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EFFECT OF WATER DEFICIT AND BURIAL DEPTH ON THE GERMINATION OF *Periploca angustifolia*

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Abstract

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Periploca angustifolia (Labill.) is a multipurpose xerophytic shrub in the Apocynaceae, which is widely disturbed in arid zones. This shrub is often used in programs for the rehabilitation of degraded areas, so it is essential to investigate the impact of environmental factors (drought, burial depth) on seed germination patterns. During 20 days, germination responses of seeds were determined over a wide range of constant temperatures (25 °C), polyethylene glycol PEG-6000 solutions of different osmotic potentials (0 to -1.6 MPa), and burial depths (1–8 cm). The highest germination percentages (99%) were obtained under control conditions without PEG, and increasing osmotic pressure progressively inhibited seed germination, which was about 2% at -1.6 MPa. When seeds were buried deep, there was a significant decrease in seedling emergence percentage and rate. Seedlings of *P. angustifolia* emerged well at depths of 1–2 cm with the highest emergence percentage of 74 and 69%, respectively. They could not emerge when the sand burial depth was higher than 4 cm.

Key words: burial depth, osmotic potential, seed germination, seedling emergence, *Periploca angustifolia*.

Introduction

Water availability is a major factor limiting species regeneration in arid and semi-arid areas (Adams, 1999). So, drought caused vegetable cover loss in arid areas which are characterized by unpredictable rainfall, extended droughts, and very intensive evapotranspiration (Ren, Tao, 2003). Although several attempts have been made, in the past, to restore degraded rangelands in the Mediterranean arid zone with exotic herbaceous species and shrubs (Chaieb, 1989), all these efforts have largely failed due to the inability of the introduced species to adapt to the ecological constraints of the region. As a solution, reseeding with autochthonous species has become a more attractive option and a necessary alternative for soil improvement in Tunisian Sahara (Grouzis, 1992; Aronson et al., 1993; Le Floc'h et al., 1999). Consequently, for the rehabilitation of degraded zones of the Tunisian Sahara, it is necessary to have accurate information on the characteristics of the candidate species and its propagation methods. Climatic conditions for germination and growth are an essential part of an autecological study of any target species. The distribution (Andrews et al., 1997) and abundance of desert plants depend strongly on the efficiency of seed dispersal as well as the existence of safe sites that provide the requirements for successful establishment (Rebollo et al., 2001). To increase the success rate and reduce the cost of rehabilitation operation, it is essential to have a good understanding of the conditions of germination, i.e., the passing from the most-resistant stage (seed) to the most sensitive stage (seedling) of the plant's life cycle (Gutterman, 1993). Carefully chosen species can play a decisive role in environmental rehabilitation and protection in desert lands. Seed germination is considered a key stage in the reproductive cycle that is very important for species fitness, and changes in germination rates are interpreted as adaptations to ecological conditions (Navarro, Guitian, 2003; Rajjou, Debeaujon, 2008). The successful establishment of plants largely depends on successful germination (Gorai, Neffati, 2007). Germination is a critical stage in the plant life cycle and is often highly unpredictable in space and time. Multiple environmental factors such as temperature, salinity, light, and soil moisture simultaneously affect germination (Huang et al., 2003, El-Keblawy, Al-Rawai, 2006). Furthermore, the germination behavior of several species can be determined by examining many parameters, such as environmental conditions. The context of the analysis of fight against the desertification means that we were interested in a particularly resistant and autochton species such as *Periploca angustifolia*. This woody shrub is well adapted to an arid zone, where the deep rooting allows fixation of sandy dune and promotes water infiltration and the redistribution of nutritive elements in the soil. It is well adapted to disturbances such as drought and browsing. Despite its ecological importance and

