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SALINITY EFFECTS ON SEED GERMINATION OF TWO POTENTIAL HORTICULTURAL SPECIES (PHYSALIS PERUVIANA AND ARTEMISIA HERBA-ALBA)

SUMMARY

Salinity stress presents a challenging encounter to seed germination, deeply impacting plant establishment, particularly in regions characterized by arid and semiarid conditions. This study investigates the effect of varying NaCl concentrations on the seed germination of two multipurpose plant species, *Artemisia herba-alba* and *Physalis peruviana*. Through controlled experimental protocols, we evaluated critical germination attributes, including final germination percentage (FGP), mean germination time (MGT), time to 50% germination (T_{50}) and germination tolerance index (GTI). After 22 days of saline treatment, our results revealed distinct responses for each species to salinity stress. *A. herba-alba* demonstrated a moderate sensitivity, with FGP declining from 67.3% at 0 mM NaCl to 10.7% at 200 mM NaCl, whereas *P. peruviana* exhibited remarkable tolerance, maintaining a consistently high FGP of 100% across all NaCl concentrations except for the concentration of 200 mM (36.7%). Statistical analysis employing two-way ANOVA underscore the significant main effects of salinity, species, and their interactions on seed germination parameters. This study highlights the imperative of understanding species-specific adaptive strategies to mitigate salinity-induced inhibitions on seed germination. These insights advance our comprehension of seed responses to environmental stress and hold implications for the conservation, cultivation, and management of *A. herba-alba* and *P. peruviana* in saline-affected ecosystems.

Keywords: *Artemisia herba-alba*, NaCl, germination attributes, salinity, *Physalis peruviana*

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INTRODUCTION

An elevated concentration of soluble salts in soils has detrimental effects on agricultural lands, crops, and subsequently, the livelihoods of people worldwide. Over 100 nations are dealing with challenges related to soil salinity and the concurrent salinization of groundwater resources. Irrigation of agricultural crops with saline water indeed increases the concentration of soluble salts in soil, thereby reducing the productivity of crop plants (Srivastava *et al.*, 2019). Seed germination is affected by salinity stress, particularly in regions characterized by arid and semiarid conditions (Kigel, 2017; Kheloufi *et al.*, 2018; Christiansen *et al.*, 2022). Saline soils in arid rangelands of Algeria are primarily constituted by the accumulation of diverse chloride and sulfate salts, with NaCl predominating at over 50% (Halitim, 1988; Mansouri and Kheloufi, 2024). When salinity stress and drought interact, seeds are subjected to osmotic stress, reducing water uptake and metabolic processes needed to germinate. Salinity stress is intensified by drought by reducing soil moisture, which increases salt accumulation in root zones (Johal and Goyal, 2023). Consequently, the dual stress of drought and salinity hampers seed germination and negatively impacts crop growth, development, and productivity. Moreover, the accumulation of salts in the soil further reduces its fertility, leading to long-term degradation of agricultural land in arid and semiarid regions (Muhammad *et al.*, 2024).

Artemisia herba-alba Asso. (*Asteraceae*) (also called white wormwood) and *Physalis peruviana* L. (*Solanaceae*) (also called golden berry) possess a range of ecological, medicinal, and economic attributes. *A. herba-alba* is known for its anti-inflammatory, antimicrobial, and antioxidant properties, making it valuable in traditional medicine practices (Nedjimi and Beladel, 2015). P. peruviana is also valued for its medicinal properties, with various parts of the plant used to treat diseases such as inflammation, asthma, and gastrointestinal disorders (Ezzat and Salama, 2024). *P. peruviana* produces edible fruits enclosed in a papery husk, which are commonly consumed fresh or used in culinary applications such as jams, desserts, and salads (Cortés *et al*., 2012). The fruit is rich in vitamins, minerals, and antioxidants, contributing to its nutritional value and culinary versatility. It is cultivated commercially for its fruits, which are traded internationally and have economic value in fresh and processed forms (Obregón La Rosa, 2024). A. herba-alba possesses aromatic properties, with the plant emitting a distinctive fragrance due to its essential oil content. This aromatic quality has led to its use in perfumery, aromatherapy, and the production of essential oils (Fadel *et al.*, 2023). Both species are perennial and play significant roles in their respective ecosystems. *A. herba-alba* is known to have allelopathic effects, influencing the composition and dynamics of plant communities in its habitat (Arroyo *et al*., 2016). *P. peruviana*, on the other hand, serves as a food source for various wildlife species and contributes to ecosystem biodiversity.

