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ACACIA KARROO HAYNE AS A PROMISING CANDIDATE FOR THE RESTORATION OF SALT-AFFECTED SOILS UNDER MEDITERRANEAN BIOCLIMATE

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Abstract

Description of the subject: *Acacia karroo* is regarded as a promoting candidate to rehabilitate lands suffering different levels of environmental stresses (e.g., salinity and drought stress).
Objective : We have conducted, therefore, a study on the germination behavior in seeds using two abiotic constraints: salt stress through using NaCl and Na_2SO_4 at different levels (90, 180, 270 and 360 mM) and water stress, as simulated by PEG_{6000}, at different water potentials (-0.25, -0.5,-0.75 and –1 MPa).
Methods : First, seed germination features were recorded through final percentage and germination rate. On the other hand, we appreciated the response of seedlings to different treatments by measuring the length of seedlings, fresh and dry weights, as well as the seedling vigor index.
Results : Salt and water stress significantly affect germination as it was displayed through a steady decrease in seed emergence on increasing both stresses. Still, despite a high stress levels, *A. karroo* seeds successfully established and could germinate up to 360 mM NaCl (44%), 270 mM Na_2SO_4 (11%), and –1 MPa PEG (31%). Overall, this species seems to be tolerant to salt and drought stresses, albeit a reduction in seedling length, at the initial growth phases.
Conclusion : The results on germination attributes and growth features, being the most sensible stage in plant life cycle, of *A. karroo* seeds and seedlings against the abiotic stresses is certainly useful to imbedding this multipurpose plant in reforestation projects and consequently spreading its distribution for a beneficial exploitation.
Keywords : *Acacia karroo* ; growth ; germination ; salt stress ; water stress.

ACACIA KARROO HAYNE : UN CANDIDAT PROMETTEUR POUR LA RÉSTAURATION DES SOLS AFFECTÉS PAR LE SEL SOUS LE BIOCLIMAT MÉDITERRANÉEN

Résumé

Description du sujet : *Acacia karroo* est considéré comme un candidat promoteur pour réhabiliter les régions souffrant de différents niveaux de stress environnementaux (à savoir la salinité et le stress hydrique).
Objectifs : Nous avons donc mené une étude sur le comportement germinatif des graines en utilisant deux contraintes abiotiques : le stress salin en utilisant du NaCl et du Na_2SO_4 à différents concentrations (90, 180, 270 et 360 mM) et le stress hydrique, tel que simulé par le PEG_{6000}, à différents potentiels (-0,25, -0,5, -0,75 et –1 MPa).
Méthodes : Tout d'abord, les caractéristiques de germination des graines ont été exprimées par le pourcentage final et le taux de germination. D'autre part, nous avons apprécié la réponse des plantules aux différents traitements en mesurant la longueur des plantules, les poids frais et sec, ainsi que l'indice de vigueur des plantules.
Résultats : Le stress salin et hydrique affecte de manière significative la germination, car il s'est manifesté par une diminution constante de l'émergence des graines lors de l'augmentation des deux stress. Pourtant, malgré des niveaux de stress élevés, les graines d'*A. karroo* se sont établies avec succès et ont pu germer jusqu'à 360 mM de NaCl (44 %), 270 mM de Na_2SO_4 (11 %) et -1 MPa PEG (31 %). Dans l'ensemble, cette espèce semble tolérer les stress salins et hydriques, malgré la réduction de la longueur des plantules, lors des premières phases de croissance.
Conclusion : Les résultats sur les attributs de germination et les caractéristiques de croissance, étant l'étape la plus sensible du cycle de vie des plantes, des graines et des semis d'*A. karroo* contre les stress abiotiques sont certainement utiles pour intégrer cette plante polyvalente dans les projets de reboisement et par conséquent étendre sa distribution pour une exploitation bénéfique.
Mots clés: *Acacia karroo* ; croissance ; germination ; stress salin ; stress hydrique.