wide distribution, the study of seed germination under drought stress and seedling depth allows us to understand this species' ability to regenerate plants, particularly in the case of our studied species which represents a keystone species growing across the Mediterranean ecosystems. In this case, to better control the initial difficulties encountered during seedling installation testing, we focused on the study of *P. angustifolia* seed germination. These tests have been carried out to first understand optimal water potential and the appropriate depth for this species to germinate. A better understanding of these factors is crucial for the successful regeneration and recruitment of this shrub, and it is essential to guide activities for reintroducing it into degraded ecosystems. Therefore, we studied the germination characteristics of *P. angustifolia*. This woody and perennial shrub is an autochton plant of the Apocynaceae family (Cronquist, 1981). This species colonizes the Mediterranean basin (Spain, Morocco, Algeria, Sicily, Tunisia, Malta, Libya, Egypt, Lebanon, and Syria) (Quezel, Santa, 1962). It is the only species of this genus in Tunisia (Chaieb, Boukhris, 1998). It reaches up to 3 m high and branches short and rigid, and the upper ones sometimes lax and twining (Ghrabi, 2005). This species has a reputation for high tolerance to water deficiency in the Tunisian Saharan regions. It appears to be suitable for the re-vegetation of areas that are subjected to the desertification process. This shrub has great potential to provide different products and services such as forage, traditional medicine, halting desert encroachment, and stabilizing dunes. Until today, germination of this species has received little experimental research. Previous studies focusing on the germination behavior of *P. angustifolia* seeds showed that germination percentage is influenced by burial depth, temperature, salt, and osmotic stress (Noumi et al., 2013, Dghim et al., 2015). A comparative study of root system growth of this shrub and *Rhus tripartitum*, cultivated in rhizotrons, showed that in the first months following germination (in November), the root development of the shrubs was rapid despite the negative influence of low winter temperature on the growth of the *Periploca angustifolia* root system (Yobi et al., 2001). Osmotic solutions are used to induce water stress repeatedly under *in-vitro* conditions (Pandey, Agarwal, 1998). Polyethylene glycol (PEG-6000) molecules are virtually impermeable chains that were frequently used to maintain a uniform water potential throughout the experimental period (Hohl, Schopfer, 1991; Lu, Neumann, 1998). They are small enough to influence the osmotic potential but large enough not to be absorbed by plants (Carpita et al., 1979). Therefore, PEG solutions mimic dry soil, which infiltrates the cell wall with solutes (Verslues et al., 1998). Sand burial is an important factor in controlling the composition and distribution of vegetation in desert ecosystems (Wang et al., 1998; Chen, Kuo, 1999). The sand deposition has been recognized as an indispensable selective force for seed size, germination, seedling emergence, and seedling and adult plant survival (Maun, 1994). The objective of this study is to determine the effects of osmotic stress, induced by PEG-6000, and burial depth on seed germination of *P. angustifolia*. Studying the effect of different factors (drought and seedling depth) affecting the germination of *P. angustifolia* seeds helps us to understand its adaptability to drought and burial depth and would provide useful information for understanding its life cycle. This information is necessary for ecologists, especially in the restoration of dry regions.

Material and methods

Seed collection

Seeds of *P. angustifolia* were obtained from wild plants which were collected from natural populations at Sidi-Toui (32°44´N, 11°14´E; 110 m altitude) in 2006; this area is arid to semi-arid with a typical Mediterranean climate, characterized by irregular rainfall events and a harsh dry summer period. Collected seeds were cleaned and stored at the seed bank at the Laboratory of Range Ecology in the Arid Regions Institute of Medenine (Tunisia) in which relative humidity was set at 30% and the temperature was maintained at 20 °C until their use. Seeds were surface sterilized in 5% sodium hypochlorite solution for 10 min, subsequently washed with distilled water, and air dried before being used in the germination experiments to avoid fungus attack.

Effects of osmotic potential on seed germination

The effects of osmotic potential on seed germination were examined by incubating seeds, as described in the first experiment, at the most suitable temperature found with PEG-6000 solutions of known osmotic potential ($\Psi\pi$): 0, -0.1, -0.2, -0.4, -0.6, -0.8, -1, and -1.6 MPa (Michel, Kaufmann, 1973). For each treatment, four Petri dishes (with a diameter of 90 mm) containing two discs of a Whatman N°1 filter paper each containing 25 seeds were used and soaked with 5 ml of a test solution. Germination experiments were conducted in the dark in incubators set at 25 °C (Noumi et al., 2013) (Luminincube II; Analys, Belgium; MLR-350, Sanyo, Japan). Germinated seeds were counted and removed every 2 days for 20 successive days. A seed was considered germinated when the emerging root was elongated to 2 mm. The counting of germinated seeds stops when no further germination has occurred for two consecutive days. A quantity of distilled water, equal to the mean loss of water from dishes, was added to each Petri dish every 2 days to maintain the PEG concentration near the target levels throughout the germination period. Three characteristics of germination were determined: final germination percentage and the germination rate or the mean time to germination (MTG). The germination rate (GR) is calculated by the Timpson index (germination velocity index) modified by Khan and Ungar (1984): $GS = \Sigma G /t$; G: percentage of seeds germinated after 20 days; t: germination period. MTG was estimated according to the formula: $MTG = - (ni - di)/N$, where n is the number of seeds germinated at day i; d is the incubation period in days, and N is the total number of germinated seeds in the treatment (Brenchley, Probert, 1998).

