h day/night).

Seed water imbibition test

All the seeds in each petri dish were weighed (initial weight) and then soaked with BABA, exposed to salinity stress, and incubated in the growth chamber. At 6 h after the beginning of water imbibition, they were weighed again to determine the final weight. For each seed water uptake determination, seeds were carefully removed, drained, and blotted quickly with absorbent paper, weighed, and placed again into the petri dishes. Environmental condition for water uptake was the same as in seed germination. Seed water uptake was determined as follow:

$$\text{Seed water uptake (\%)} = (\text{Final weight} - \text{Initial weight} / \text{Initial weight}) \times 100$$

Germination parameters

Germination count was started after 48 h of sowing and continued until the 10th day at 24 h interval. The seeds were considered to have germinated when their radicle length reached 2 mm. From this, the following germination parameters were computed:

$$\text{Germination (\%)} = (\text{Nr germinated seeds} / \text{Total number of seeds}) \times 100$$

Germination index (GI) was determined according to AOSA (1983) as follows:

$$\text{GI} = (\text{Nr germinated seeds in first count} / \text{Days of first count}) + \dots + (\text{Nr germinated seeds in final count} / \text{Days of final count})$$

Mean germination time (MGT) was calculated to assess the rate of germination (Ellis and Roberts, 1981) as $\text{MGT} = \Sigma(n \times d) / \Sigma n$, where n is the number of seeds germinated on each day, and d is the day of counting.

Coefficient of velocity of germination (CVG) was evaluated according to Maguire (1962) as follows:

$$\text{CVG} = (G_1 + G_2 + \dots + G_n) / 1 \times G_1 + 2 \times G_2 + \dots + nG_n$$

where G_1 , G_2 , and G_n are the number of germinated seeds in the first, second, and last day of the germination and n is the last day of germination.

Seed vigor index (SVI) was calculated according to Abdul-Baki and Anderson (1973) as $(\text{SVI}) = \text{Seedling length} \times \text{GP}$ (%), where GP is the germination percentage.

Allometry was calculated as Shoot length/Root length.

On the 10th days after seeds sowing, the lengths (cm) of root and shoot were measured using a ruler. The root and shoot of five seedlings were weight and dried in an oven at 70 °C for 3 d to constant weight for dry weight determination.

Statistical analyses

This study was a three-factorial design arranged in a completely randomized design with three replicates for each treatment. The data collected were subject to ANOVA with the statistical package of MSTAT-C (Gomez and Gomez, 1983). When the F values were significant, means were separated by the LSD test at the 0.05 probability level.

RESULTS

Salinity, variety and β -aminobutyric acid, and their combinations produced diverse effects on different parameters of chickpea as presented in Tables 1 and 2.

Table 1. ANOVA results for seed water uptake, germination percentage, mean germination time (MGT), germination index (GI), seed vigor index (SVI), coefficient of velocity of germination (CVG), allometry, as influenced by salinity and β -aminobutyric acid application in chickpea.

Source of variation	Water uptake		Germination percentage		MGT		GI		SVI		CVG		Allometry	
	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value
Salinity (S)	0.009	1.423 ^{ns}	389.79	13.91*	0.890	40.29*	87.08	27.02*	794248	37.56*	0.102	37.31*	0.178	4.038*
Variety (V)	0.031	5.090*	1250.60	44.63*	0.662	29.94*	138.20	42.86*	471298	22.29*	0.054	19.62*	0.254	5.763*
BABA (B)	0.099	16.377*	253.08	9.033*	0.234	10.67*	42.55	13.20*	101448	4.797*	0.023	8.467*	0.081	1.838 ^{ns}
S×V	0.002	0.412 ^{ns}	49.43	1.764 ^{ns}	0.009	0.418 ^{ns}	2.205	0.684 ^{ns}	30258	1.431 ^{ns}	0.001	0.371 ^{ns}	0.086	1.951 ^{ns}
S×B	0.007	1.097 ^{ns}	14.86	0.530 ^{ns}	0.067	3.052*	8.598	2.667*	96460	4.561*	0.007	2.726*	0.215	4.883*
V×B	0.013	2.086 ^{ns}	78.54	2.803*	0.172	7.771*	28.120	8.722*	13781	0.652 ^{ns}	0.016	5.913*	0.065	1.464 ^{ns}
S×V×B	0.007	1.078 ^{ns}	23.52	0.839 ^{ns}	0.033	1.502 ^{ns}	1.844	0.572 ^{ns}	12617	0.597 ^{ns}	0.004	1.517 ^{ns}	0.024	0.548 ^{ns}