Unfortunately, both species are subjected to diverse environmental stresses, including salinity, which significantly affect their growth, development, and yield potential (Nedjimi and Zemmiri, 2019; Aydin, 2024). In previous studies, *A. herba-alba* and *P. peruviana* have demonstrated significant horticultural potential due to their tolerance to salinity and drought, making them suitable for cultivation in arid regions. These characteristics position both species as valuable options for sustainable agriculture in areas facing water scarcity and soil salinity challenges (Nedjimi and Zemmiri, 2019; Muñoz *et al*., 2021). On the other hand, there is a scarcity of information regarding the ecophysiological factors influencing germination in these two species. Therefore, understanding the responses of key plant species, such as *A. herba-alba* and *P. peruviana*, to salinity stress is crucial for creating strategies to mitigate the adverse effects of salinity on crop production in these challenging environments. Indeed, previous studies have highlighted the detrimental impact of salinity on seed germination, attributing it to alterations in water uptake, osmotic potential, and ion imbalance within seeds (Nikolić *et al.*, 2023; Khan *et al.*, 2023). The sensitivity of seeds to salinity varies across species, with some revealing tolerance mechanisms such as osmotic adjustment, ion exclusion, and antioxidant defense systems (Johnson and Puthur, 2021). However, the comprehensive mechanisms underlying salinity tolerance during seed germination remain incompletely understood, requiring further investigation.

In this study, we aim to elucidate the salinity effects on seed germination of *P. peruviana* and *A. herba-alba*, focusing on key germination responses underlying their differential tolerance to salinity stress under varying salinity levels of sodium chloride. The findings from this study are expected to enhance our understanding of the adaptive mechanisms employed by these two species to cope with salinity stress during seed germination. Furthermore, the insights gained could have implications for the conservation, cultivation, and management of these species in salt-affected environments, contributing to sustainable agricultural practices and ecosystem resilience in the face of global environmental changes.

MATERIAL AND METHODS

Seed harvest and origin

Table 1 presents the provenances of the seeds used in this study for *Physalis peruviana* and *Artemisia herba-alba*. The table also presents seed biometric parameters for each species, including the 1000-seed weight, as well as seed length and width. The measurements were taken based on a sample of 100 seeds per species. Both seed species were collected on November 2023 from several individuals growing in apple orchard (Figure 1). For *P. peruviana*, the ripe fruits were selected, opened, and the seeds were extracted manually before being left to dry naturally for two weeks. Seeds of both species were then stored in paper bags at room temperature until their use on February 2024.

Table 1. Seed characteristics and origins of *Physalis peruviana* and *Artemisia herba-alba*.

Parameters	*Physalis peruviana*	*Artemisia herba-alba*
1000-seed weight (g)	0.11	0.21
Length (cm)	0.20 ± 0.01	0.11 ± 0.01
Width (cm)	0.15 ± 0.01	0.05 ± 0.01
Region in Algeria	Thniet El Abed (Batna, Algeria)	
GPS coordinates	35°20' N ; 6°20' E	

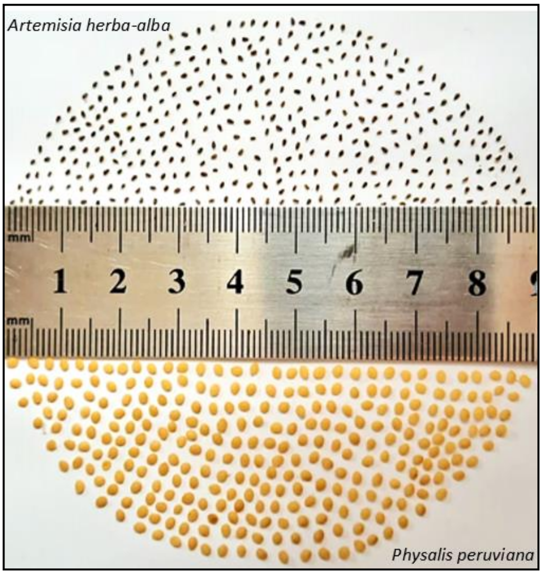

Figure 1. Seeds of Artemisia herba-alba and Physalis peruviana.