Effects of burial depth on seedling emergence

The effect of burial depth on seedling emergence was studied under semi-controlled conditions. Seeds were sown in May 2009, and climatic data are presented in Table 1. All sand burial treatments consisted of ten replicates of 10 seeds per pot. For each replicate, seeds were sown at depths of 1, 2, 4, 6, and 8 cm in plastic pots (20 cm diameter) filled with sand. A completely randomized design was used for the sand burial depth tests. The pots were perforated at the bottom and contained a layer of gravel to provide water drainage. The pots were watered every alternate

Table 1. Mean climatic data during the month of May 2009 in semi-field burial depth experiment of *Periploca angustifolia* seeds.

PP (mm)	T (°C)	TM (°C)	Tm (°C)	H (%)
16.1	24.5	36.4	10.5	60.3

Notes: H – mean humidity; PP – precipitation amount; T – mean temperature; TM – maximum temperature; and Tm – minimum temperature.

Table 2. Germination percentage (GP), germination rate (GR), final emergence (FE), and mean time germination (MTG) and emergence (MTE) of *Periploca angustifolia* seeds at various PEG-6000 concentrations and depth for 20 days.

	Burial depth			PEG-6000		
	ddl	Test F	*P*	ddl	Test F	*P*
Germination percentage (%)	4	17.721	.000	5	208.562	.000
Germination rate (%)	4	27.375	.000	5	126.809	.000
Mean time germination (%)	4	4.106	.006	5	55.923	.000
Final emergence (%)	4	44.595	.000			
Mean emergence time (%)	4	37.442	.000			

Note: Means within a column followed by the same letter are not significantly different at the P=0.05 level for the given values (mean±95% confidence limits, Duncan's test).