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INTRODUCTION

Acacia karroo Hayne is a member of the genus Acacia Miller, family Fabaceae and subfamily Mimosoideae. The genus was first described by Philip Miller in 1754, the name was derived from the Greek word 'akis' which means point or barb, referring to the thorns found on African Acacia species [1]. The species name 'karroo' is the old spelling for the South African semi-desert natural biome 'karroo', where the species was first described by botanical explorers [2]. *A. karroo* has been recorded throughout south-western African countries [3]. It has been introduced to North Africa, Australia, India, Myanmar and South America, where it is often used as live fence around agricultural fields [4, 5]. *A. karroo* grows from sea level to 1800 m on soils ranging from pure unconsolidated sand to heavy clays with an annual rainfall from 200 mm, where ground water is available along drainage lines and around dams and pans, up to 1500 mm [5]. According to this author, *A. karroo* is a multipurpose tree with great potential for increasing productivity in agroforestry and silvopastoral systems over a wide range of sites in the dry zones of the tropics and subtropics. It is also categorized as a species with potential commercial value in Botswana, South Africa and Zimbabwe [5, 6]. In Algeria, this species is used in reforestation under verious type of soils within all climatic conditions. For example, Kheloufi et al. [68] noticed that, although seeds tolerated high levels of salinity, *A. Karroo* germination of steppic area was more pronounced as compared to that of coastal habitat. Plant communities undergo a range of experiences provided by environmental stresses with varying sources and magnitudes (e.g., salty soil, drought, waterlogging, heat, heavy metals, low-nutrient soils content, anthropogenic pressure), and therefore shape their natural distribution [7]. Among the major factor hampered vegetable production and land development all over the world is soil salinisation [8]. Affecting 932.2 Mha globally, this widespread adversity, predicted to increase up to 50% by 2050, can be exaggerated by *(i)* excessive evaporation generated by global warming, *(ii)* intensive use of saline groundwater (mainely in arid and semi-arid regions) or *(iii)* faulty agricultural practices [9]. According to many studies, unfortunately, all Mediterranean countries suffering salt-soil increase which can pose, indeed, an outstanding dilemma for land use and plant occurrence [8-10]. North African lands, Algeria included, shows a high level uptake of not only by chloride salts (e.g. $NaCl$ and $CaCl_2$) but also sulfate salts (e.g. Na_2SO_4 and K_2SO_4) are excessively present [11]. Substrate salinity reduces crops productivity, increases soil osmotic pressure [9], induces scarcity of good water quality [12], affects photosynthesis by decreasing CO_2 levels [13], and subsequently decreases storage accumulation and availability [14]. The underground effects of high salinity is reflected by disruption of cell ion homeostasis induced by dwindled root-uptake of essential minerals such as K^+, Ca^{2+}, and NO_3^- and increasing accumulation of lethal ions (Na^+ and Cl^-) [15]. Salinity impairs and even inhibits germination of halophytes and glycophytes, rather for some species, low salt concentrations may stimulate germination [16]. After exposition under highly saline conditions, ungerminated seeds of most plant species remain viable and can recover germination successfully when stress is reduced or removed [17]. In fields, this probably occurs only after rainfall events when soil salinity is usually lessened because of ion leaching [18]. In controlled conditions, sodium chloride ($NaCl$) is conventionally used to study the salinity effect (osmotic or ionic potential) on seed germination for a large spectrum of species as it is the mainly salinity agent encountered in soils [11, 19]. Downward precipitation trend, displayed in recent decades, has consistently increased drought in Mediterranean Basin and this situation is still projected to worsen in the future [20]. The climate of this region is characterized by moderate wet winter with irregular-timing rainfall followed by hostile and prolonged hot summer. Broad drought season means young seedlings might be exposed to scarcity in water availability for a large period soon after germination [21]. There is a growing body of evidence that under such scenario, seeds of most of the plants avoid germination till arrival of appropriate conditions for seedling survival including enough rains [22]. Sustaining seeds' embryo viability and the ability to recover after stress alleviation seems to be the main plant adaptive traits involving to deal with scarcity in water supply [23]. Thus, germination failure by decreasing water potential, caused by either salt accumulation or water dearth, is likely owing to the inactivated enzymes and hormones found in seeds which disrupt mechanisms leading to radicle protrusion and *in fine* delaying seed germination trigger [24]. Amongst processes usually used to simulate water stress *in vitro* is by treating seeds and seedlings with polyethylene glycol (PEG_{6000}), an osmotic, non-toxic water polymer that impede seed water-uptake [25]. A thorough understanding of seed germination ecology has been an underlying research topic in plant sciences. In plant stress research, it is so obvious to well understand of how stress impacts seed behaviour and how seed affords it, involving self-protection mechanisms such as physiological modulations by synthesizing hormones, urging or delaying germination and so on [26]. Therefore, the aim of this study was to assess the salinity and moisture stress tolerance on *A. karroo* seed emergence originated from sub-humid Mediterranean climate (Bejaia provance). This, in turn, will help to frame the accurate location/time features for germination and seedling establishment of this species in their natural habitat in order to planning of an intended mass-scale reforestation programme through sowing pre-treated seeds in targeted marginal open fields of Algerian lands.