Experimental design and application of salt stress

The germination test was performed in plastic Petri dishes (9 cm Ø) included one Whatman filter paper moistened of the different saline concentrations (0, 50, 75, 100 and 200 mM) of NaCl (Table 2). For each salinity level, three replicate Petri dishes, each with 50 seeds, were wrapped in aluminum foil (continuous dark) and incubated under 25 °C (±2 °C). Maintaining a specific humidity level for the seeds was a critical aspect of the experiment. The papers were replaced every three days to prevent salt accumulation during the 22 days of the experiment. A complete randomized design was used to conduct the germination test (Kheloufi and Mansouri, 2019).

Table 2. Saline solutions and corresponding pH and electrical conductivity

Concentrations (mM NaCl)	pH at 19°C	Electrical conductivity (EC) ($mS.cm^{-1}$) at 23.3°C
0 (Control)	9.11	0.03
50	8.80	5.08
75	7.81	7.55
100	8.09	9.52
200	8.04	18.7

Germination parameters

Final germination percentage (FGP): The FGP designates the seeds that successfully germinated relative to the total number of seeds sown in each Petri dish. This parameter was determined using the formula:

$$\mathrm{FGP}\ (\%) = \frac{\sum \mathrm{ni}}{\mathrm{N}} \times 100$$

where FGP is the final germination percentage, ni is the number of germinated seeds on the last day of the test, and N is the total number of seeds incubated per test (Côme, 1970).

Mean Germination Time (MGT): The MGT indicates the rate at which seeds germinate within a population. A reduced MGT value reflects a faster germination rate, while a higher value signifies a slower rate. MGT was calculated using the following formula:

$$\mathrm{MGT}\ (\mathrm{days}) = \frac{\sum (ti.\, ni)}{\sum ni}$$

where MGT is the mean germination time, ti is the number of days since the beginning of the test, ni is the number of germinated seeds recorded at time t(i), and Σni is the total number of germinated seeds (Orchard, 1977).

Time to 50% germination (T_{50}): The T_{50} was designed to determine the time needed for 50% of the seeds to germinate. It is calculated using the following formula:

$$\mathrm{T50}\ (\mathrm{days}) = \frac{\mathrm{ti} + (\mathrm{N}/2 - \mathrm{ni})(\mathrm{tj} - \mathrm{ti})}{(\mathrm{nj} - \mathrm{ni})}$$

where N final number of seeds emerged, nj and ni are the cumulative numbers of seeds emerged after adjacent counts during tj and ti, when ni < N/2 > Nj (Coolbear et al., 1984).

Germination Tolerance Index (GTI): The GTI is a quantitative parameter used to evaluate the capacity of seeds to germinate under varying salinity levels. The calculation follows the formula provided by Khan and Ungar (1997):

$$\mathrm{GTI}\ (\%) = \frac{\mathrm{FGP\ under\ stress\ condition}}{\mathrm{FGP\ under\ non-stress\ condition}} \times 100$$

Statistical analyses

The effects of different NaCl concentrations on the four variables studied were tested by a one-way and two-way analysis of variance (ANOVA). Differences between treatments following ANOVA were made by means comparison. Multiple comparisons of means were carried out using Tukey's test ($p \leq 0.05$). A repeated measures analysis of variance was carried out for the germination kinetics. All statistical analyses were performed using SAS software Version 9.0 (Statistical Analysis System) (2002).

RESULTS AND DISCUSSION

The data presented in Figure 2 displays the overall germination rates for seeds of *Artemisia herba-alba* and *Physalis peruviana* over a period of 22 days as a function of increasing NaCl concentrations (mM). The figure highlights three distinct phases: an initial phase of seed imbibition resulting in a latency period, followed by an exponential phase of rapid germination, and, finally, a plateau phase indicating a cessation in germination (stationary phase). Notably, the two species were able to germinate at all NaCl concentrations during the 22-day experimental period.

For *A. herba-alba*, the control group shows 17.3% germination by the 6th day with a stationary phase starting on the 21st day. Seeds treated with 50, 75, and 100 mM have a low initial germination rate at the 6th day, which improves starting of the 14th day with a stationary phase not exceeding 40% of germination (Figure 2).