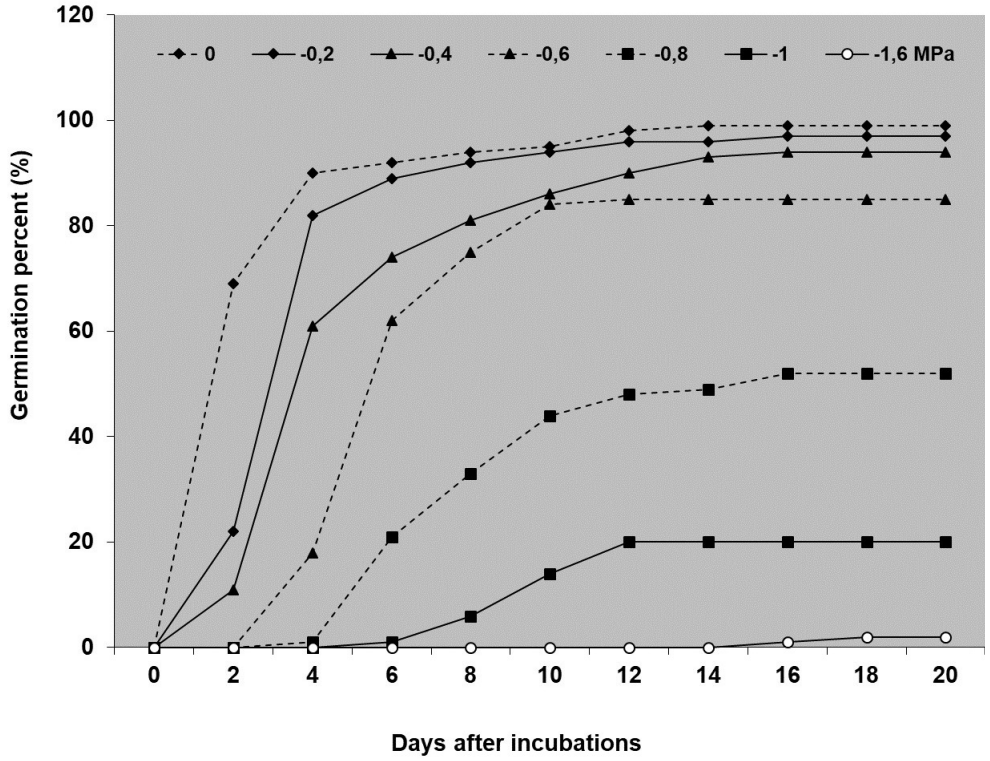

Fig. 1. Cumulative germination percentage of *Periploca angustifolia* for 20 days at different PEG-6000 treatments (0 to -1.6 MPA) at the optimum temperature germination (25 °C) (n = 4).

day with rainwater throughout the experimental period. Emerged seedlings (cotyledons visible on the surface of the sand) were counted daily and removed. The entire contents of the pot were emptied and washed at the end of the experiment through a sieve (2 mm) through which the sand escaped, and ungerminated seeds and unmerged seedlings were recorded. All dormant or decayed seeds were recorded as ungerminated. Three characteristics of seedling emergence were determined: final emergence percentage, the number of days to first emergence (delay of emergence), and mean time to emergence (MTE). MTE was estimated accord-

ing to the formula: MTE=Σ (ni×di)/N, where ni is the number of emerged seedlings at day i, d is the incubation period in days, and N is the total number of emerged seedlings in the treatment.

Statistical analysis

Germination and emergence percentages were arcsine transformed before statistical analysis to ensure homogeneity of variance. Data were analyzed using SPSS for windows, version 11.5. A one-way analysis of variance (ANOVA) was performed on all results. Duncan's test was used to estimate the least significant range between means.

Results

Effect of osmotic pressure on seed germination

The effects of osmotic potential on seed germination were examined by incubating seeds, as described in the first experiment, at the most suitable temperature found with PEG-6000 solutions of known osmotic potential (Ψπ): 0, -0.2, -0.4, -0.6, -0.8, -1, and -1.6 MPa (Michel, Kaufmann, 1973). PEG-6000 solutions were renewed every 48 h under sterile conditions to ensure relatively constant Ψπ in the treatments. Figure 1 shows that both the mean time to germination (MTG) and the germination rate of *P. angustifolia*'s seeds increase with PEG-6000 concentrations. Also, the germination percentage is significantly affected by water stress induced by increasing water potentials (Table 2). The maximum germination percentage (99%) was reached in distilled water (0 MPA). *P. angustifolia* germination was not significantly affected by low PEG concentrations which corresponded to water potentials of -0.2 and -0.4 MPa. The osmotic pressure of -1.6 MPa corresponds to the point at which the *P. angustifolia* seeds no longer absorb water, and the germination rate drops from 99% (0 MPa) to 2% (-1.6 MPa). The highest germination percentages were obtained under low PEG-6000 concentrations, and their increase progressively inhibited seed germination. High osmotic pressure values decrease the germination rate and increase the average time of germination. All tested osmotic potentials (-1.6 to -0.2 MPa) significantly affected the mean duration time (MTG) (Table 2). From the value of -0.6 MPa, the osmotic pressure has a significant effect on the germination percentage. However, a value of -0.2 MPa has significantly affected the germination rate of *P. angustifolia* seeds (Fig. 2, Table 2). The average germination time is lengthening according to the intensity of osmotic pressure. All water potentials tested (from -1.6 to -0.2 MPA) have a significant effect on the mean duration time (MTG). From the value of -0.6 MPa, the osmotic pressure has a significant effect on the germination percentage. But an osmotic pressure of -0.2 MPA has significantly affected the germination rate of the seeds of *P. angustifolia* (Fig. 2).