MATERIALS AND METHODS

1. Study species and seed harvesting site

Acacia karroo displays considerable variation in its morphology. Typically, this species has a rough, longitudinally fissured bark which is dark along the trunk. The foliage is mainly dense and comprises dark green compound leaves. Inflorescences are balls of small sweetly scented yellow flowers, while the pods are flat, mostly sickle shaped (Fig. 1) with minor constrictions between seeds and dehiscent. The thorns are long, paired, straight, and shining white. *A. karroo* is characterised as a small to medium-sized tree commonly growing to 5–12 m in height but may become a very large tree of up to 22 m when found in favourable conditions [1].

Ripe pods, containing *A. karroo* mature seeds ready to be spread, were collected in August 2019 from a wild growing population in the Gouraya National Parc, North east Algeria (36º76' N; 05º08' E). The seed harvesting site has a typical Mediterranean climate, characterized with subhumid bioclimate, where mean annual rainfall is between 600-800 mm with extreme heterogeneity in time, most of the precipitation occurs in winter, and average temperature of about 19.5 ºC.

2. Germination tests

Before starting germination tests, seeds were soaked in 96% H_2SO_4 for 20 minutes to break physical dormancy (personal observation). After that, seeds were washed abundantly with sterilized H_2O. Seeds were germinated at different concentrations (0, 90, 180, 270, and 360 mM) of two soluble salts (NaCl and Na_2SO_4), concentrations selected are within the range of those reported for multiple Algerian substrates [27], and five levels (0, -0.25, -0.5, -0.75, and -1 MPa) of PEG_{6000} solutions. These levels were got dissolving different concentrations of PEG_{6000} in deionized H_2O according to the require water potential (Ψ) to induce, as described by Michel & Kaufmann [28] : $\Psi = -(1.18 \times 10^{-2})\,\mathbf{C} - (1.18 \times 10^{-4})\,\mathbf{C^2} + (2.67 \times 10^{-4})\,\mathbf{CT} + (8.39 \times 10^{-7})\,\mathbf{C^2T}$. Where: Ψ: water potential (bars), **C**: PEG concentration (g/l), **T**: temperature (◦C) - 1 MPa = - 10 bars

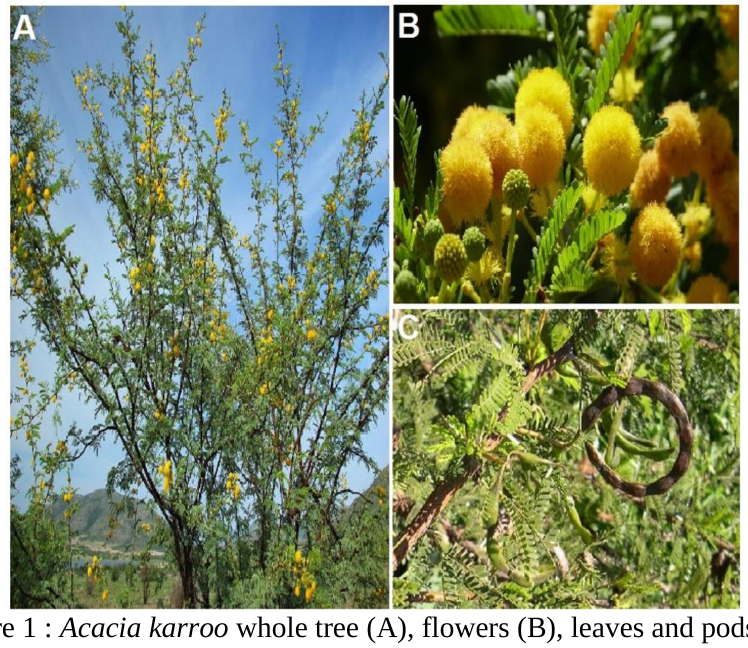

Figure 1 : *Acacia karroo* whole tree (A), flowers (B), leaves and pods (C).