*Significant at $P < 0.05$; ^{ns}: nonsignificant; MS: mean square.

Table 2. ANOVA results for root length, root fresh weight, root dry weight, shoot length, shoot fresh weight, shoot dry weight as influenced by salinity and β -aminobutyric acid application in chickpea.

Source of variation	Root length		Root fresh weight		Root dry weight		Shoot length		Shoot fresh weight		Shoot dry weight	
	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value
Salinity (S)	35.080	24.910*	29740.0	40.650*	476.20	81.79*	9.974	40.230*	3806.2	19.91*	120.20	42.21*
Variety (V)	9.612	6.827*	6972.6	9.529*	82.83	14.23*	13.710	55.29*	6084.9	31.84*	93.20	32.72*
BABA (B)	4.869	3.458*	349.0	0.477 ^{ns}	6.50	1.117 ^{ns}	0.442	1.783 ^{ns}	2517.3	13.17*	33.46	11.75*
S×V	1.750	1.243 ^{ns}	2741.9	3.747*	14.83	2.531*	0.328	1.324 ^{ns}	422.4	2.21*	6.74	2.37*
S×B	6.919	4.914*	979.8	1.339 ^{ns}	20.68	3.552*	0.840	3.389*	1007.9	5.27*	24.19	8.49*
V×B	0.687	0.488 ^{ns}	139.1	0.190 ^{ns}	1.461	0.251 ^{ns}	0.071	0.287 ^{ns}	427.1	2.23 ^{ns}	6.07	2.13 ^{ns}
S×V×B	0.746	0.523 ^{ns}	105.9	0.145 ^{ns}	2.421	0.416 ^{ns}	0.228	0.921 ^{ns}	241.4	1.26 ^{ns}	3.76	1.31 ^{ns}

*Significant at $P < 0.05$; ^{ns}: nonsignificant; MS: mean square.

Water uptake

Among three varieties, ‘Shendi’ had maximum water uptake 0.633 kg kg^{-1} followed by ‘Porgeg’ and ‘Jabel Marra’ (Table 4). Both concentrations (0.25 and 0.50) of BABA were raised water imbibition, 0.25 mM BABA increased water uptake by 18.1% compared with 0.0 mM (Figure 1).