Effect of burial depths on germination percentage

Seed germination was directly related to the depth at which seeds were buried (Zhang, 2001). Burial in the sand is an important

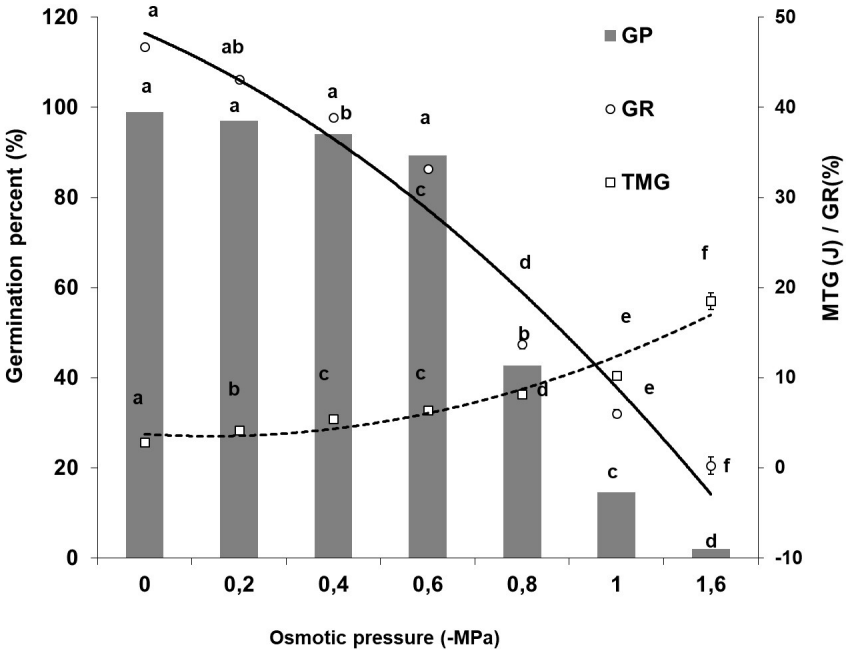

Fig. 2. Variation of the final germination percentage (%), the germination rate (%), and the mean time to germination (MTG, days) of *Periploca angustifolia* seeds during 20 days at different PEG-6000 solutions of different osmotic pressures (0 to −1.6 MPa) at 25 °C. The broken and continue lines describing, respectively, the evolution of MTG and germination rate (GR) were obtained by polynomial regression. Values of each parameter (mean±95% confidence limits, n=4) having the same letter are not significantly different (P>0.05) from each other (Duncan test).

Table 3. Final emergence (FE) seedling and mean time to emergence (MTE) of *Periploca angustifolia* seeds at various depths for 20 days. At burial depth > 4 cm, no emergence was recorded.

Seedling depth (cm)		Final emergence (%)	Mean time to emergence (days)
1		74 ± 5.41 a	6.427 ± 0.20 a
2		69 ± 3.48 a	10.98 ± 0.42 b
4		30 ± 4.94 b	14.4 ± 0.56 c
6		0 ± 0 c	-
8		0 ± 0 c	-
	ddl	4	4
ANOVA	Test F	100.776	433.288
	P	.000	.000

Note: Means within a column followed by the same letter are not significantly different at the P=0.05 level for the given burial depths (mean±95% confidence limits, Duncan's test) (n=10).