Seeds were laid on a double layer filter paper sheet containing within 90 mm Petri dishes and supplied with 10 ml of the test solutions. For each treatment, 80 seeds were split evenly in 4 replicates (20 seeds each). As precaution to minimize evaporation, the dishes were sealed hermetically with parafilm. The dishes were randomized in the dark at a constant optimum temperature of 20 ± 1°C [66], in a thermostatically controlled germinator.

3. Germination data expression

The final germination percentage (GP) as noted by radicle reaching 2 mm long, was counted every 24 h. The experimental period lasted for 12 days, at which germination had ceased. The germination rate (GR), using the mean germination time, was expressed by the formula: $GR=\Sigma_{niti}/\Sigma_{ni}$. Where *ni* is the number of seeds that had germinated at time i and *ti* is the period from the beginning of the experiment to the ith observation [29].

4. Growth parameters assessement

Growth features were also estimated at the end of the germination incubation period on seedlings submitted in each salt concentration and each PEG_{6000} levels. For this purpose, five seedlings were sampled randomly from each Petri box to measure their total length. Fresh (FW) and dry weight (DW) were determined either by using a high precision analytical balance (0.1 mg). Dry weight was measured after placing seedlings at 60 °C for 48 h. Seedling vigor index (SVI) was calculated as SVI = GR × seedling dry weight [67].

5. Statistical analysis

The data were tabulated and analysed using SPSS for Windows, version 22. Germination data were arcsine transformed from the number of germinated seeds to percentages ± standard error (SE), before the statistical analysis, to ensure the homogeneity of variance. A two-way analysis of variance (ANOVA II) was carried out to test the effects of the two salts, concentrations and their interaction on both germination attributes and growth traits. A paired-samples *t*-test (pairwise), by using Tukey test, was conducted to estimate the least significant differences at $P = 0.05$ among all studied parameter means. To correlate the results obtained with different studied expressions, a regression analysis was carried out and correlation coefficients were calculated.

RESULTATS AND DISCUSSION

1. Effect of salt and water stress on germination traits

ANOVA two way analysis (Table 1) showed a significant difference among salt agent, concentrations and their interactions, except in salt type × concentration upon germination rate ($p = 0.068$). The seed germination traits (germination percentage and germination rate) in both salts decreased steadily with increasing salt concentration (Fig. 2), though the maximum germination rate was recorded in the milder concentration (GR=10,27 days in the control *vs.* 12.04 days in 90 mM NaCl and 12.22 days in 90 mM Na_2SO_4). Such results in germination reduction have been reported by using either NaCl only in *Retama raetam* [30], *Prosopis pallida* [31], or various single soluble salts in *Accacia saligna*, *A. decurrens* [65] *Artemisia herba–alba* [32], *Marrubium vulgare* [11], and *Lavandula stoechas* [33]. Seed germination was completely ceased at 360 mM Na_2SO_4, while seeds still germinated at the same concentration in NaCl. The results of former investigations on the effect of multiple soluble salt agents in germination are contradictory and species dependent. For example, NaCl was more depressive than Na_2SO_4 on seed germination of *Pinus halepensis* [34], *Arthrocnemum macrostachyum*, and *Juncus acutus* [35], but Na_2SO_4 was more detrimental than NaCl on the germinability of *Prosopis strombulifera* [36], *Ceratoides latens* [37], *Medicago sativa*, *Elymus dahuricus* [38] and *M. vulgare* [11].

Accacia Karroo can withstand salinity and kept high germination performance at 360 mM NaCl. *A. saligna* and *A. decurrens* have a tolerance threshold of 150 and 300 mM NaCl, respectively [65]. Interestingly, *A. decurrens* was more sensitive to salt stress compared to *A. ehrenbergiana* and *A. tortilis* when experiencing irrigation with different levels of diluted seawater (ranged from 0% to 100%) [69]. Tavakkoli [70] reported that increasing salinity causes a decrease in barely germination; this might be due to the toxic effects of Na^+ and Cl^- in the process of germination. These both ions alter the seeds imbibition of water and cause toxicity, resulting therefore deleterious changes in activity of enzymes, nucleic acid and protein metabolism, which consequently interrupts hormonal balance, and reduces the utilization of seed reserve [71].

Table 1 : Results obtained of two–way analysis of variance (F values) testing the effects of salts (S), doses (C), and their interaction (S × C) on seed germination features and seedling responses in *A. karroo*.