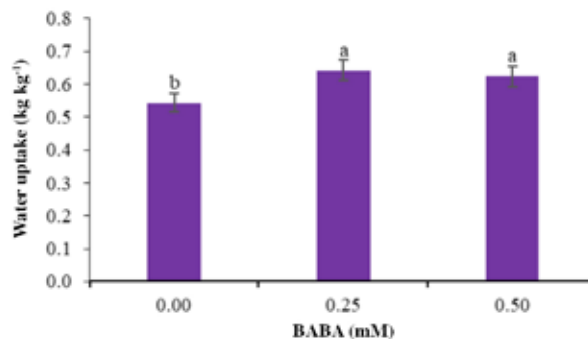
Germination parameters

Salinity of 50 mM NaCl decreased germination percentage of ‘Jabel Marra’ and ‘Porgeg’ by 18.2% and 16.3%, respectively, as compared with 0 mM NaCl at 0.0 mM BABA. In addition, 100 mM NaCl reduced germination percentage of ‘Shendi’ by 5.7% relative to 0 mM NaCl at 0.25 mM BABA. Seeds primed with 0.50 mM BABA showed increased germination percentage of ‘Jabel Marra’ and ‘Porgeg’ by 6.7% and 11.9% as compared with 0.0 mM BABA at 150 mM NaCl. Moreover, 0.25 mM BABA improved germination percentage of ‘Shendi’ by 11.4% as compared with 0.0 mM BABA at 50 mM NaCl. The response of three varieties to BABA was different, the highest (93.1%) and lowest (79.8%) germination percentage were recorded in ‘Jabel Marra’ with 0.50 mM BABA and ‘Porgeg’ with 0.0 mM BABA, respectively. Under hormone and salinity treatments, ‘Jabel Marra’ outperformed ‘Porgeg’ and ‘Shendi’ by 9.8% and 8.2%, respectively (Table 3).

The mean germination was raised with increasing salinity. High level of salinity 150 mM NaCl increased mean germination time by 10.0% compared with the control. BABA significantly enhanced mean germination time under normal and salinity stress conditions except at 150 mM NaCl. Application of 0.25 mM BABA decreased mean germination time by 16.5% and 18.9% at 0 and 50 mM NaCl compared with control 0.0 mM BABA (Figure 2a). Highest and lowest mean germination times were recorded in ‘Porgeg’ and ‘Jabel Marra’. In ‘Porgeg’, 0.25 mM BABA decreased mean germination time by 22.7% compared with control 0.0 mM BABA (Figure 5a).

Germination index (GI) decreased with increasing salinity levels; 100 mM NaCl decreased GI by 21.8% when compared with control. Priming with 0.25 mM BABA increased GI by 19.6% at 0 mM NaCl, while at 50 mM NaCl GI was increased by 31.8% compared with 0.0 mM BABA (Figure 2b). ‘Jabel Marra’ had highest GI (16.5) as compared with other varieties. ‘Porgeg’ had a lowest GI, but the index was increased by 57.3% when 0.25 mM BABA was added (Figure 5b).

Figure 1. Effects of β -aminobutyric acid (BABA) on seed water uptake of three chickpea varieties.



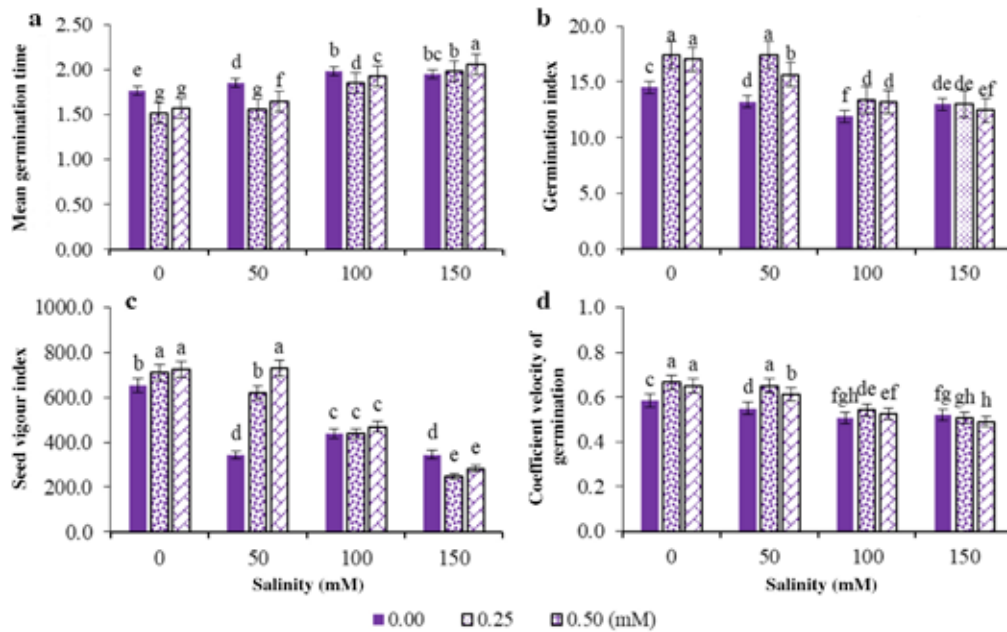
Bars with the same letters above are not significantly different at the 0.05 probability level.