For *P. peruviana*, the stationary phase begins on the 6th day in the control and 50 mM NaCl group with 100% germination. As salinity increases, the stationary phase starts at around the 10th day for 75 mM NaCl and 100 mM NaCl and the germination rate decreases with increasing NaCl concentration. As the NaCl concentration increases by 200 mM, the exponential phase begins with a lower germination rate, reaching 6% germination at the 13th day and reaching the maximum at the 21st day with 36.7% germination.

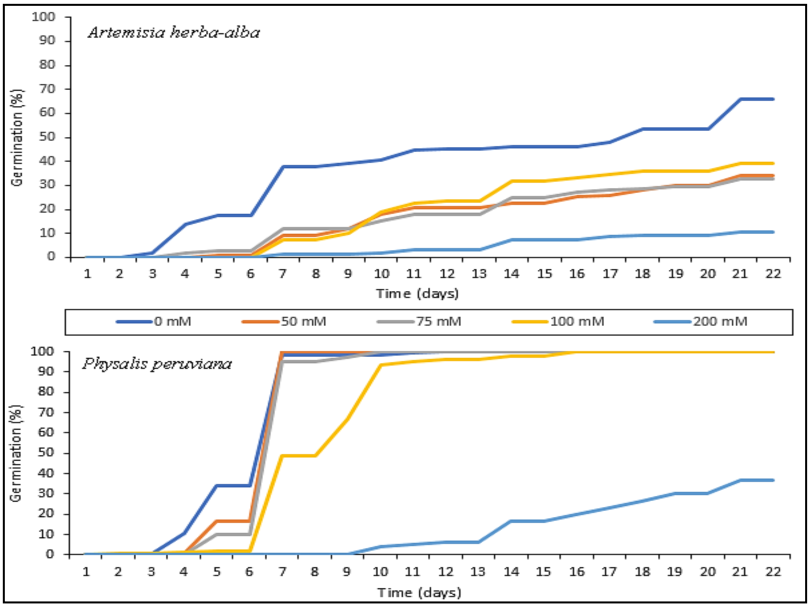

Figure 2. Cumulative germination percentages of *Artemisia herba-alba* and *Physalis peruviana* seeds treated with NaCl for a 22-day period.

According to Figure 2, the germination rates of all the species examined decrease with increasing salinity stress, and NaCl has a significant effect on this reduction especially at 200 mM ($p<0.001$). In addition, it is evident that the length of the latency period varies among species and increases as the concentration of NaCl increases. A repeated measures analysis of variance (performed over a 22-day period with daily evaluations) indicates that there is a highly significant effect (p<0.001) between various factors and variables, such as salinity concentration, species, and time, with both between-subject and within-subject effects and their correlation.

The delay in germination and inhibition of growth induced by salinity is caused by various factors such as reduced external water potential, ion imbalance, and specific ion toxicity (Soni *et al.*, 2023). In such conditions, there is a reduction in water uptake alongside an over-absorption of ions. The salinity tolerance of seeds includes both their duration in the soil, during which they may encounter elevated salinity levels and extreme temperatures, as well as their germination phase (Haider *et al.*, 2023).

Table 3. Effect of NaCl concentrations on germination traits of *Artemisia herba-alba* and *Physalis peruviana*

Species	**Salinity (NaCl)**	**FGP (%)**	**MGT (days)**	**T_{50} (days)**	**GTI (%)**
Artemisia herba-alba	0 mM	67.3^{a}	3.81^{a}	6.01^{ab}	100^{a}
	50 mM	39.3^{b}	4.14^{a}	5.73^{ab}	58.5^{b}
	75 mM	32.7^{b}	3.89^{a}	5.99^{ab}	48.5^{b}
	100 mM	34.1^{b}	4.42^{a}	8.21^{a}	50.9^{b}
	200 mM	10.7^{c}	1.26^{a}	1.91^{b}	16.2^{c}
	F-value	24.76	1.92	4.71	22.73
	***p*-value**	<0.001	0.183	0.021	<0.001
Physalis peruviana	0 mM	100^{a}	5.61^{a}	5.19^{a}	100^{a}
	50 mM	100^{a}	5.82^{a}	5.39^{a}	100^{a}
	75 mM	100^{a}	5.97^{a}	5.47^{a}	100^{a}
	100 mM	100^{a}	6.51^{a}	6.12^{a}	100^{a}
	200 mM	36.7^{b}	1.45^{b}	2.00^{a}	36.7^{b}
	F-value	59.77	32.34	3.26	59.77
	***p*-value**	<0.001	<0.001	<0.001	<0.001

FGP-final germination percentage; MGT-mean germination time; T_{50}-time to 50% germination; GTI-germination tolerance index.