Independent variables	Salts (S)	Concentrations (c)	S × C
GP (%)	13.11**	24.68***	7.48***
GR (% day^{-1})	9.41**	13.28***	2.57ns
SL (cm)	10.06**	41.73***	4.80**
FW (mg)	29.45***	28.01***	7.62***
DW (mg)	13.45**	4.85**	7.80***
SVI	9.31**	9.70***	3.05*

ns not significant. * $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.001$

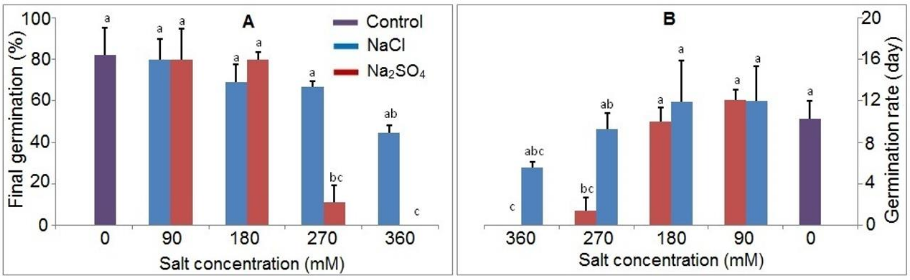

Figure 2 : Final germination percentage (A) and germination rate (B) of *Acacia karroo* seeds at different concentrations of soluble salts. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p < 0.05$).

On the other side, no statistically significant differences were noted among water stress levels on the seed germination percentage till –0.75 MPa, and the lowest value was obtained at –1 MPa (GP = 31%). Interestingly, the highest GR value was reached at –0.25 MPa (21.66% day^{-1}) in which GR fell gradually by decreasing water potential beyond this level (Fig. 3). Many authors reported formerly the dreadful effects of decreasing water potential on germination for severals plants species [39-41]. Regarding our species, water in soil has more complicated effects on germination than other abiotic factors because water is the initial cue causing seed imbibition and thus the germination; it is directly and indirectly involved in subsequent germination metabolic stages [42] in particularly under arid and semi-arid environment. Our findings corroborate those of Aljasmi et *al*. [31], who reported that seeds of *P. pallida* were negatively affected by the water potential and seeds had germinated better in the absence of stress. The reduction of GP may be due to the alteration of enzymes and hormones confered in the seeds [43]. It could also be a deficit of water percolation in seeds due to high osmotic potential causing inhibition of the mechanisms leading to the output of the embryonic axis out of the seed shell and therefore suspend germination trigger [24].

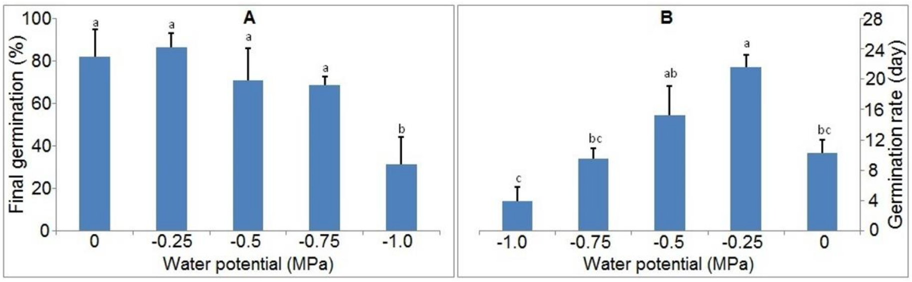

Figure 3 : Final germination percentage (A) and germination rate (B) of *Acacia karroo* seeds at different levels of water stress. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p \leq 0.05$).

2. Effect of salinity on early growth parameters

Seedling length had shown an outstanding drop with increasing salinity (even though no significant differences have been noted between control and 90 mM in both salts) (Fig. 4). For example, at 360 mM NaCl the seedling length was 6 times less than in distilled water (1.52 cm *vs.* 9.12 cm, respectively).