Table 3. Effect of interaction between variety, salinity and β -aminobutyric acid on germination percentage of three chickpea varieties.

Variety	Salinity	β -aminobutyric (mM)			Mean
		0.00	0.25	0.50	
Jabel Marra	mM NaCl	0.00	0.25	0.50	
	0	95.7	98.3	96.7	
	50	78.3	85.7	86.7	
	100	93.3	93.0	93.0	
	150	90.3	94.7	96.0	
	Mean	89.4c	92.9ab	93.1a	91.8
Progeg	0	88.0	90.7	86.7	
	50	73.7	91.3	85.3	
	100	87.3	88.0	91.7	
	150	70.3	71.0	78.7	
	Mean	79.8f	85.3e	85.6e	83.6b
	0	85.7	87.3	87.7	
Shendi	50	82.3	91.7	84.7	
	100	74.3	82.3	84.3	
	150	85.0	87.3	85.7	
	Mean	81.8d	87.2bc	85.6d	84.8b

Means within columns followed by different letters are significantly different at $P < 0.05$.

Figure 2. Effects of the interaction between salinity and β -aminobutyric acid on mean germination time (a), germination index (b), seed vigor index (c), and coefficient velocity of germination (d) of chickpea.



Bars with the same letters above are not significantly different at the 0.05 probability level.

Highest (614.8) and lowest (386.0) seed vigor index (SVI) were recorded in ‘Shendi’ and ‘Porgeg’, respectively (Table 4). Seed vigor index was increased gradually with increased BABA levels at 0 and 50 mM NaCl. In addition, 0.50 mM BABA increased SVI by 112.2% compared with 0.0 mM BABA at 50 mM NaCl. Moreover, 0.50 mM BABA had highest (468.3) SVI at 100 mM NaCl (Figure 2c).

Increased salinity levels caused reduction in coefficient of velocity of germination (CVG). At 150 mM NaCl, CVG decreased by 12.1% compared with control. Coefficient of velocity of germination increased at 0.25 mM BABA by 13.9% at 0 mM NaCl, while at 50 mM NaCl it was increased by 18.6% compared with 0.0 mM BABA (Figure 2d). Maximum CVG was achieved for ‘Jabel Marra’. In the interaction between variety and BABA, 0.25 mM BABA increased CVG by 19.3% and 10.1% in ‘Porgeg’ and ‘Shendi’, respectively (Figure 5c).

Table 4. Seed water uptake, root length, shoot length, and seed vigor index of three chickpea varieties.

Variety	Water uptake	Seed vigor index	Root length	Shoot length	Allometry
	kg kg ⁻¹		cm	cm	
Jabel Marra	0.575b	497.4b	3.23ab	2.13b	0.748b
Porgeg	0.602ab	386.0c	2.76b	1.96b	0.781b
Shendi	0.633a	614.8a	3.79a	3.10a	0.907a

Means within columns followed by different letters are significantly different at $P < 0.05$.