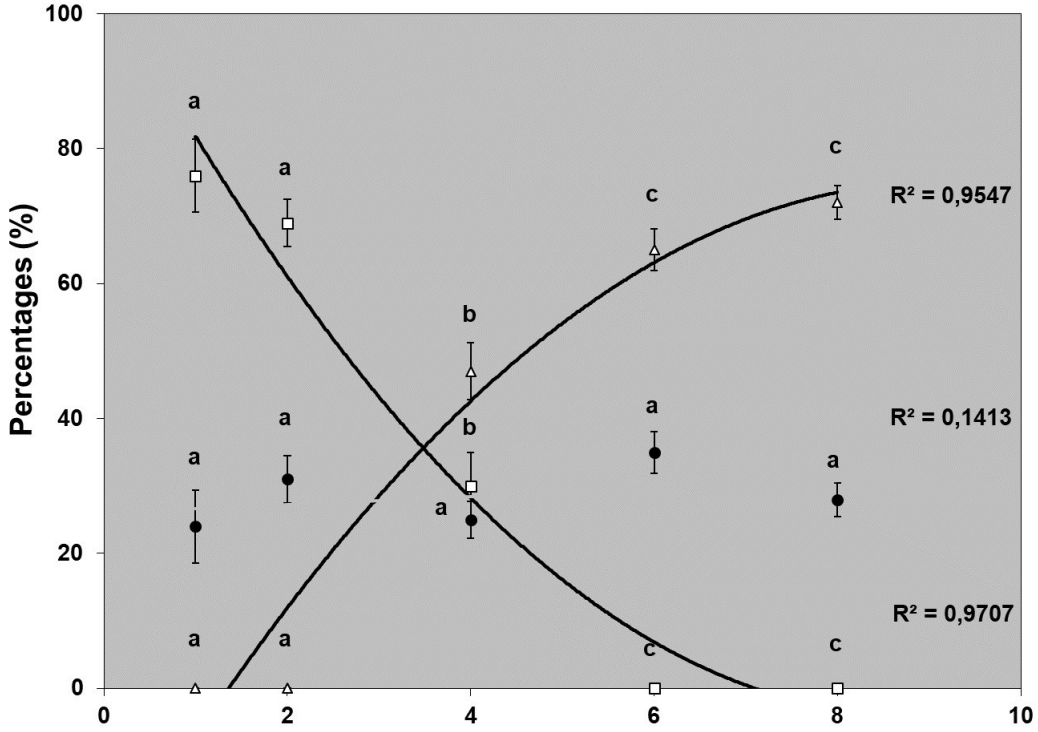

Fig. 3. Regression plots for mean germinated and not emerged seeds (Δ) and emerged seedlings (▫) and not germinated seed (•) of *Periploca angustifolia* at different burial depths (1–8 cm). Lines describing the course of these two parameters were obtained by the logarithmic regression. Values of each parameter (mean±95% confidence limits, n=10) having the same letter are not significantly different (P>0.05) from each other (Duncan test).

factor controlling the distribution and composition of vegetation in desert ecosystems (Chen, Kuo, 1999). Indeed, sand deposition has been recognized as a major selective force in the evolution of seed size, seed germination, seedling emergence, and survivorship of seedling and adult plants (Huang, Gutterman, 2000). Thus, the failure of resowing operations of small-seeded species results from their sowing at a significant depth (Pearson, Ison, 1987). Resowing small seeds of pastoral plants deep enough in the soil would reduce seedling emergence and vigor. In this experiment, seed germination at all burial depths (2, 4, 6, and 8 cm) was significantly negatively correlated with the burial depth (Table 2). Also, the number of dormant seeds of *Periploca* species increased with the burial depth. A small proportion of seeds acquired dormancy, especially at deeper depths in the soil. Burial at shallow depths stimulated more germination than surface-lying seeds because it maintains a moist environment around seeds and prevents seeds and seedlings from drying out (Benvenuti et al., 2001). However, excessive burial may affect seed germination and prevent the seedling emergence above the sand. Usually, as the depth of burial increased there was a significant decrease

in both seed germination and seedling emergence (Table 3). At the end of the 20-day experiment, seeds germinated at all burial depths from 1 to 8 cm. In contrast, seedling emergence was highly influenced by burial depth (Fig. 3). The highest seedling emergence occurred from 1 and 2 cm burial depths. There was a significant decline in seedling emergence at a 4 cm burial depth, and none emerged from a depth reached 6 cm (Table 3). The fastest seedling emergence occurred from a 1 cm burial depth, and there was a significant increase in days of the first emergence at 2 and 4 cm burial depths. Table 2 shows that the seed burial depth significantly affects the variation in mean emergence time (MTE) and final emergence (FE). The mean time to emergence recorded at 4 cm was statistically different from that at 2 cm and significantly higher than values recorded at 6 and 8 cm. Seedling depth belated emergence up to 14 days at a depth of 4 cm. The highest emergence values were obtained at depths of 1 and 2 cm (76 and 69%, respectively). However, no emergence was recorded at burial depths of 6 and 8 cm. Logarithmic regression analysis was used to determine the relationships between germinated seeds that did not emerge and emerged seedlings at different burial depths. There were strong relationships between seed germination and seedling emergence according to the burial depth with $R^2 = 0.95$ and 0.97, respectively. Burial depth does not have a significant effect ($P>0.001$) on the percentage of not germinated seeds with the lowest correlation coefficient ($R^2=0.141$) (Fig. 3).