As represented in figure 5, the higher the salt stress, the lower the fresh weight. This inhibition was more pronounced at 270 mM Na_2SO_4 upwards. Surprisingly, the increasing NaCl and Na_2SO_4 concentrations stimulate the biomass production as expressed via dry weight (despite the statistically insignificant differences among concentrations at $p \leq 0.05$), except for 270 mM Na_2SO_4 (DW = 12.5 mg *vs.* 15.32 mg at the control). Salinity induced promoted the vigor index and the higher values were noted at 180 mM NaCl (SVI = 214) and 90 mM Na_2SO_4 (SVI = 207). Beyond 180 mM Na_2SO_4 the SVI fell steeply (SVI = 26.6 at 270 mM) (Fig. 6). Pearson correlation coefficient indicated that seedling vigor index is most positively correlated with germination rate in the two experienced salt agents (r = 0.959, $p \leq 0.01$ with NaCl and r = 0.984, $p \leq 0.01$ with Na_2SO_4) (tables 2).

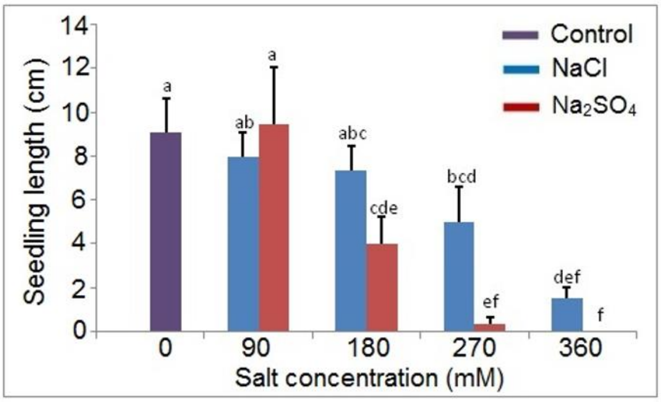

Figure 4 : Seedling length of *Acacia karroo* (12 days) at different concentrations of salts. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p \leq 0.05$).

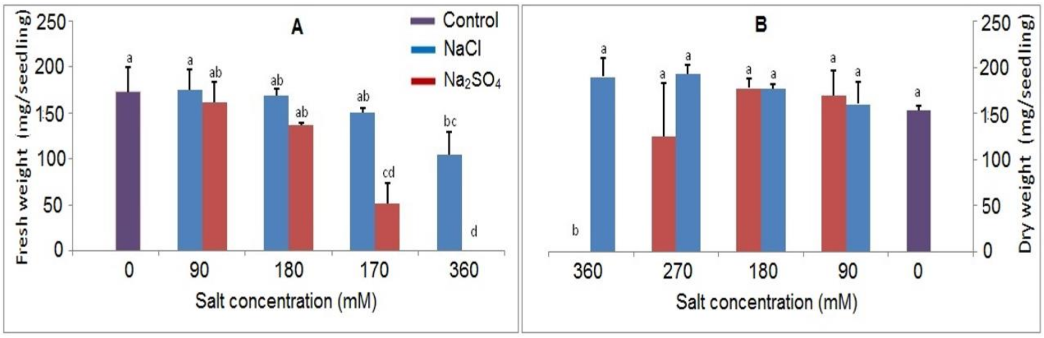

Figure 5 : Fresh (A) and dry weight (B) of *Acacia karroo* seedlings (12 days) at different concentrations of soluble salts. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p \leq 0.05$).

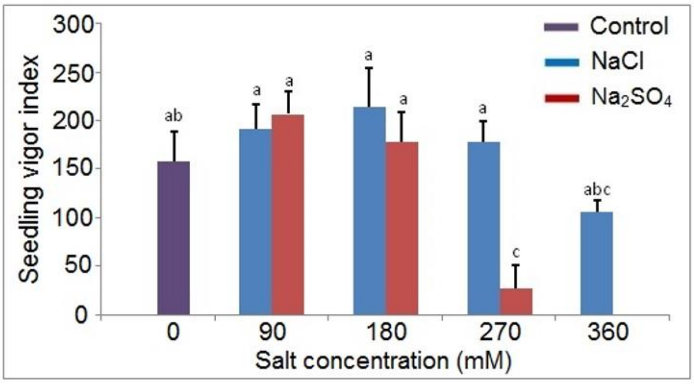

Figure 6 : Vigor index of *Acacia karroo* seedlings (12 days) at different concentrations of soluble salts. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p \leq 0.05$).

Table 2 : Pearson correlation coefficient between germination/growth features in seeds treated with NaCl, Na_2SO_4 and PEG_{6000}.