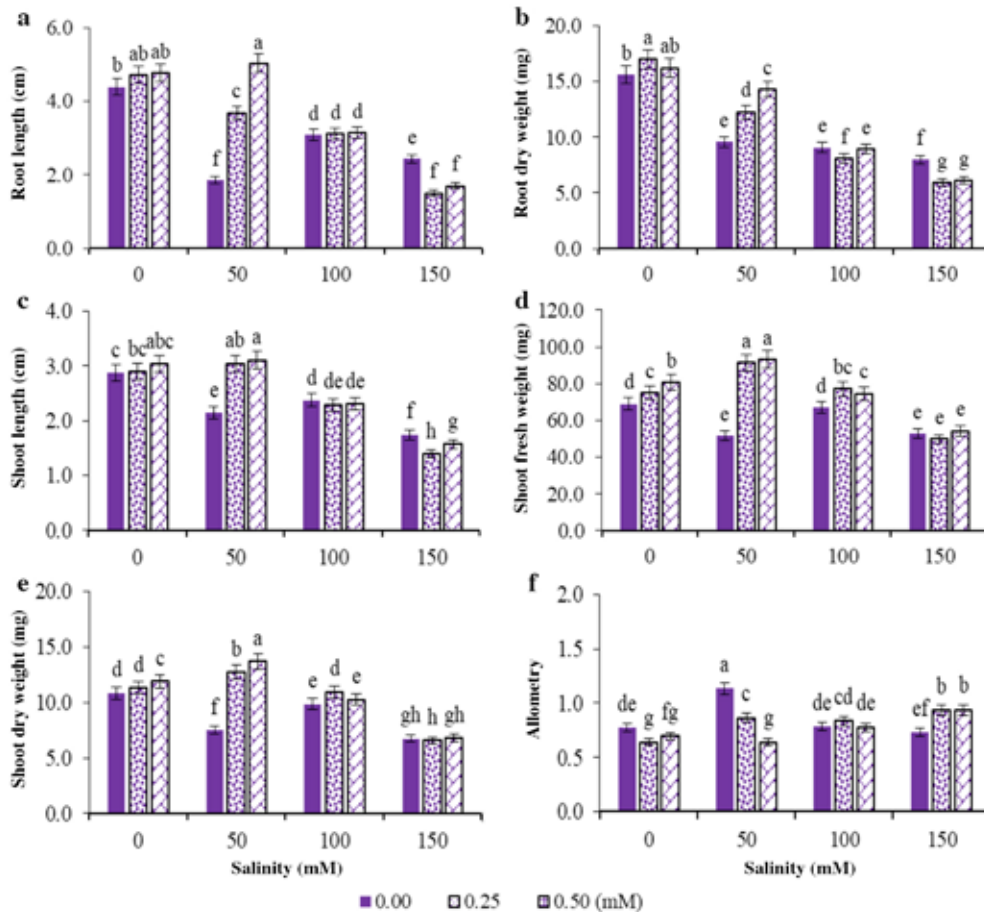
Allometry

Among the three varieties, ‘Shendi’ raised allometry by 21.2% and 16.2% relative to ‘Jabel Marra’ and ‘Porgeg’, respectively (Table 4). The interaction between salinity and BABA, 0.50 mM BABA increased allometry by 27.7% at 150 mM NaCl compared with 0.0 mM BABA (Figure 3f).

Seedling growth parameters

Highest (3.79 cm plant⁻¹) and lowest (2.76 cm plant⁻¹) root length were recorded in ‘Shendi’ and ‘Porgeg’, respectively (Table 4). Root length was increased gradually with increased BABA levels at 0 and 50 mM NaCl. At 50 mM NaCl, 0.50 mM BABA was increased root length by 170.6% relative to 0.0 mM (Figure 3a).

Figure 3. Effects of the interaction between salinity and β -aminobutyric acid on root length (a), root dry weight (b), shoot length (c), shoot fresh weight (d), shoot dry weight (e), allometry (f) of chickpea.



Bars with the same letters above are not significantly different at the 0.05 probability level.

‘Shendi’ had the best performance of root fresh weight among the three varieties at 0, 100 and 150 mM NaCl, it was exceeded root fresh weight by 84.7% and 48.7% relative to ‘Jabel Marra’ and ‘Porgeg’, respectively, at 0 mM NaCl. In addition, ‘Shendi’ at 100 mM NaCl had maximum root fresh weight (65.22 mg plant⁻¹). Salinity decreased root fresh weight gradually within the three varieties. At ‘Jabel Marra’, 150 mM NaCl decreased root fresh weight by 118.4% compared with 0 mM (Figure 4a).