Table 3 summarizes the effects of varying NaCl concentrations on the final germination percentage (FGP), mean germination time (MGT), time to 50% germination (T_{50}), and germination tolerance index (GTI) for *A. herba-alba* and *P. peruviana*, along with the results of a one-way ANOVA for each species. In addition to the results presented, the statistical analysis conducted through a two-way ANOVA provides further insights into the effects of salinity, species, and their interactions on seed germination parameters (Table 4).

A. herba-alba exhibited varying responses to increasing NaCl concentrations. At lower concentrations (0 mM and 50 mM), the FGP was relatively high, with values of 67.3% and 39.3% respectively. However, as salinity levels increased to 75 mM and 100 mM, the FGP declined substantially to 32.7% and 34.1% respectively. Notably, the highest NaCl concentration (200 mM) resulted in a significant reduction in FGP to 10.7%, indicating a pronounced inhibitory effect on germination (Table 3). These findings suggest that *A. herba-alba* is moderately sensitive to salinity stress during seed germination, with higher concentrations exerting greater inhibitory effects. Similar findings were reported by Nedjimi and Zemmiri (2019), demonstrating a significant decrease in final germination percentage (FGP) with increasing salinity levels. The highest FGP of 80% was observed in the distilled water control group. Salinity can influence germination by promoting the uptake of toxic ions, which in turn can lead to alterations in certain enzymatic or hormonal activities within the seed (Martínez-Ballesta *et al*., 2020). Salinity has been reported to cause substantial reductions in both the rate and final percentage of germination and emergence across various vegetable crops. Consequently, this may lead to uneven stand establishment and reduced crop yields (Gul *et al.,* 2022).

In terms of germination timing, *A. herba-alba* seeds exposed to different NaCl concentrations exhibited comparable MGT values, ranging between 3.81 to 4.42 days. However, the time to 50% germination (T50) showed slight variations across treatments, with seeds exposed to 200 mM NaCl requiring significantly less time (1.91 days) compared to other concentrations. This accelerated germination rate at higher salinity levels may be attributed to osmotic adjustment mechanisms triggered by salt stress, aiming to mitigate the adverse effects on seedling establishment.

The germination tolerance index (GTI) provides a comprehensive measure of seedling performance under salinity stress, considering both germination percentage and germination timing. *A. herba-alba* seeds exhibited the highest GTI (58.5%) when exposed to 50 mM NaCl, indicating relatively better tolerance to moderate salinity levels. However, as salinity increased, the GTI declined progressively, reaching the lowest value of 16.2% at 200 mM NaCl (Table 3). This decline in GTI underscores the detrimental impact of high salinity on seedling vigor and overall germination performance in *A. herba-alba.*

In contrast, *P. peruviana* demonstrated remarkable tolerance to salinity stress during seed germination. *P. peruviana* seeds consistently achieved a high FGP of 100%, indicating minimal inhibitory effects on germination even at elevated salinity levels. This high germination percentage suggests intrinsic physiological adaptations that enable *P. peruviana* seeds to tolerate salt stress during germination, thus ensuring successful establishment under adverse environmental conditions. Furthermore, both MGT and T_{50} values remained relatively consistent across different NaCl concentrations for *P. peruviana*, indicating that salinity did not significantly influence the timing of germination. This consistent germination timing suggests efficient physiological processes involved in seed imbibition and embryo development, unaffected by salt stress (Dey and Bhattacharjee, 2023).

The GTI values for *P. peruviana* remained consistently high across all salinity treatments, maintaining optimal seedling performance irrespective of NaCl concentration. This remarkable germination tolerance underscores the species' resilience to salinity stress during the critical germination stage, highlighting its potential for cultivation in salt-affected soils. Several authors have described a decrease in germination attributed to elevated salinity levels (Alkharabsheh *et al*., 2021). The present study revealed significant differences in all observations concerning salinity. These findings are consistent with earlier observations made for several cultivars of golden berry (Miranda *et al*., 2010; Yildirim *et al*., 2011; Cebeci and Hanci, 2015).

For FGP, both salinity (F=67.95, $p<0.001$) and species (F=424.97, $p<0.001$) showed significant main effects, indicating their individual contributions to variations in germination percentage. Additionally, the interaction between salinity and species (S×SP) was also significant (F=12.86, $p<0.001$), suggesting that the effects of salinity on FGP varied between *A. herba-alba* and *P. peruviana*.