Discussion

The seeds of *Periploca angustifolia* are enclosed in two follicles (dehiscent fruits) divided or even opposite. They are led by feathery aigrettes in the shape of a parachute ensuring their anemophilous dissemination (by the wind). Danthu et al. (2003) mentioned that the widespread temperatures in arid and semi-arid areas vary between 15 and 40 °C. Any species, from these areas, should have maximum germination ability in this temperature range. Noumi et al. (2013) showed that the germination of *P. angustifolia*'s seeds was successful over a wide temperature range (10 to 30 °C) in the dark and with a maximum of 25 °C. Hence, this temperature was chosen as the optimum to study water stress's effect on our species' seeds. At this thermal optimum, water stress was applied to *P. angustifolia* seeds by PEG-6000 solutions of increasing osmolarity. Many authors showed that the highest germination percentages were obtained under control conditions, and it was about 89.2% for *Lavandula stoechas* (Dadach et al., 2021) and 80% for *Lygeum spartum* (Zouidi et al., 2023). The increase in water stress induced a significant reduction in final germination percentage (from 99 to 2%) and germination rate (46.7 to 0.2%), and it increased the mean time to germination (2 to 19 days) for the osmotic pressure of 0 and -1.6 MPa, respectively. Similar results were found for some trees and shrubs such as *Cedrus libani* (Dirik, 2000), *Eucalyptus globulus* (Lopez et al., 2000), *Argania spinosa* (Bouzoubaa, El Mousadik, 2003), and *Ziziphus lotus* (Maraghni et al., 2010). Many desert species can germinate in soil with relatively low water potential, but germination percentage decreases with decreasing water availability. When the water potential of the imbibition solutions was lowered by the addition of PEG-6000, the germination of one species studied was significantly affected by low concentrations of PEG-6000 corresponding to water potentials of -0.2, -0.4, and -0.6 MPa for *Periploca angustifolia*. This stress resulted in a slight decrease in the germination percentage and germination rate. These results are similar to those obtained for *Mesembryanthemum crystallinum* (Youssef, 2009), as well as *Calligonum polygonoides* and *Spartidium saharae* (Derbel, Chaieb, 2007). For other species, such as *Rhanterium suaveolens* and *Plantago albicans*, water potentials of -0.5 MPa and -0.7 MPa, respectively, can inhibit germination (Talbi, 2008). Sharma (1973) mentioned that low water potentials of -0.2 and -0.4 MPa can inhibit the germination of *Atriplex vesicaria* and *A. nummularia*, respectively. The application of severe stress (above -0.6 MPa) caused a high decrease in the germination rate and an increase in the mean time to germination (MTG). Studies by Neffati and Akrimi (1996), on *Retama raetam* from southern Tunisia, showed that the germination rate decreased with the severity of water stress. The germination of *Acacia tortilis* and *A. karroo* is null for the osmotic pressure of -0.8 MPa (Choinski, Tuohy, 1991). Singh et al. (1991) showed that seeds of many *Acacia* species used in India do not germinate as soon as the water potential reaches -0.9 or -1.2 MPa. The results found by Jaouadi et al. (2010) showed that the application of osmotic pressure of -0.8 MPa inhibits the germination of seeds of *A. tortilis*. Water potential of -1 MPa reduced germination from 99% (distilled water; 0 MPa) to 14.7%, while this potential completely inhibited germination in *Periploca sepium* (Ma et al., 2008), *Diplotaxis hara* (Tlig et al., 2008), *Retama raetam* (Youssef, 2009), and *Lotus creticus* (Talbi, 2008). Beyond a water potential of -1.2 MPa and -1.3 MPa, the germination capacity for seeds of *Ziziphus spina-christi* (Sannad, 1999) and *Anthyllis henoniana* and *Spartidium saharae* (Derbel et al., 2010) cancels. On the other hand, Bonvissuto and Busso (2007) reported that the germination of several shrubs (*Atriplex lampa*, *Larrea divaricata*, *Leymus erianthus*) and grasses (*Stipa neaei* and *Poa ligularis*) in arid areas of Argentina is better when water potentials are between -0.93 and -1.39 MPa. The osmotic pressure of -1.6 MPa corresponds to the point beyond which *Henophyton deserti* and *Haloxylon persicum* fail to extract water, and the germination capacity is canceled (Derbel et al., 2010). However, this osmotic pressure corresponds to -1.4 MPa in *Euphorbia guyoniana*, *Calligonum polygonoides*, and *Ephedra-alata-alenda* (Derbel et al., 2010). It is -1.5 MPa in *Rhus tripatita* (Noumi et al., 2013) and *Agropyron cristatum* (Briede, McKell, 1992). A severe stress of -1.6 MPa applied to *Periploca angustifolia* seeds reduced germination to 2%. On the other hand, Noumi et al. (2013) mentioned that the seeds of this species, coming from Bouhedma, can reach a germination capacity of 9% at -3 MPa. This difference in response may be due to the provenance effect or the age of the seeds used or the experimental conditions. Various other species are known to be tolerant to this type of severe stress in the germination phase. Examples include *Salsola vermiculata*, *Plantago albicans* (Neffati, 1994), and *Allenrolfea occidentalis*, which can germinate at osmotic pressure up to -4 MPa (Blank et al., 1994). Although it represents one of the most important factors in the establishment of species (Boydston, 1989), germination is either an advantage or a disadvantage depending on the conditions that follow this first phase of the vegetative cycle and especially how well a given plant tolerates the constraining conditions during this phase (Grouzis, 1976). In arid zones, water deficit in the superficial layers following intense evapotranspiration constitutes a major constraint to the germination of seeds and especially those of small size. In this case, the depth of burial can be added to these constraints, and it can be one of the main factors condition-