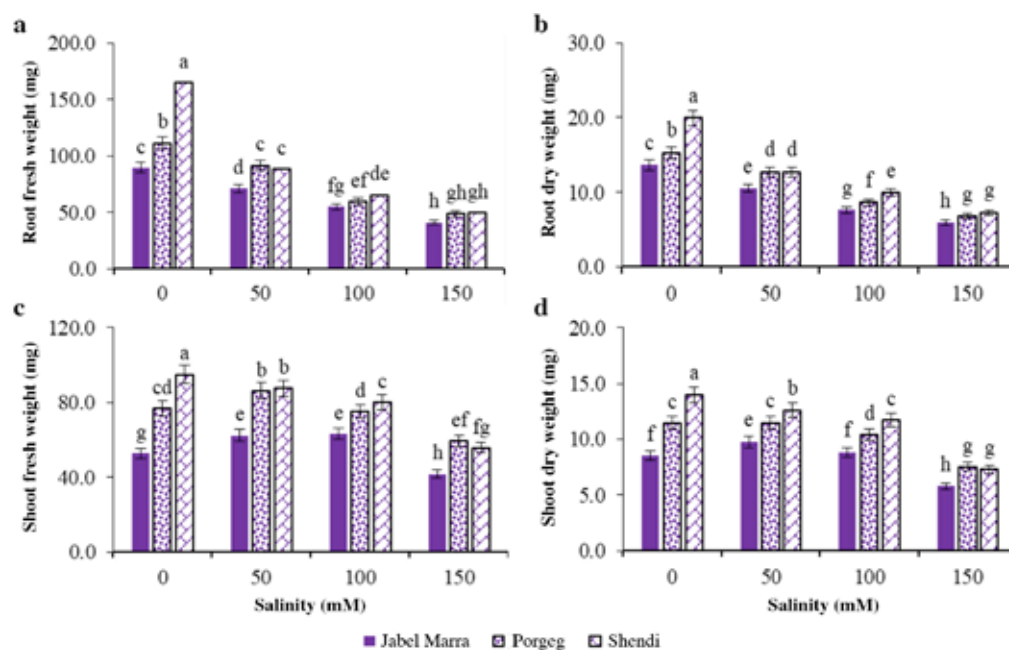
Root dry weight decreased with increasing salinity levels; 150 mM NaCl caused reduction in root dry weight by 96.2% compared with 0 mM NaCl. Root dry weight was increased with increased BABA levels at 0 and 50 mM NaCl; 0.50 mM BABA enhanced root dry weight by 49.3% compared with 0.0 mM BABA at 50 mM NaCl (Figure 3b). In interaction between salinity and varieties, salinity decreased root dry weight gradually within the three varieties. ‘Shendi’ produced greater root dry weight relative the other varieties (Figure 4b).

Shoot length was increased gradually with increased BABA levels at 0 and 50 mM NaCl. At 50 mM NaCl, 0.50 mM BABA increased the shoot length by 44.8% compared with 0.0 mM BABA (Figure 3c). ‘Shendi’ exhibited a greater shoot length than ‘Jabel Marra’ and ‘Porgeg’ (Table 4).

In the interaction between salinity and BABA, 0.50 mM BABA increased shoot fresh weight by 17.0% and 80.0% in 0 and 50 mM NaCl, respectively (Figure 3d). The highest fresh weight (95 mg plant⁻¹) was obtained by ‘Shendi’ and the lowest (52.2 mg plant⁻¹) was obtained by the ‘Jabel Marra’. In interaction between salinity and varieties, ‘Shendi’ had the best performance of shoot fresh weight among three varieties at different salt concentrations (Figure 4c).

Shoot dry weight decreased gradually with increasing salinity levels in all varieties except in ‘Porgeg’ at 50 mM NaCl. ‘Shendi’ had the highest shoot dry weight (14.0 mg plant⁻¹) as compared with other varieties (Figure 4d). Application of BABA gradually increased shoot dry weight at 0 and 50 mM NaCl. Furthermore, 0.50 mM BABA increased shoot dry weight by 82% compared with 0.0 mM BABA at 50 mM NaCl (Figure 3e).

