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Multi-agent Comparison: Toward a Hierarchy of Priming Solutions for the Resilience of *Lens culinaris* Medik. to Saline Stress

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ABSTRACT

Background: Salinity is considered a major abiotic factor that restricts the germination and growth of legumes, including lentil (*Lens culinaris* Medik.), due to its detrimental effects on physiological and biochemical behaviour. In order to mitigate these effects, in this context, seed priming emerges as an effective approach to enhance their tolerance to saline stress.

Methods: Eight priming strategies were applied to lentil seeds, including KH_2PO_4 (1%), KH_2PO_4 (3%), KNO_3 (1.5%), KNO_3 (3%), PEG (10%), ascorbic acid (As A. 0,1 mmol) and (As A. 0,6 mmol) and the control (unprimed).

Result: The results reveal that As A. (0.1% mmol) and (0.6% mmol) emerge as the most effective, maintaining high germination rates (82.5-90%) under saline stress. Furthermore, KH_2PO_4 (1%) shows moderate efficiency with an 80% germination rate under saline stress, while PEG (10%) and KNO_3 (5%) exhibit poor performance. The results obtained reveal marked differential effects of the various types of priming. Treatments based on ascorbic acid (As A. 0.1% and 0.6% mmol) demonstrate better efficacy, significantly stimulating root length (62.16-74.5 mm) and epicotyl (71.41 mm) and generating the highest vigour index (931.5-1166.7), which could be explained by their antioxidant action neutralising reactive oxygen species and preserving cellular integrity. KH_2PO_4 (1%) shows moderate efficacy with a root length (42.25 mm) and vigour index (372.35). Priming with ascorbic acid (As A.) enhances the resilience of *Lens culinaris* Medik. Against the harmful effects of saline stress at germination and seedling growth.

Key words: Ascorbic acid, *Lens culinaris* Medik., Resilience, Saline stress, Seed priming.

INTRODUCTION

The lentil (*Lens culinaris* Medik.) is an important legume in the agricultural systems of the Mediterranean region, as it constitutes a source of high-quality protein for human and animal consumption (Katerji *et al.,* 2001).

The production of lentils is 4.4 million tons over a total area of 4.2 million hectares and 127,680 tons in Algeria, spread over a total area of 32,641 hectares (FAOSTAT-Agriculture, 2011). The lentil is a nutrient-rich legume that contains notable concentrations of protein (20 to 30%), poorly digestible carbohydrates (20%), lipids (1%), iron (Fe), zinc (Zn) and a range of vitamins (22%) (Dixit *et al*., 2017). The lentil's ability to fix nitrogen helps maintain soil fertility and increase the yield of other crops grown in rotation (Kaya *et al*., 2006). After chickpeas, they represent the second most frequently cultivated winter legume under rainfed conditions (Ayub *et al*., 2001).

Their cultivation is primarily carried out in arid and semi-arid environments, characterized by limited temporal water availability and where they are often exposed to abiotic stresses, such as drought and salinity, during the early stages of seedling growth (Windauer *et al*., 2007; Sadji *et al.*, 2018, 2022).

Salinization remains one of the main abiotic factors limiting the productivity of legumes (Nabi *et al*., 2024). Saline stress influences almost all phases of legume growth, particularly the germination phases, vegetative growth and reproduction (Mansouri and Kheloufi, 2017).

Germination is the most sensitive stage in the life cycle of plants and subsequent seedling growth represent the crucial stage for crop establishment. It is therefore conceivable to ensure optimal and increased yield by improving seed quality and optimizing the germination process (Haider and Rehman, 2022). One of the methods used to improve germination and seedling quality is seed

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priming, also known as "priming". It is a technique that stimulates the early emergence of seedlings thru pre-germinative metabolism, which allows for an earlier and more uniform seedling emergence in cases of saline stress. It activates biochemical pathways that prepare the seeds for radicle protrusion and strengthens the antioxidant system for cellular protection (Verma and Solanki, 2021).

Multiple research studies demonstrate that soaking in water (hydropriming), in chemicals and biological agents (*e.g.*, PEG, KH_2PO_4, KNO_3, Ascorbic Acid, Humic Acid, plant extracts,...) can improve germination rates, seedling emergence and early growth, particularly under unfavourable conditions such as drought, salinity and thermal stress (Biswas *et al.*, 2023; Rao *et al.*, 2024).

Sutnga *et al*. (2020) reported an improvement of germination rates and early growth in lentil by seed priming with KNO_3 (1%), KH_2PO_4 (1%) and PEG 6000 (1%-2%) for 12 hours.