Table 4. Two-way ANOVA of salinity and species effects on germination traits of *Artemisia herba-alba* and *Physalis peruviana*.

Variables	Factors	df	Mean square	F-value	*p*-value
FGP	S	4	3062.13	67.95	<0.001
	SP	1	19152.13	424.97	<0.001
	S × SP	4	579.46	12.86	<0.001
MGT	S	4	16.56	11.29	<0.001
	SP	1	18.39	12.53	<0.001
	S × SP	4	0.93	0.64	ns
T_{50}	S	4	22.51	7.84	<0.001
	SP	1	4.05	1.41	ns
	S × SP	4	1.02	0.36	ns
GTI	S	4	4391.15	55.16	<0.001
	SP	1	7933.82	99.66	<0.001
	S × SP	4	719.41	9.04	<0.001

FGP-final germination percentage; MGT-mean germination time; T_{50}-time to 50% germination; GTI-germination tolerance index; S-salinity; SP-species; df-degree of freedom; ns-non significant at $p<0.05$.

Similarly, MGT exhibited significant main effects of both salinity (F=11.29, $p<0.001$) and species (F=12.53, $p<0.001$), indicating their influence on the timing of germination. However, the interaction between salinity and species was not significant ($p>0.05$), suggesting that the effect of salinity on MGT did not differ significantly between the two species. For T_{50}, salinity demonstrated a significant main effect (F=7.84, $p<0.001$), indicating its impact on the time required for 50% germination. However, the effect of species and the interaction between salinity and species were not significant ($p>0.05$), suggesting that both *A. herba-alba* and *P. peruviana* responded similarly to salinity in terms of T_{50}. Regarding GTI, significant main effects of salinity (F=55.16, $p<0.001$) and species (F=99.66, $p<0.001$) were observed, indicating their influence on seedling vigor under different salinity levels. Additionally, the interaction between salinity and species (S×SP) was significant (F=9.04, $p<0.001$), suggesting differential responses of *A. herba-alba* and *P. peruviana* to salinity stress in terms of GTI (Table 4).

Despite the harmful effects of NaCl, this study shows that seeds of *A. herba-alba* and *P. peruviana* can germinate under 200 mM (Table 3). Such a salt concentration is considered to correspond to a significantly high level of salinity. This level of salinity exceeds the salinity tolerance level of the majority of cultivated vegetable species, as well as several halophytes (Bayuelo-*Jiménez et al.*, 2002; Malcolm *et al.*, 2003). As noted by Ungar (1982) and more recently by Suleiman *et al*. (2023), seeds of many perennial species possess the ability to preserve their viability for prolonged periods of exposure to harsh conditions, especially salinity and drought, and then to propagate when the ecological conditions are favorable. The maturation of seeds common to arid climates takes place during the autumn and the seeds begin to germinate within a few days of the first precipitation of the spring season. The seeds are typically found in the surface layers of the soil and propagate when high salt concentrations are leached away by rainfall.

CONCLUSIONS

Contrasting responses of *A. herba-alba* and *P. peruviana* to salinity stress during seed germination highlight species-specific adaptive mechanisms influencing germination performance under adverse conditions. Our analysis of germination attributes and statistical assessments reveals species-specific reactions to varying NaCl concentrations, offering valuable insights into their adaptive strategies under saline conditions. *A. herba-alba* showed moderate sensitivity to salinity, with decreasing germination percentages and tolerance indices as NaCl levels increase. In contrast, *P. peruviana* displayed remarkable resilience, maintaining high germination rates and vigorous tolerance across all salinity treatments. These distinct responses underscore the importance of species-specific adaptations in mitigating salinity stress effects on seed germination. These findings develop our knowledge of seed responses to salinity stress, relevant for conservation, cultivation, and management of these economically and ecologically vital species in saline-affected areas. Further exploration of molecular and physiological mechanisms behind salinity tolerance is essential for developing resilient crop varieties and sustainable agricultural practices in saline environments. Cultivating these species for horticultural purposes supports biodiversity while providing effective strategies to enhance agricultural productivity in challenging environments.

