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Effects of temperature and water limitation on the germination of *Stipagrostis ciliata* seeds collected from Sidi Bouzid Governorate in Central Tunisia

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Abstract: Most ecological studies in North Africa reveal a process of continuous degradation of rangeland ecosystems as a result of overgrazing. This degradation appears across the decreasing of perennial grass diversity. Indeed, the majority of steppe ecosystems are characterized by a low density of perennial grass species at present. This study evaluated the effects of temperature and water limitation on the seed germination of *Stipagrostis ciliata* (Desf.) de Winter, a perennial grass species. The seeds were collected from the Bou Hedma Park, Sidi Bouzid Governorate, Central Tunisia. The thermal time and hydrothermal time models were used to describe the seed germination of *S. ciliata* under different water potentials and temperatures. The germination response of *S. ciliata* seeds in darkness was evaluated over a range of temperatures (15°C, 20°C, 25°C, 30°C and 35°C) and across a wide range of osmotic potentials (0.0, –0.2, –0.6, –1.2, –1.6 and –2.0 MPa) of the polyethylene glycol (PEG$_{6000}$) solutions at each temperature level. Among the tested temperatures, 25°C was found to be the optimal temperature to the germination of *S. ciliata* seeds. The final germination percentage (75.2%) was obtained with distilled water. The progressive decrease of osmotic potential of the PEG$_{6000}$ solutions inhibited the seed germination. However, the number of days to first germination was increased with a reduction of osmotic potential. A significant positive relationship was identified between final germination percentage of *S. ciliata* seeds and osmotic potential of the PEG$_{6000}$ solutions, with R^2 ranging from 0.5678 to 0.8761. Furthermore, a high degree of congruency between predicted and observed germination time course curves was observed. In general, *S. ciliata* exhibits a significant adaptation capacity for water limitation and high temperature in arid ecosystems.

Keywords: *Stipagrostis ciliata*; germination; temperature; water potential; hydrothermal model; arid zone; Bou Hedma Park

1 Introduction

Vegetation in arid regions of North Africa is characterized by low biodiversity. The climate change and human activities have been accused for the degradation of arid ecosystems during the last decades (Le Houérou, 1984; Chaieb et al., 1992, 1996; Valencia et al., 2015). Indeed, in addition to overgrazing, among climatic factors, the high temperature, low and irregular rainfall

and high potential evaporation, are the top ecosystem disturbance factors in arid regions. In this regard, desertification affects about 40% of the terrestrial ecosystems around the world (Reynolds et al., 2007). This problem is interestingly ever increasing in North Africa, and especially in Tunisia (Ouled Belgacem et al., 2006). Except for the decreasing of herbaceous species diversity (especially the perennial species), many species of the arid zones (i.e., *Cenchrus ciliaris* L., *Digitaria commutata* Schult, and *Stipagrostis ciliata* (Desf.) de Winter) have been replaced by other chamaephytes species with a very low pasture value (Maestre et al., 2006; Mnif and Chaieb, 2010). Meanwhile, for degraded pastures, restoring rangeland quality and reducing wind erosion both require an integrated rehabilitation process. In this context, several researches have been conducted in Tunisia (Aronson et al., 1993). These studies concerned specially the ecophysiological responses of native species, particularly to drought and water stress (Aronson et al., 1993; Chaieb et al., 1996; Le Houérou, 2005). Several studies have shown that the species establishment processes may differ in their response to drought, reproductive effort, flowering time, seed dispersal and germination behavior (Gorai et al., 2009). Particularly, the seed germination behavior and seedling establishment in relation to thermal and water stress, are very important to determine the growth and production of plant species. In fact, extremely high temperature and low soil moisture conditions were reported to significantly affect the seed germination in arid and semi-arid regions (Jauffret and Visser, 2003).

S. ciliata is a perennial C_4 grass that has a wide distribution in the hot and dry regions of the tropical zones (Kellogg, 2001). This species can tolerate arid bioclimate and wind erosion. Hence, *S. ciliata* is a useful grass species for fixing sand in shifting and semi-fixed sandy lands (Daur, 2012). Therefore, it would be interesting to study its ecophysiological germination characteristics and its field ecological requirements.

The present study hypothesized that the seed germination percentage of *S. ciliata* may increase with increasing temperature between 15°C and 35°C and decreasing water potential. Specifically, the aims of this study were (1) to examine the effect of constant temperature (between 15°C and 35°C) on the seed germination of *S. ciliata*; (2) to analyze the germination response of *S. ciliata* seeds to a wide range of osmotic potential of the polyethylene glycol (PEG_{6000}) solutions at each temperature level; and (3) to describe the patterns of seed germination response to incubating temperature regimes in terms of the hydrothermal time parameters.