Azooz *et al*. (2013) revealed an enhancement in the metabolic and physiological status of *Vicia faba* through seed priming with 100 mg L^{-1} of ascorbic acid for 10 hours at ambient temperature, which was negated under elevated NaCl stress.

Despite the growing interest in seed priming as a strategy to improve crop tolerance to salinity, comparative studies evaluating the effectiveness of various priming agents in lentils (*Lens culinaris* Medik) remain limited. The present study stands out for its original approach of systematically evaluating and comparing the effect of various priming agents (chemical and vitaminic), under saline conditions, with the aim of identifying the most effective priming strategy for resilience of *Lens culinaris* Medik. to saline stress at germination and seedling growth.

MATERIALS AND METHODS

The experiments were carried out at laboratory of Dr Yahia Fares University in Medea-Algeria, Faculty of Science during 2023 and 2024. The lentil seeds (*Lens culinaris* Medik) (variety SYRIE 229) were obtained from the Cereal and Dried Vegetable Cooperative CCLS of Berrouaghia in Medea, Algeria. The seeds were surface-sterilized in a 5% sodium hypochlorite solution for 3 minutes, then rinsed with sterilized water and air-dried to prevent any fungal attack. For priming treatments, the seeds were soaked for 6 hours with various priming agents, such as:

-KH_2PO_4 (1%-3%) "Monopotassium phosphate''.
-KNO_3 (1.5%-3%) "Potassium nitrate''.
-PEG 6000 (10%) "PolyEthylene Glycol''.
-Ascorbic acid (0.1 mmol -0.6 mmol) "Vitamin C''.
-The control "Unprimed''.

The concentrations used in the present study were determined based on previous reports. (Tamindžić *et al*., 2023). After the soaking period, the seeds were rinsed three times with distilled water, then dried (at room temperature; 25±2°C) to their original weight over two days.Petri dishes (9 cm in diameter) containing two layers of Whatman No. 1 filter paper were prepared. Ten seeds per Petri dish were distributed into four replicates according to a completely randomized block design (CRBD) and kept in a germinator at 25±0.5°C and 80±1% relative humidity for the germination test. These seeds germinated on germitest papers soaked in distilled water (H_2O) or in a NaCl solution at a concentration of 100 mmol. Germination was defined as effective when the radicles reached a length of 2 mm (Nabi *et al*., 2020).

Several germination parameters were calculated, namely

GP: Germination percentage.
FGP: Final germination percentage.
SG: The speed of germination.
SVI: Seedling vigour index.

The germination stability index is a statistical method used to evaluate the consistency and reliability of seed germination under different conditions. The coefficient of variation (CV) quantifies the relative variability of seed germination (Duan *et al*., 2025).

Seedling growth features, radical, epicotyl and total seedling length, were measured with the aid of a caliperin millimeters.

Data analysis

The results obtained were subjected to a two-factor analysis of variance test. When the ANOVA reveals a significant difference ($P<0.05$), we proceed to conduct a Tukey (HSD) analysis to determine the most effective types of priming under saline stress. All statistical analyses are performed using R software (CRAN, 2024).

RESULTS AND DISCUSSION

The present study stands out for its original approach of systematically evaluating and comparing the effect of various priming agents, chemical (KNO_3, PEG...) and vitaminic (ascorbic acid), under saline conditions, with the aim of identifying the most effective priming strategy for resilience of *Lens culinaris* Medik. to saline stress at germination and seedling growth (Table 1).

Fig 1 (A) illustrates the time required to reach 50% germination, indicating that most controlled treatments reach a threshold of two (02) days. While under saline stress, we observe a slight extension of time, reaching 3 days, especially for unprimed seeds and KH_2PO_4 (3%) with a germination rate of 12.5% and 37.5% respectively. However, treatments with KH_2PO_4 (1%), ascorbic acid 0.1 mmol and 0.6 mmol maintain rapid germination under saline stresswith a germination rate of 65%, 75% and 47.5% respectively. These results indicate that priming promotes germination even under saline stress.

Our results confirm previous studies indicating that saline stress significantly reduces the germination of cowpea (Nabi *et al*., 2017); Ivory Coast bean (Camara *et al*., 2018), faba bean (Chaker-haddadj *et al*., 2014), pea (Petrović *et al*., 2016) and lentil (El-Monemand Sharaf, 2008). These studies reported a delay in germination and

a reduction in the germination rate due to both osmotic effects and specific ionic toxicity, which inhibited the mobilization of seed reserves and altered enzymes and hormones in the seeds (Farissi *et al*., 2011; Farooq *et al*., 2015; Nabi *et al*., 2025).