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REFERENCES

Alkharabsheh, H.M., Seleiman, M.F., Hewedy, O.A., Battaglia, M.L., Jalal, R.S., Alhammad, B.A., Schillaci, C., Ali, N. & Al-Doss, A. (2021). Field crop responses and management strategies to mitigate soil salinity in modern agriculture: A Review. Agronomy, 11(11): 2299.

Arroyo, A.I., Pueyo, Y., Reiné, R., Giner, M.L. & Alados, C.L. (2016). Effects of the allelopathic plant *Artemisia herba-alba* Asso on the soil seed bank of a semi-arid plant community. Journal of Plant Ecology, 10(6): 927-936.

Aydin, S. (2024). Effect of ecosystems and agricultural practices on *Physalis peruviana* phytochemicals. In Handbook of Goldenberry (*Physalis peruviana*) (pp. 227-238). Academic Press.

Bayuelo-Jiménez, J.S., Craig, R. & Lynch, J.P. (2002). Salinity tolerance of *Phaseolus* species during germination and early seedling growth. Crop Science, 42 (5): 1584-1594.

Cebeci, E. & Hanci, F. (2015). The influences of different salinity levels on germination performance of golden berry, (*Physalis peruviana* L.) seeds. Research journals, 26-29.

Christiansen, A.H.C., Norman, H.C. & Andreasen, C. (2022). Utilization of the halophytic shrubs *Atriplex nummularia* Lindl and *Rhagodia preissii* Moq as crops in salt-affected semi-arid regions: How temperature, salinity, seed weight and size affect seed germination. Frontiers in Plant Science, 13: 989562.

Côme, D. (1970). Les obstacles to germination. Masson et Cie (Paris), 14: 24-27.

Coolbear, P., Francis, A. & Grierson, D. (1984). The effect of low temperature pre-sowing treatment on the germination performance and membrane integrity of artificially aged tomato seeds. Journal of Experimental Botany, 35(11): 1609-1617.

Cortés, F.B., López, V. & Rojano, B.A. (2012). Sorption Properties of Cape Gooseberry (*Physalis peruviana* L.). International Journal of Food Engineering, 8(1).

Dey, A. & Bhattacharjee, S. (2023). Temporal regulation of oxidative window and hormonal homeostasis are the key events regulating germination under salinity and oxidative stress. Journal of Plant Growth Regulation, 42(5): 2907-2932.

Ezzat, S.M. & Salama, M.M. (2024). *Physalis peruviana* fruit bioactive compounds. In Handbook of Goldenberry (*Physalis peruviana*) (pp. 209-215). Academic Press.

Fadel, H., Benayache, F., Chalchat, J.C., Figueredo, G., Hazmoune, H. & Benayache, S. (2023). GC-MS analysis and antioxidant evaluation of two Aurèsian *Asteraceae* species *Artemisia herba-alba* Asso. and *Artemisia campestris* L. Vegetos, 1-9.

Gul, Z., Tang, Z.H., Arif, M. & Ye, Z. (2022). An insight into abiotic stress and influx tolerance mechanisms in plants to cope in saline environments. Biology, 11(4): 597.

Haider, M.Z., Ashraf, M.A., Rasheed, R., Hussain, I., Riaz, M., Qureshi, F.F., Iqbal, M. & Hafeez, A. (2023). Impact of Salinity Stress on Medicinal Plants. In Medicinal plants: their response to abiotic stress (pp. 199-239). Singapore: Springer Nature Singapore.

Halitim, A. (1988). Sols des régions arides algérienne. OPU 384p.

Johal, N. & Goyal, P. (2023). Drought and Salinity Stress: An overlapping osmotic resistance. Salinity and Drought Tolerance in Plants, 87-96.

Johnson, R. & Puthur, J.T. (2021). Seed priming as a cost-effective technique for developing plants with cross tolerance to salinity stress. Plant Physiology and Biochemistry, 162: 247-257.

Khan, M.A. & Ungar, I.A. (1997). Effects of thermoperiod on recovery of seed germination of halophytes from saline conditions. American Journal of Botany, 84(2): 279-283.

Khan, M.N., Fu, C., Li, J., Tao, Y., Li, Y., Hu, J., Chen, L., Khan, Z., Wu, H. & Li, Z. (2023). Seed nanopriming: How do nanomaterials improve seed tolerance to salinity and drought?. Chemosphere, 310: 136911.