2 Materials and methods

2.1 Seed collection

Stipagrostis ciliata is a C_4 plant of the Poaceae family. The geographical distribution of this plant species covers the desert regions of South and North Africa (Mosallam et al., 2009). Considering its significant adaptability to hot arid climate and gypsum soil, *S. ciliata* has been advocated to fix sand in shifting and semi-fixed sandy lands (Daur, 2012). In this study, the *S. ciliata* seeds were collected from plants growing in the protected area of Bou Hedma Park (34°39′N, 9°48′E) in October 2012. This park is located in Sidi Bouzid Governorate, Central Tunisia. This area is characterized by a Mediterranean arid and semi-arid climate with an irregular precipitation and a dry summer period. Annual mean temperature varies from 3.9°C in winter to 36.2°C in summer and mean annual precipitation is around 180 mm.

2.2 Drought and temperature exposure conditions and seed germination tests

The effect of temperature on the seed germination of *S. ciliata* was evaluated by incubating seeds in a 90-mm glass Petri dish with 10 mL of distilled water at constant temperatures of 15°C, 20°C, 25°C, 30°C and 35°C, respectively. The incubation was made for in a dark incubator (LMS Cooled Incubator, LMS Ltd., Kent, UK). The temperature range was set according to the observed temperatures in arid zones of Tunisia, as well as the optimum temperature for the growth of C_4 species (Yamori et al., 2014). In the arid zones, photosynthesis typically exhibits an optimum temperature range of 10°C–30°C. Eight replicates of 50 seeds were used for each temperature treatment. Control sets also with eight replicates were maintained separately. The germinated

seeds were counted every 2 d during a 20-d period after exposure. A seed was considered germinated when the emergence of the radicle was 1.0 mm in length (Bewley and Black, 1994). Different concentrations of the Glycol Polyethylene (PEG$_{6000}$) solutions were used to expose *S. ciliata* seeds for studying the effect of water potential on the seed germination. PEG$_{6000}$ solutions equivalent to the following osmotic potentials were prepared according to the formula developed by Michel and Kaufmann (1973). The obtained water potentials (0.0, –0.2, –0.6, –1.2, –1.6 and –2.0 MPa) were verified by an osmometer. The germination tests were conducted at constant temperatures of 15°C, 20°C, 25°C, 30°C and 35°C in dark conditions, respectively. The PEG$_{6000}$ solution was used in this study because it is non-penetrating and has been reported to form a colloidal solution, which had a similar effect on the matrix properties of soil particles. This method provides a good estimate of seed germination behavior in relation to soil moisture under field conditions.

The final germination percentage of *S. ciliata* seeds was calculated as the proportion of final number of germinated seeds in the total seeds at the end of experiment. The cumulative germination percentage is defined as the proportion of accumulated number of germinated seeds in the total seeds by the corresponding number of days. The days to first germination (delay of germination) was determined as the mean time to germination (MTG), following the formula, MTG=$\sum(n_i \times d)/N$ (where n_i is the number of seeds germinated at the ith day, d is the incubation period (d) and N is the total number of germinated seeds). The germination rate (GR) was estimated using a modified Timson's index of germination velocity, GR=$\sum G/t$, where G is the percentage of seed germinated after 2 d intervals, and t is the total time of germination (Khan and Unger, 2001). The maximum value possible for this index was 50.

2.3 Analyses of germination time and temperature-related parameters

In this study, we analyzed the germination time and temperature-related parameters by regressions based on the thermal time and hydrothermal time models to estimate the relationship between temperature and water potential. The thermal time combined the initial germination time courses in water at five temperatures (15°C, 20°C, 25°C, 30°C and 35°C). Germination data were analyzed following the thermal time concept (Dahal and Bradford, 1990, 1994; Bradford, 2002), as shown in Equation 1.

$$\theta_T(g)=(T-T_b)t_g, \tag{1}$$

where, θ_T is the thermal time (°C days) to radicle emergence of percentage g; T is the actual temperature at which the germination test is conducted (°C); T_b is the constant base (or minimum) temperature at the sub-optimal temperature range (°C); and t_g is the actual time to germination of percentage g. The hydrothermal time model was used to evaluate the germination time courses in water and osmotic solutions at 15°C, 20°C, 25°C, 30°C and 35°C (Gummerson, 1986; Bradford, 1990). This model is similar to the thermal time model, except the base water potential (Ψ_b) values.