	Germination rate	Seedling length	Fresh weight	Dry weight	Vigor index
			NaCl		
Germination percentage	742**	660**	438*	-642**	573*
Germination rate	1	444*	353*	-303*	959**
Seedling length		1	703**	-688**	275 *
Fresh weight			1	-178ns	325*
Dry weight				1	-030ns
Seedling vigor index					1
			Na_2SO_4		
Germination percentage	946**	740**	919**	752**	960**
Germination rate	1	856**	923**	731**	984**
Seedling length		1	838**	530*	786**
Fresh weight			1	840**	914**
Dry weight				1	763**
Seedling vigor index					1
			PEG_{6000}		
Germination percentage	457*	583*	682**	-297*	378*
Germination rate	1	508*	422*	-098ns	961**
Seedling length		1	813**	-387*	433*
Fresh weight			1	-267*	377*
Dry weight				1	147ns
Seedling vigor index					1

ns − not significant correlation, * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

Reduction in seedling height is a common phenomenon of various plants sprouting under saline conditions [11, 44, 45]. The gradual decrease in seedling length with the increase in Na_2SO_4 as observed might be due to more inhibitory effect of Na_2SO_4 than NaCl salt to root and shoot growth [46]. Amzallag [47] reported that seed germination, seedling growth, cell respiration and further related processes can be altered in seeds that are subjected to abiotic stress in the natural conditions. *A. karroo*, a moderately salt-tolerant species, shows a decrease in growth under saline constraint conditions. Igartua et al. [48] reported that, during imbibition, the effect of salt was solely osmotic until a hydration threshold was suppressed. After this, salt had combined toxic and osmotic affects that could be noxious at high concentrations. Other studies have emphasized that the inhibitory effect of salts can be mainly an osmotic effect [49], ion toxicity [50] or both [51], which suggests that the effect is species specific [52]. Similarly, Jamil & Rha [53] observed that shoot length, root lengths and fresh weight were decreased with increasing salt stress in rice (*Oryza sativa*). There is an obvious positive effect for salt stress on the dry weight in *A. karroo* seedlings. These results are consistant with those presented by Abdul Qados [54] in a study carried out on *Vicia faba* where the treatment with salt increased the dry weight by about 24% at 120 mM NaCl compared to the control, and also meet the results of Dantus et *al*. [55] on cowpea (*Vigna unguiculata*), where they report that using 10 mM of NaCl increased dry weight of the seedlings. Moreover, dry weight of the seedlings is affected, either negatively or positively, rather by changes in salinity concentration, kind of salt agent, or type of plant species and varieties [56].

3. Effect of water stress on initial plant growth

Drought stress remarkably affected seedling length (Fig. 7), and the clear inhibitory effect begins from –0.5 MPa upwards, and the minimum value was obtained at –1 MPa (2.04 cm). Regarding the fresh weight, the greater value was reached at control (173.4 mg), while water stress induced decreases significantly the fresh weight too, and this inhibition was apparent from the level of –0.5 MPa (FW = 108.88 mg) (Fig. 8). Similarly to salt stress, despite water potential drop, no significant effect ($p \leq 0.05$) has been noted for the dry weight either in low or high levels of stress (Fig. 8). As concerns the vigor index, a noticeable increase was observed already at -0.25 MPa (SVI = 415,86), a value that is almost five-folds than at -1 MPa (SVI = 80,04) (Fig. 9). Pearson analysis revealed a best correlation among vigor index and germination rate (r = 0.961, $p \leq 0.01$), fresh weight and seedling length (r = 0.813, $p \leq 0.01$), fresh weight and germination percentage (r = 0.682, $p \leq 0.01$), and seedling length and germination percentage (r = 0.583, $p \leq 0.05$) (table 2).

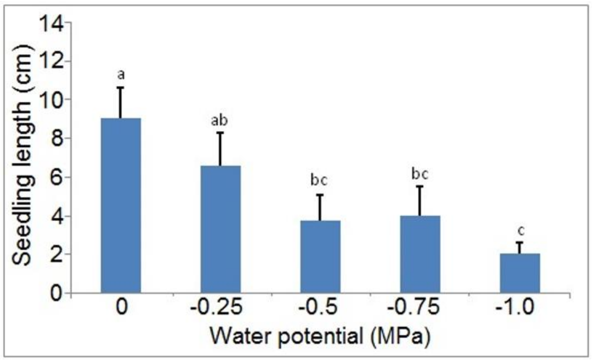

Figure 7 : Seedling length of *Acacia karroo* (12 days) at different levels of water stress. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p \leq 0.05$).