The results of the germination stability analysis illustrated in Fig 1 (B) present the coefficient of variation as an indicator of germination stability. Lower values indicate more consistent growth. Under saline stress, the coefficient of variation increases. The PEG, KH_2PO_4 (1%) and ascorbic acid (0.1 mmol) treatments maintain relatively low coefficients of variation (10%-15%), which suggests increased stress tolerance.

ANOVA test results

The analysis of variance (Table 2) shows significant results for the three studied factors (F=24.962 and P<0.001) and the type of priming reveals a highly significant effect (F=11.4, P<0.001). The interaction between treatment and priming is significant at the 5% threshold (F=2.581, P=0.0428), which means that the type of priming varies depending on the treatment used.

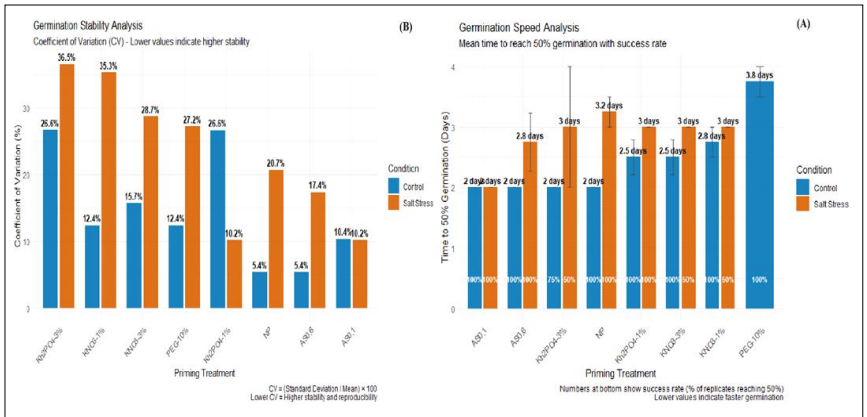
After a significant ANOVA, the Turkey (HSD) test was applied to compare the germination rates among the different types of priming. The results of the Tukey HSD test (Fig 2A) indicate that ascorbic acid (0.1 mmol) and ascorbic acid (0.6 mmol) show the highest germination rates, exceeding 80%. On the other hand, PEG (10%) and KH_2PO_4 (3%) show lower rates (50%-60%).

Lentil germination decreases under salt stress (Fig 2B), primarily due to increased production of reactive oxygen species (ROS) and an accumulation of Na^+/Cl^- ions, which disrupt cellular ionic balance and embryonic physiological processes (Hasanuzzaman *et al*., 2021;

Table 1: Statistical summary of the evolution of the germination percentage of lentil.

NaCl treatment	Priming	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Distilled water (Control)	Unprimed	0	77.5±9.57	92.5±5	92.5±5	92.5±5	92.5±5	92.5±5
	Kh_2PO_4 1%	0	62.5±26.30	75±19.15	77.5±20.62	77.5±20.62	77.5±20.62	77.5±20.62
	Kh_2PO_4 3%	0	50±16.33	55±12.91	62.5±17.08	62.5±17.08	65±17.32	65±17.32
	KNO_3 1.5%	0	42.5±12.58	80±8.16	80±8.16	85±5.77	85±5.77	85±5.77
	KNO_3 3%	0	62.5±17.08	87.5±15	92.5±9.57	95±5.77	97.5±5	97.5±5
	As A. 0.1	0	85±19.15	87.5±15	87.5±15	90±11.55	90±11.55	90±20.49
	As A. 0.6	0	80±8.16	85±5.77	90±8.16	92.5±5	92.5±5	92.5±5
	PEG 10%	0	25±5.77	55±5.77	62.5±9.57	72.5±5	75±5.77	75±5.77
100 mmol	Unprimed	0	12.5±9.57	12.5±15	72.5±11.55	72.5±15	72.5±15	72.5±15
	KH_2PO_4 1%	0	15±5.77	65±5.77	77.5±9.57	77.5±9.57	80±8.16	80±8.16
	KH_2PO_4 3%	0	25±17.32	37.5±22.17	47.5±17.08	50±18.26	50±18.26	50±18.26
	KNO_3 1.5%	0	32.5±9.57	45±12.91	45±12.91	45±12.91	45±12.91	45±12.91
	KNO_3 3%	0	22.5±15	37.5±15	42.5±15	45±12.91	45±12.91	45±12.91
	As A. 0.1	0	67.5±15	75±12.91	80±14.14	80±14.14	82.5±9.57	82.5±9.57
	As A. 0.6	0	37.5±15	47.5±5	67.5±9.57	72.5±12.58	72.5±12.58	72.5±12.58
	PEG 10%	0	2.5±5	2.5±5	15±12.91	22.5±15	32.5±5	32.5±5

As A.: Ascorbic acid (Vitamin C).