Figure 4. Effects of the interaction between salinity and variety on root fresh weight (a), root dry weight (b), shoot fresh weight (c), and shoot dry weight (d), of chickpea.



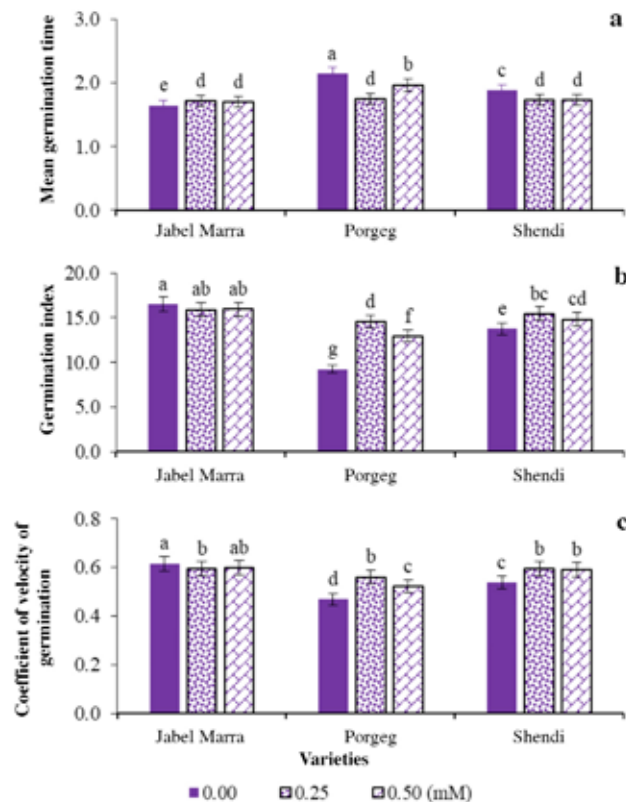
Bars with the same letters above are not significantly different at the 0.05 probability level.

DISCUSSION

Salinity stress is one of the major abiotic factors limiting crop production, especially in arid and semi-arid areas in the world. In this study, all germination attributes examined were influenced by increased NaCl level. The impact of salinity on seed germination was clearly demonstrated in many plants species (Ali et al., 2018). Germination was directly related to the amount of water absorbed and the delay of germination was related to high salt concentrations of the medium (Haileselesie and Teferii, 2012). These results indicated that salt affected number of seeds germinated and increased germination time. The reduction in germination percentage with increasing NaCl levels in chickpea seeds was also reported by Ceritoğlu et al. (2020). The highest mean germination time (MGT) was observed at high level of 150 mM NaCl and the lowest was observed at 0.0 mM NaCl (Figure 2), which agreed with that of Fatih and Kirli (2018) who stated that germination time was prolonged with increasing salt doses. Increased germination time with increasing salinity level may be attributed to the fact that salt induced osmotic stress and ionic stress and resulted in poor seed water uptake (Tabassum et al., 2017). Delayed or inhibition of seeds germination by oxidative stress also has been confirmed to be an important factor, which impacts the balance of reactive oxygen species production and scavenging or detoxification (Nimir et al., 2020). Dantas et al. (2007) reported that the NaCl content influenced seed germination and concentrations above 50 mM decreased germination and seedling growth. The reduction in seed germination due to salt may be due to damage of viability at higher salinity level or induced high oxidative stress (Ehtaiwesh and Rashed, 2019).

The present study indicated that varieties exhibited a large variation in terms of response to salinity. ‘Jabel Marra’ significantly surpassed other studied varieties in germination characters, it achieved higher germination index (GI) than ‘Porgeg’ and ‘Shendi’ (Figure 5c). The superiority of ‘Jabel Marra’ in germination parameters over than other studied varieties might be attributed to genetic factors, which resulted from genetic makeup relations for the variety. Our finding is in agreement with the observations of Fatih and Kirli (2018), who stated that genetic differences between the cultivars may have significant effects on germination rates.