Kheloufi A. & Mansouri L.M. (2019). Anatomical changes induced by salinity stress in root and stem of two acacia species (*A. karroo* and *A. saligna*). Agriculture and Forestry, 65(4): 137-150.

Kheloufi A., Chorfi A., Mansouri L.M. & Benyamina H. (2018). Morpho-physiological characterization and photosynthetic pigment contents of *Acacia karroo* Hayne seedlings under saline conditions. Agriculture and Forestry, 64(2):87-99.

Kigel, J. (2017). Seed Germination in arid and semiarid regions. Seed Development and Germination, 645-699.

Malcolm, C.V., Lindley, V.A., O'leary, J.W., Runciman, H.V. & Barrett-Lennard, E.G. (2003). Halophyte and glycophyte salt tolerance at germination and the establishment of halophyte shrubs in saline environments. Plant and Soil, 253: 171-185.

Mansouri, L.M. & Kheloufi, A. (2024). Salinity effects on germination of Portulaca oleracea L.: A multipurpose halophyte from arid rangelands. Journal of Applied Research on Medicinal and Aromatic Plants, 41: 100549.

Martínez-Ballesta, M. del C., Egea-Gilabert, C., Conesa, E., Ochoa, J., Vicente, M.J., Franco, J.A., Bañon, S., Martínez, J.J. & Fernández, J.A. (2020). The importance of ion homeostasis and nutrient status in seed development and germination. Agronomy, 10(4): 504.

Miranda, D., Ulrichs, C. & Fischer, G. (2010). Imbibition and percentage of germination of Cape Gooseberry (*Physalis peruviana* L.) seeds under NaCl stress. Agronomia Colombiana, 28(1): 29-35.

Muhammad, M., Waheed, A., Wahab, A., Majeed, M., Nazim, M., Liu, Y.H., Li, L. & Li, W.J. (2024). Soil salinity and drought tolerance: An evaluation of plant growth, productivity, microbial diversity, and amelioration strategies. Plant Stress, 11: 100319.

Muñoz, P., Parra, F., Simirgiotis, M.J., Sepúlveda Chavera, G.F. & Parra, C. (2021). Chemical characterization, nutritional and bioactive properties of Physalis peruviana fruit from high areas of the Atacama Desert. Foods, 10(11): 2699.

Nedjimi, B. & Beladel, B. (2015). Assessment of some chemical elements in wild Shih (*Artemisia herba-alba* Asso) using INAA technique. Journal of Applied Research on Medicinal and Aromatic Plants, 2(4): 203-205.

Nedjimi, B. & Zemmiri, H. (2019). Salinity Effects on Germination of *Artemisia herba–alba* Asso: Important Pastoral Shrub from North African Rangelands. Rangeland Ecology & Management, 72(1): 189-194.

Nikolić, N., Ghirardelli, A., Schiavon, M. & Masin, R. (2023). Effects of the salinity-temperature interaction on seed germination and early seedling development: a comparative study of crop and weed species. BMC Plant Biology, 23(1): 446.

Obregón La Rosa, A.J. (2024). Physicochemical, nutritional, and bioactive characteristics of Physalis peruviana L. fruit. In Handbook of Goldenberry (*Physalis peruviana*) (pp. 141-151). Academic Press.

Orchard, T. (1977). Estimating the parameters of plant seedling emergence. Seed Science and Technology, 5: 61-69.

Soni, P.G., Basak, N., Rai, A.K., Sundha, P., Chandra, P. & Yadav, R.K. (2023). Occurrence of salinity and drought stresses: status, impact, and management. In Salinity and Drought Tolerance in Plants: Physiological Perspectives (pp. 1-28). Singapore: Springer Nature Singapore.

Srivastava, P., Wu, Q.S. & Giri, B. (2019). Salinity: an overview. Microorganisms in Saline Environments: Strategies and Functions, 3-18.

Suleiman, M.K., Bhatt, A., Jacob, S., Thomas, R.R. & Sivadasan, M.T. (2023). Seed longevity in desert species and the possibility of forming a persistent soil seed bank. Sustainability, 15(22): 15904.

Ungar, I.A. (1982). Germination ecology of halophytes. In Contributions to the ecology of halophytes (pp. 143-154). Dordrecht: Springer Netherlands.

Yildirim, E., Karlidag, H. & Dursun, A. (2011). Salt tolerance of Physalis during germination and seedling growth. Pakistan Journal of Botany, 43(6): 2673-2676.