AS: Ascorbic acid (Vitamin C).

Fig 1: Effects of priming on the speed and stability of lentil germination under saline stress.

Munns and Tester, 2008). However, some treatments, such as KH_2PO_4 (1%) and ascorbic acid, maintain a high germination rate. Ascorbic acid, in particular, reduces lipid peroxidation and stimulates the activity of antioxidant enzymes (peroxidase, catalase), thus mitigating the effects of oxidative stress (Ghiyasi *et al*., 2025). Conversely, PEG and KH_2PO_4 (3%) prove ineffective under these conditions.

Effect of priming types on growth parameters

The results of different types of priming on the growth parameters of lentils reveal that (0.1 mmol) ascorbic acid is the most effective, particularly under saline stress conditions, with radicle length values of 62.16 mm and a vigor index of 931.5 (Table 3). Ascorbic acid (0.6 mmol) has a notable effect on all growth parameters under both normal and saline conditions at T0 and T1. Our results are consistent with the majority of previous studies (Ishaq *et al*., 2021; AL-Kazzaz, 2023).

On the other hand, treatments with KNO_3 (1.5%, 3%) show the lowest performance with a decrease in the total length of the seedlings with a value of (34.24 mm and 42.99 mm) and a vigor index of (163.3 and 105.87) respectively.

The results of the analysis of variance on the different growth parameters (Table 4) show that salt stress and priming have a highly significant effect on each growth parameter. We observe that saline stress affects the radicle length ($F=15.35$ and $P<0.001$), the epicotyl length ($F=11.39$, $P=0.001$), as well as the total length ($F=11.45$, $P=0.001$) and the vigor index ($F=2.892$, $P=0.003$), indicating a generalized inhibition of lentil seed growth.

Priming has a notable effect on all growth parameters ($p<0.05$) and significant F values, particularly for epicotyl length ($F=26.3$). This indicates that the type of priming differently influences the resumption of seedling growth. However, the interaction is not significant for the total length ($F=1.6$, $P=1.159$), which suggests that the overall growth response remains constant despite the variations specific to each organ.

Tukey's (HSD) test

The results of the Tukey HSD test (Fig 3) show a significant difference between the different types of priming, both in terms of root length, epicotyl length, total length and vigor index. Ascorbic acid 0.1 mmol shows a high-performing result in terms of radicle length (62 mm), epicotyl length (65 mm), total length (118 mm) and vigor index (1050). It is followed by (0.6 mmol) ascorbic acid, which exhibits an epicotyl (72 mm) and vigor index (1150). These results indicate that ascorbic acid is a crucial antioxidant that significantly improves plant resilience to stressful conditions and corroborate the results of Sutnga *et al*. (2020); Shah *et al*. (2025).

The unprimed control shows high values, although slightly lower (radicle 60 mm, vigor (1000)). In contrast, the treatments with PEG (10%), KNO_3 (1.5%) and KNO_3 (3%) exhibit lower values.

Under saline stress, the Tukey HSD test indicates that various types of priming maintain a positive effect on growth (Fig 4). For the length of the radicles, the best results were recorded with ascorbic acid (0.6 mmol) (75 mm), followed by ascorbic acid (0.1 mmol) (60 mm) and KH_2PO_4 (1%) (45 mm), while the other treatments showed low values, indicating an inhibitory effect on root growth.

Regarding the length of the epicotyl, ascorbic acid (0.1 mmol) remains dominant with a value of 70 mm. On the other hand, all other types of treatment show low values

Table 2: Effect of saline stress and priming on the speed of germination of *Lens culinaris* Medik.

	Df	Sum Sq.	Mean Sq.	F value	Pr (>F)
Salinity	1	3675	3675	24.962	0.00001520
Priming	5	8392	1678	11.400	0.00000122
Salinity×Priming	5	1900	380	2.581	0.0428
Residuals	36	5300	147		

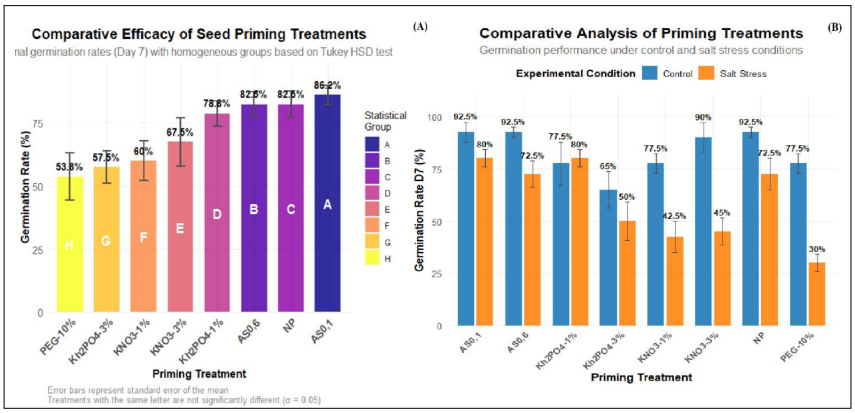


Fig 2: Comparative germination response of primed seeds under control (T0) and saline stress (T1).