Figure 5. Effects of the interaction between variety and on β -aminobutyric acid on mean germination time (a), germination index (b), and coefficient velocity of germination (c) of chickpea.



Bars with the same letters above are not significantly different at the 0.05 probability level.

Under salt stress, seeds primed with BABA enhanced germination characteristics, including MGT, GI, seeds vigor index and coefficient velocity of germination (Figure 2). Increased in seeds germination soaked with gamma aminobutyric acid (GABA) was also reported in perennial ryegrass (Tang et al., 2021). The non-protein GABA is also a kind of aminobutyric acid (ABA) used for abiotic stress tolerance. Water is necessary to activate metabolic processes in the seeds, which are significantly affected by salt stress (Nimir et al., 2020). Enhanced germination is associated with maintain water absorption, even in unfavorable osmotic conditions (Munns and Tester, 2008). In our study, chickpea seeds primed with BABA were significantly increased water imbibition (Figure 1). The BABA may regulate water uptake and maintenance by seeds resulting better in germination attributes. Our evidence was in line with previous study of Mostek et al. (2016), who reported that seeds of barley lines primed with BABA significantly increased relative water content, indicating that BABA maintains holding water in the plants. The mechanisms of ABA of promoting seed germination might be attributed to the altering carbohydrate and antioxidant enzyme activities (Tang et al., 2021). After water absorption, hormones stimulate hydrolytic enzymes, which are essential for the breakdown of storage macromolecules such as carbohydrates and proteins, resulting in their conversion into forms that are available to the developing embryo (Nimir et al., 2020). In this regard, Jakab et al. (2005) stated that BABA induced salt tolerance in *Arabidopsis* through enhanced ABA accumulation.

Root and shoot lengths are the most important parameters for salt stress because roots are in direct contact with soil and absorb water from soil and supply it to the rest of the plant. In this study, the growth of shoot and root was reduced with the progressive increase of salinity (Figure 3). Similar results were found by Hozayn and Ahmed (2019) when studying the influence of salinity on barley. Another influence of salinity on seedling growth, it is effect on biomass and DM production. Our results indicated that root and shoot fresh and dry weights were significantly reduced by salinity stress (Figures 3 and 4). However, root fresh and dry weights were more affected by salinity stress than shoot length. The reduction in seedling growth may be due to the toxic effects of the increased level of NaCl concentration in addition to decrease in water uptake by the plant roots (Ehtaiwesh and Rashed, 2019). In other study by Ali et al. (2018) reported that salinity induced a highly significant reduction on seedling fresh and dry weights. 'Shendi' outperformed other varieties in root and shoot length, fresh, and dry weights; it appeared to be moderately salinity tolerant at early seedling growth than other varieties of chickpea involved in this study.

The application of BABA under salt stress produced higher root and shoot length, shoot fresh and dry weights and root dry weight (Figure 3). Our results agree with those of Jisha and Puthur (2016) in rice, and partially in line with those of Mostek et al. (2016) who mentioned that BABA may increase salt stress resistance in barley, causing a significant augmentation of dry and fresh matter. Other study by Mahmud et al. (2020) indicated that seedling of rapeseed pretreated with BABA showed tolerance against salt toxicity. The increases in root and shoot growth could be attributed to that BABA enhances water absorption and decreases toxic effect of NaCl. Our evidence agreed with that of Mahmud et al. (2020) who mentioned that BABA might be involved in salt tolerance due to its role in decreasing Na⁺ and K⁺ content of salt-treated plants.

CONCLUSIONS

Our experiment studied the changes in germination characteristics and subsequent growth of three chickpea varieties subjected to seed priming with exogenous β -aminobutyric acid (BABA) and then exposed to salinity stresses in an attempting to alleviate the stress. Salinity stress considerably suppressed germination and seedling growth. Seed priming with BABA significantly enhanced seed water uptake, germination attributes, and growth of root and shoot. BABA could help seeds to mitigate salinity stresses during germination and early seedling growth.

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