$$\theta_H=(\Psi-\Psi_{b(g)})t_g, \tag{2}$$

where, θ_H is the hydrotime constant (MPa days); Ψ is the water potential of the imbibition medium; $\Psi_{b(g)}$ is the base value of Ψ just preventing radicle emergence of percentage g; and t_g is the actual time to germination of percentage g. Furthermore, the $\Psi_{b(50)}$ in this study is defined as the mean of the base water potential $\Psi_{b(g)}$ of percentage g. Finally, Equations 1 and 2 were combined and the hydrothermal time model was adopted to analyze the seed germination percentages across T and Ψ conditions (Gummerson, 1986; Bradford, 1990, 1995). The hydrothermal time was expressed as Equation 3.

$$\theta_{HT}=(\Psi-\Psi_{b(g)})t_g(T-T_b)t_g, \tag{3}$$

where, θ_{HT} is the hydrothermal time constant (MPa °C days).

2.4 Statistical analysis

Results of the germination experiments were analyzed using SPSS for Windows (version 13.0). Tukey test (Honestly significant differences, HSD) was used to evaluate the least significant range

between means. A two-way analysis of variance (ANOVA) was carried out to explain the effects of main factors (temperature and water limitation) and their interaction on the seed germination.

3 Results

3.1 Effect of temperature on the seed germination of *S. ciliata*

The germination responses of *S. ciliata* seeds to a wide range of temperature treatments are shown in Figure 1a. It can be seen that temperature regimes significantly affected the seed germination percentage of this species ($P<0.001$). The germination curves were sigmoid at 25°C and 30°C. It should be noted that the final germination percentage was higher than 70% at 25°C (Table 1). *S. ciliata* seeds were able to germinate at temperatures of 25°C–30°C, and the optimal temperature was 25°C. Seed germination was significantly inhibited at temperatures 15°C, 20°C and 35°C, with final germination percentages being 10.25 %, 39.00% and 34.75 %, respectively.
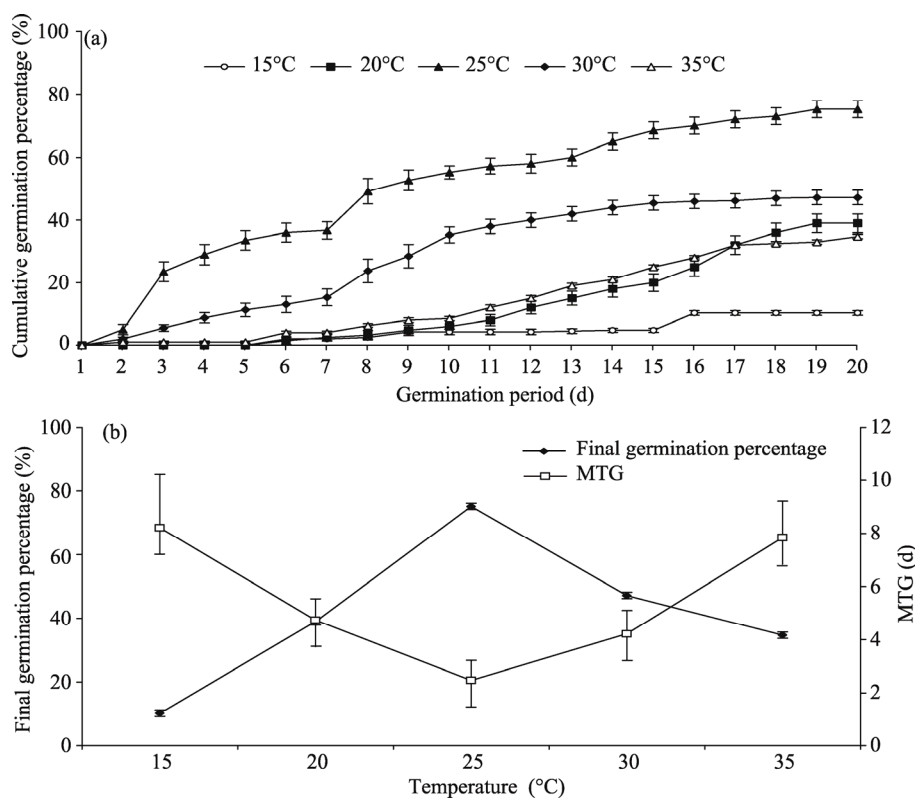
Fig. 1   (a) Cumulative germination percentage of *S. ciliata* seeds during a 20-d germination period at different temperatures (15°C, 20°C, 25°C, 30°C and 35°C) (*n*=8), and (b) variations of final germination percentage and mean time to germination (MTG) of *S. ciliata* seeds at different temperatures (*n*=8). Bars mean standard errors.