Table 3: Effects of different priming methods on the growth parameters of lentil seedlings under saline stress.

	Radical lengh (mm)		Epicotyl length (mm)		Total seedling length (mm)		Seedling vigour index	
	T0	T1	T0	T1	T0	T1	T0	T1
Unprimed	60.66±0.71	18.25±4.48	29.83±1.23	35.83±5.16	108.91±15.8	83.16±6.61	993.45±95.89	174.05±77.53
Kh_2PO_4 1%	42.91±25.78	42.25±4.27	26.66±1.57	21.24±9.38	73.87±46.35	59.80±19.90	469.9±381.34	372.35±131.81
Kh_2PO_4 3%	27.75±19.82	35.00±13.81	20.75±13.81	14.89±8.48	53.25±35.15	51.87±22.32	250.95±198.88	198.2±178.02
KNO_3 1.5%	7.91±1.39	7.00±3.41	16.16±2.39	15.41±4.19	34.24±25.34	35.24±8.42	292.4±31.50	163.3±67.21
KNO_3 3%	14.91±9.44	4.66±4.61	15.08±1.87	7.91±7.18	42.99±20.93	19.08±17.99	457.5±167.50	105.87±105.87
As A. 0.1 mmol	64.58±17.90	62.16±21.94	64.63±21.94	71.41±9.99	117.99±59.9	59.80±19.90	1060.8±457.82	931.8±267.92
As A. 0.6 mmol	7.04±43.75	74.58±13.24	74.58±22.66	23.08±11.92	35.15±35.15	51.87±22.32	1166.7±338.32	430.66±167.27
PEG 10%	46.75±12.59	9.36±4.46	24.46±2.46	16.33±5.38	14.17±34.16	9.11±9.11	363.1±387.8	593.52±593.52

Table 4: Effect of saline stress and priming on growth parameters.

	df	Radical length (mm)			Epicotyl length (mm)			Total seedling length (mm)			Seedling vigour index		
		Mean square	F- value	P- level	Mean square	F- value	P- level	Mean square	F-value	P- level	Mean square	F- value	P- level
Salinity	1	2466.86	15.35	0	1335.26	11.39	0.001	8136.94	11.45	0.001	2911379	2.892	0.003
priming	7	3172.76	19.74	0	3084.22	26.3	0	4309.02	6.06	0	6621809	6.577	0.014
Salinity*priming	7	655.78	4.08	0.001	670.3	5.72	0	1135.53	1.6	0.159	3553212	3.529	0.004

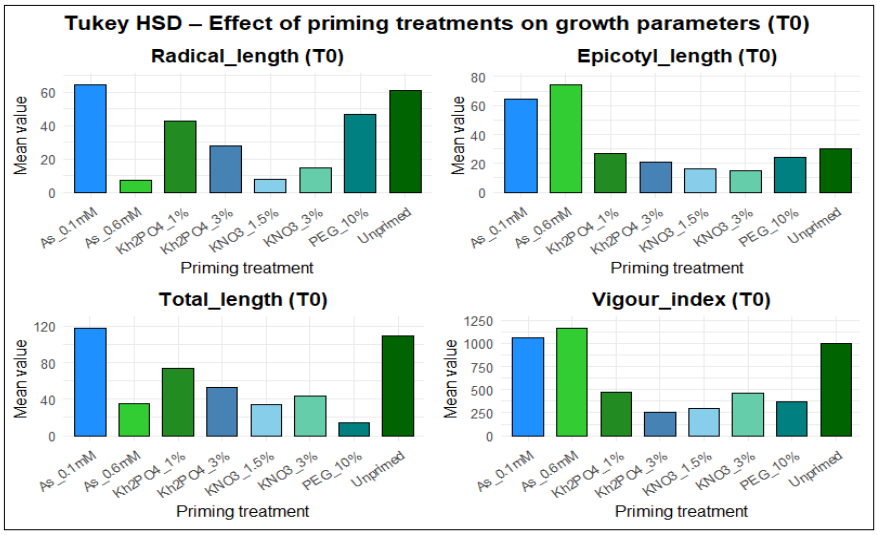


Fig 3: Effect of priming treatments on growth parameters (T0) with tukey HSD test.