ing the success of the emergence of seedlings in arid zones. Our results showed that a depth of burial of 1 and 2 cm of *Periploca angustifolia* seeds allows rather important emergence rates of 74 and 69%, respectively. At a depth of 2 cm, the emergence rate of *Ziziphus lotus* seedlings was 73%. This rate was obtained by Arif (1994) in *Argania spinosa*. From a depth of 4 cm, no emergence was observed and seed germination exceeded seedling emergence. The results obtained corroborate with those of other authors (Ferchichi et al., 2004; Ouled Belgacem et al., 2006; Maraghni et al., 2010), who have shown the importance of the effect of burial depth on seed emergence percentage. The highest values were obtained at depths of 1 and 2 cm, which shows that a relatively shallow depth of burial facilitates the emergence of the young seedling. The low emergence percentage generated by depths of 4, 6, and 8 cm confirms the fact that a high seeding depth may result in the depletion of the energy reserves of the young seedling that cannot emerge from the soil (Boyd, Van Acker, 2003). A sufficiently deep seedbed, which normally guarantees good moisture and protection against the cold, can on the other hand constitute an obstacle to the emergence of seeds. Indeed, deep seedlings hinder emergence by depleting energy reserves. Even in the case of emergence, the seedlings are weakened. However, in arid regions, where rainfall is widely spaced, shallow seeding exposes the seed to the danger of drying out before germination. However, although the tendency to sow deeper allows for germination in sufficiently moist soils, it appears that in the case of *Periploca angustifolia*, intermediate depths of 1 and 2 cm are most conducive to germination and emergence. This result is similar to the work of Ferchichi et al. (2004), who mentioned that the optimal seeding depth (corresponding to maximum emergence rates) for *Argyrolobium uniflorum*, *Astragalus gombo*, *Lotus creticus* and *Periploca laevigata* is 2 cm. This depth varies according to the species and is also dependent on the nutritive reserves of the seeds. It is 4 cm for *Stipa lagascae* (Ouled Belgacem et al., 2006) and *Ziziphus lotus* (Maraghni et al., 2010).

Conclusion

From the present study, it can be concluded that during germination, *Periploca angustifolia* follows different strategies of adaptation to the drought that have an effect not only on the determination of the germination rate of the seeds but also on their development. This species is tolerant to water deficit, during its germination phase, since the limit value of osmotic pressure allowing germination is -1.6 MPa. Indeed, its germination percentage and germination rate are at their maximum in distilled water, but they decrease as the osmotic pressure increases. Seed burial depths of 1 and 2 cm ensured a fairly high seedling emergence percentage (74 and 69%), whereas seed burial depths of more than 4 cm inhibited the emergence of *P. angustifolia* seedlings but promoted germination (moist soil). Even when moisture is available to promote germination, in the absence of subsequent rainfall, the growth of newly germinated seedlings will be compromised with potentially lethal consequences. Under natural conditions, seed germination is more complicated and influenced by many factors such as salinity, drought, light, and temperature. Future studies would focus on the interactive effects of these factors to better understand the ecophysiological strategies of plants for survival under natural environmental conditions.

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