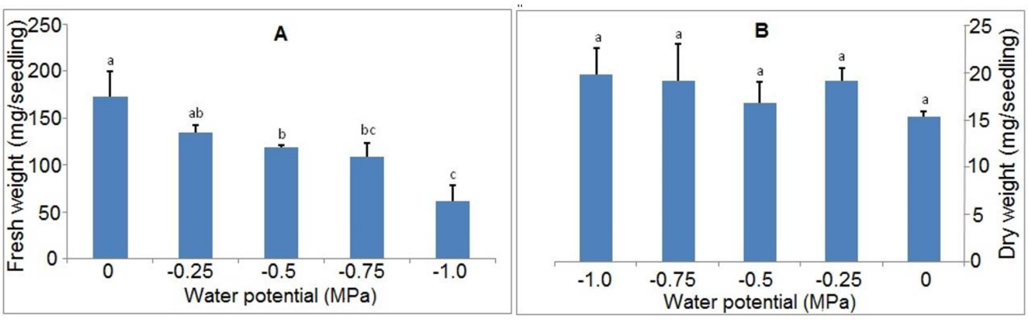

Figure 8 : Fresh (A) and dry weight (B) of *Acacia karroo* seedlings (12 days) at different levels of water stress. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p \leq 0.05$).

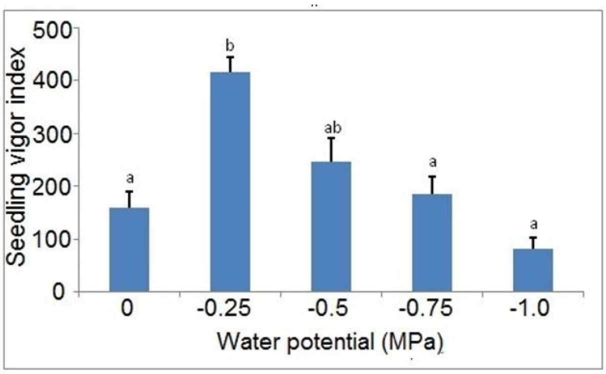

Figure 9 : Vigor index of *Acacia karroo* seedlings (12 days) at different levels of water stress. Bars represent mean ± S.E (n=4). The same alphabetical letter indicates that values are not significantly different ($p \leq 0.05$).

Drought stress is one of the most important factors limiting the growth of plants in their habitats. Higher tolerance to lower water potential during seed germination and plant growth has been considered as an adaptive strategy for plants dwelling in unpredictable and harsh environments [57, 58]. Similar to our results, drought stress decreases fresh weight in *Medicago laciniata* [59], *M. sativa* [60] and *Anthemis* [61]. In his study, Kaiser [62] reported that photosynthesis is rather insensitive to dehydration yet at 50–70% relative water content and in severe dehydration, not only photosynthesis but also dark CO_2 fixation and photorespiration are decimated. The decrease in water potential increases osmotic potential, creating a deficiency in seed hydration and causing changes in enzymatic activities, a general reduction in the hydrolysis and utilization of major seeds' natural food supplies, notably carbohydrates, lipids, and proteins, which subsequently preventing plant emergence [63]. The dry weight was the same at all PEG tested solutions, indicating that *A. karroo* entertains biomass productivity as a coping strategy to withstand drought. In fact, Faisal et al. [64] emphasized that the effects of drought depend not only upon the degree and length of water shortage but also upon the growth stage and plant part.

CONCLUSION

It is likely that *A. karroo* should be classified as a species tolerant to salinity since, at the studied level of 270 mM NaCl, the injuring effect of salt ions is still negligible.

The relatively lower germination in higher water stress medium indicates that most seeds prefer not to emerge until the arrival of proper conditions for seedling establishment, which is usually occurring after winter rainfalls. Under Mediterranean climate, characterized by erratic and unpredictable rains, using the short period of water availability after precipitation for rapid and massive germination should be an efficient strategy to ensure the success of seedling growth. Indeed, *A. karroo* is regarded as a potentiel tree to be used in the restoration of the Algerian salt-affected lands. Further investigations are recommended to extrapolate these findings from laboratory to natural conditions.

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