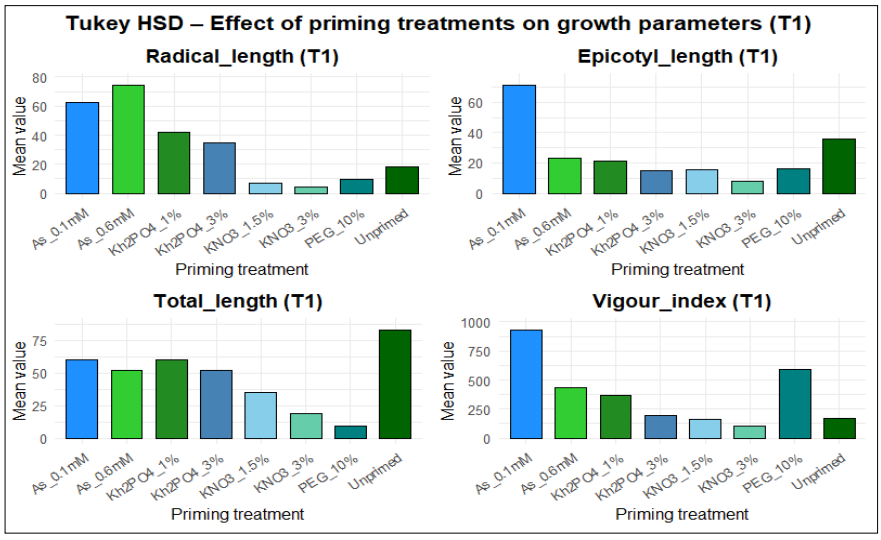


Fig 4: Effect of priming treatments on growth parameters (T1) with Tukey HSD test.

that do not exceed 25 mm. The seedlings imprinted with KH_2PO_4 (1%) and ascorbic acid (0.1 mmol) exhibit higher lengths, reaching 80 mm, 70 mm and 65 mm, respectively. The vigor index is significantly higher for ascorbic acid (0.1 mmol) (900), followed by PEG (600) and KH_2PO_4 (40), while the other treatments are less effective.

The results obtained are similar to those reported by Zhang *et al*. (2024) and Prajapati *et al*. (2025), who consider ascorbic acid to be one of the essential metabolites involved in cell division and osmotic adjustment and possess a strong antioxidant capacity by reinforcing defense enzymes against oxidative stress and reducing the generation of free radicals, thus facilitating the balance between the production and recovery of ROS (reactive oxygen species) (Zulfiqar *et al*., 2022). And also, the application of ascorbic acid mitigated photoinhibition and reduced the deleterious effects on photosynthesis by stimulating chlorophyll synthesis and decreasing oxidative stress at the chloroplast level through the control of the redox state in the latter and the dissipation of excitation energy in the PSII antennas (Chen *et al*., 2021).

CONCLUSION

Thus, seed priming with both concentrations (0.1 mmol and 0.6 mmol) of ascorbic acid for 6 hours is most effective in mitigating salt stress on germination, seedling growth and vigor index of *Lens culinaris* Medik. This method is more effective than other priming treatments and the control group. It has been reported as simple, economical and environmentally friendly. Therefore, it can be used to improve the tolerance of *Lens culinaris* Medik to saline stress.

Further research and field experiments may be required to investigate the scalability and adaptability of this method across various lentil types and environmental conditions.

Conflict of interest

All authors declare that there are no conflicts of interest regarding the publication of this article. No funding or support had any influence on the study's design, data collection, analysis, publication decision, or article preparation.

REFERENCES

Abd El Monem, S.M. (2008). Tolerance of five genotypes of lentil to NaCl-salinity stress. *New York Science Journal*. **1(3):** 70-80.

AL-Kazzaz, A.G.M. (2023). Role of Ascorbic acid in drought stress tolerance of wheat plant *Triticum aestivum* L. *Ibn AL-Haitham Journal for Pure and Applied Sciences*. **36(3):** 21-27.

Ayub, K., Rahim, M. and Khan, A. (2001). Performance of exotic lentil varieties under rainfed conditions in Mingora (NWFP) Pakistan. *J. Bio. Sci.* **1:** 343-344.

Azooz, M.M., Alzahrani, A.M. and Youssef, M.M. (2013). The potential role of seed priming with ascorbic acid and nicotinamide and their interactions to enhance salt tolerance in broad bean (*Vicia faba* L.). *Australian Journal of Crop Science.* **7(13):** 2091-2100.

Biswas, S., Seal, P., Majumder, B. and Biswas, A.K. (2023). Efficacy of seed priming strategies for enhancing salinity tolerance in plants: An overview of the progress and achievements. *Plant Stress*. **9:** 100186.

Camara, B., Sanogo, S., Cherif, M. and Kone, D. (2018). Effet du stress salin sur la germination des graines de trois légumineuses (*Phaseolus vulgaris*, *Glycine max* et *Vigna unguiculata*). *Journal of Applied Biosciences.* **124:** 12424-12432.

Chaker-Haddadj, A., Nabi, F., Kaci-Sadji, H.A. and Ounane, S.M. (2014). Effects of salt stress on growth, nodulation and nitrogen fixation of faba bean [*Vicia faba* (L.) Minor] cultivated in Algeria. *International Journal of Bio Technology and Research (IJBTR).* **4:** 1-10.

Chen, X., Zhou, Y., Cong, Y., Zhu, P., Xing, J., Cui, J. *et al.* (2021). Ascorbicacid induced photosynthetic adaptability of processing tomatoes to salt stress probed by fast OJIP fluorescence rise. *Front. Plant Sci.* **12:** 594400.

Dixit, G.P., Kumar, A. and Parihar, A.K. (2017). Variability for harvest index and biomass in lentil (*Lens culinaris* Medik) varieties. *Legume Research-An International Journal.* **40(6):** 1093-1096. doi: 10.18805/LR-3705.

Duan, H., Liu, L., Wang, W., Li, S., Shi, Z., Liang, G. and Liu, W. (2025). Stay-green trait enhances grain yield, nutritional quality and seed germination ability in oat (*Avena sativa* L.) on the Qinghai-Tibet Plateau. *Plants*. **14(16):** 2500. https://doi.org/10.3390/plants14162500.

FAOSTAT-Agriculture (2011). Food and Agricultural Commodities Production. Food and Agriculture Organization. Rome.

Farissi, M., Bouizgaren, A., Faghire, M., Bargaz, A. and Ghoulam, C. (2011). Agro-physiological responses of moroccan alfalfa (*Medicago sativa* L.) populations to salt stress during germination and early seedling stages. *Seed Science and Technology.* **39(2):** 389-401.

Farooq, M., Hussain, M., Wakeel, A. and Siddique, K.H. (2015). Salt stress in maize: Effects, resistance mechanisms and management. A review. *Agronomy for Sustainable Development.* **35(2):** 461-481. doi: 10.1007/s13593-015-0287-0.

Ghiyasi, M., RezaeeDanesh, Y., Amirnia, R., Sharifi, L., Najafi, S., Mulet, J.M. and Porcel, R. (2025). Machine learning insights into ascorbic acid-enhanced germination of black cumin (*Nigella sativa* L.) under cadmium stress. *Journal of Plant Growth Regulation.* **44(5):** 2184-2199. https://doi.org/10.1007/s00344-024-11536-z.

Haider, I. and Rehman, H.U. (2022). The impact of different seed priming agents and priming durations on stand establishment and biochemical attributes of *Stevia rebaudiana Bertoni*. *Saudi Journal of Biological Sciences.* **29(4):** 2210-2218.

Hasanuzzaman, M., Raihan, M.R.H., Masud, A.A.C., Rahman, K., Nowroz, F., Rahman, M., Nahar, K. and Fujita, M. (2021). Regulation of reactive oxygen species and antioxidant defense in plants under salinity. *International Journal of Molecular Sciences.* **22(17):** 9326.

Ishaq, H., Nawaz, M., Azeem, M., Mehwish, M. and Naseem, M.B.B. (2021). Ascorbic acid (Asa) improves salinity tolerance in wheat (*Triticum aestivum* L.) by modulating growth and physiological attributes. *Journal of Bioresource Management.* **8(1):** 1.

Katerji, N., Hoorn J.W., Hamd, A., Karam, F. and Mastrorilli M. (2001). Salt tolerance of crops according to three classification methods and examination of some hypothesis about salt tolerance. *Agricultural Water Management.* **47:** 1-8.

Kaya, M.D., Okçu, G., Atak, M., Çıkılı, Y. and Kolsarıcı, Ö. (2006). Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). *European Journal of Agronomy*. **24(4):** 291-295.

Mansouri, L.M. and Kheloufi, A. (2017). Effect of diluted seawater on seed germination and seedling growth of three leguminous crops (Pea, chickpea and common bean). *The Journal Agriculture and Forestry*. **63(1):** 131-142.

Munns, R. and Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology.* **59(1):** 651-681.

Nabi, F., Chaker-Haddadj, A., Chebaani, M., Ghalem, A., Mebdoua, S. and Ounane, S.M. (2020). Influence of seed priming on early stages growth of cowpea [*Vigna unguiculata* (L.) Walp.] grown under salt stress conditions. *Legume Research-An International Journal.* **43(5):** 665-671. doi: 10.18805/LR-504.

Nabi, F., Haddadj, A.C., Tellah, S., Ghalem, A., Ounane, G., Ghalmi, N., Djebbar, R. and Ounane, S.M. (2017). Evaluation of Algerian cowpea genotypes for salt tolerance at germination stage. *Advances in Environmental Biology.* **11(5):** 79-89.

Nabi, F., Sadji-Ait, K.H., Chebaani, M., Haddadj, A.C. and Ounane, S.M. (2024). Growth, leaf water potential, photosynthetic pigments, compatible solutes and yield components in cowpea landraces under salinity. *Natural Resources and Sustainable Development.* **14(2):** 227-244.

Nabi, F., Sadji-Aitkaci, H., Chaker-Haddadj, A. and Chebaani, M. (2025). Priming and stress memory for response to drought stress: Comparative study of adaptive bet-hedging strategy between pea and chickpea seeds. *The Indian Journal of Agricultural Sciences.* **95(6):** 42-50. doi.org/10.56093/ijas.v95i7.161347.

Petrović, G., Jovičić, D., Nikolić, Z., Tamindžić, G., Ignjatov, M., Milošević, D. and Milošević, B. (2016). Comparative study of drought and salt stress effects on germination and seedling growth of pea. *Genetika-Belgrade.* **48(1):** 373-381.

Prajapati, A., Singh, T., Kaur, H., Jagota, N., Sharma, A., Bisht, A. and Chhabra, R. (2025). Physio-biochemical and histological studies unveil ascorbic acid-induced protection in mungbean under salt stress. *Discover Plants.* **2(1):** 54.

Rao, D., Yadav, S., Choudhary, R. and Singh, D. (2024). Integrated application of silicic and humic acid seed priming for enhanced germination and yield of lentil (*Lens culinaris* L.). *Legume Research-An International Journal.* **48(10):** 1668-1672. doi: 10.18805/LR-5248.

Sadji-Ait, K.H., Chaker-Haddadj A. and Aid, F. (2018). Enhancing of symbiotic efficiency and salinity tolerance of chickpea by phosphorus supply. *Acta Agriculturae Scandinavica Section B Soil and Plant Science.* **68(6):** 534-540. doi.org/10.1080/09064710.2018.1440001.

Sadji-Ait, K.H., Chaker-Haddadj, A., Nedir-Kichou, A. and Aid, F. (2022). Act of phosphorus on cell hydraulic state, K+ use efficiency and induction of positive correlations between yield and vegetative traits in chickpea. *Acta Agriculturae Scandinavica section B Soil and plant Science*. **72(1):** 3325-332. doi.org/10.1080/09064710.2021.1988138.

Shah, S., Khan, Y., Cheng, Z., Bouskout, M., Zhang, T., Yan, H. and Wang, M. (2025). Priming effect of ascorbic acid on the growth and biomass of quinoa under saline conditions. *Frontiers in Plant Science*. **16:** 1600423. https://doi: 10.3389/fpls.2025.1600423.

Sutnga, E., Chaurasia, A.K. and Reddy, A.N. (2020). Assessment of different seed priming methods on quality parameters of lentil (*Lens culinaris* Medik.). *Int. J. Curr. Microbiol. App. Sci.* **9(11):** 3022-3029.

Tamindžić, G., Červenski, J., Milošević, D., Nikolić, Z., Vlajić, S., Jovičić, D. and Ignjatov, M. (2023). Alleviation of salinity stress in garden pea using hydro-and osmopriming. *Contemporary Agriculture.* **72(3):** 122-129.

Verma, S.R. and Solanki, H.K. (2011). Alleviating salinity stress during seed germinating by priming techniques: A review. *International Journal of Scientific Research in Science and Technology*. **8(2):** 198-202.

Windauer, L., Altuna, A. and Benech-Arnold, R. (2007). Hydrotime analysis of *Lesquerella fendleri* seed germination responses to priming treatments. *Industrial Crops and Products.* **25(1):** 70-74.

Zhang, K., Khan, M.N., Khan, Z., Luo, T., Zhang, B., Bi, J. and Luo, L. (2024). Seed priming with ascorbic acid and spermidine regulated auxin biosynthesis to promote root growth of rice under drought stress. *Frontiers in Plant Science.* **15:** 1482930.

Zulfiqar, F., Nafees, M., Chen, J., Darras, A., Ferrante, A., Hancock, J.T., Zaid, M.A.A., Latif, N., Corpas, F.J., Altaf, M.A. and Kadambot, H.M.S. (2022). Chemical priming enhances plant tolerance to salt stress. *Frontiers in Plant Science.* **13:** 946922.