To explain the effect of temperature on the seed germination of *S. ciliata*, we established the relationship between MTG and final germination percentage (Fig. 1b). The MTG varied significantly with temperatures. The high MTG was in correspondence with the low final germination percentage. The temperature 25°C was characterized by the lowest MTG (2.47±1.5 d), indicating a rapid seed germination and high final germination percentage. Generally speaking, the seed germination percentage decreased significantly at lower (15°C and 20°C) and higher temperatures (35°C).

3.2 Hydrothermal time analyses

Germination responses of *S. ciliata* seeds to temperature were well described by the thermal time, hydrotime and hydrothermal time at both sub-optimal and supra-optimal temperatures (Table 2).

Table 1 Days to first germination, mean time to germination (MTG) and final germination percentage of *Stipagrostis ciliata* seeds at different temperatures during a 20-d germination period

Temperature (°C)	Days to first germination (d)	MTG (d)	Final germination percentage (%)
15	7.10±2.4^c	8.22±2.8^b	10.25±1.5^c
20	6.50±2.9^{bc}	4.74±4.0^b	39.00±4.8^c
25	2.25±0.4^a	2.47±1.5^a	75.20±2.0^a
30	2.38±0.5^a	4.22±1.7^{ab}	47.22±5.7^{ab}
35	4.00±2.1^{ab}	7.84±1.9^{ab}	34.75±1.0^c

Note: MTG, mean time to germination. Values in the same column with different lowercase letters were significantly different ($P<0.05$) at different temperatures. Mean±SE.

Table 2 Parameters of *S. ciliata* seed germination at the sub-optimal and supra-optimal temperature ranges based on a hydrothermal time model analysis

Temperature range	Model parameter	*S. ciliata*
Sub-optimal temperature range (15°C–20°C)	T_b (°C)	12
	$\theta_{T_b(50)}$ (°C days)	72
	σT_b	0.54
	R^2	0.84
Supra-optimal temperature range (30°C–35°C)	T_c (°C)	43
	$\theta_{T_c(50)}$ (°C days)	44.46
	σT_c	0.06
	R^2	0.72

Note: T_b, constant base (or minimum) temperature at the sub-optimal temperature range; $\theta_{T_b(50)}$, constant thermal time for 50% of seeds to germinate at the sub-optimal temperature range; σ, standard deviation; σT_b, standard deviation of constant base (or minimum) temperature at the sub-optimal temperature range; T_c, constant ceiling (or maximum) temperature at the supra-optimal temperature range; $\theta_{T_c(50)}$, constant thermal time for 50% of seeds to germinate at the supra-optimal temperature; σT_c, standard deviation of constant ceiling (or maximum) temperature at the supra-optimal temperature.

Responses of *S. ciliata* seed germination to different temperatures were characterized by three temperatures, namely the ceiling (or maximum), optimum and base (or minimum). The base (or minimum) temperature (T_b) and the ceiling (maximum) temperature (T_c) are the lowest temperature at the sub-optimal temperature range and the highest temperature at the supra-optimal temperature range, respectively, in which a seed is able to germinate. The change trend of final germination percentage with respect to temperature was reflected by the variation in MTG against temperature (Table 1). The final germination percentage exhibited a continuous increase at the sub-optimal temperature range (from 15°C to 20°C). However, the final germination percentage decreased when the temperature increased from 30°C to 40°C. Germination percentages of *S. ciliata* seeds were strongly correlated at the sub-optimal (15°C–20°C) and supra-optimal (30°C–35°C) temperature ranges with $R^2>0.70$. However, the ceiling temperature at the supra-optimal temperature range (T_c) was 43°C for *S. ciliata* seed germination.

The hydrothermal time model was fitted to data for *S. ciliata* seed germination with high R^2 values, indicating a high degree of congruency between predicted and observed germination time course curves. The hydrothermal time constant values were different between the tested temperatures. The $\Psi_{b(50)}$ values for seeds were highly negative, particularly at lower incubation temperature (15°C). However, the $\Psi_{b(50)}$ values increased linearly with increasing incubation temperature. In fact, the two-way ANOVA of final germination percentage indicated a significant main effect of water limitation. The interaction of temperature and water potential had a non-significant effect on final germination percentage of *S. ciliata* seeds (Table 2). The final germination percentage was higher at 25°C–30°C, intermediate at 35°C, and lower at 15°C–20°C.

3.3   Effect of water limitation on the seed germination of *S. ciliata*

The kinetics of *S. ciliata* seed germination under osmotic stress conditions at different temperatures (15°C, 20°C, 25°C, 30°C and 35°C) is presented in Figure 2a. The kinetics of final germination percentage proved the sensitivity of *S. ciliata* to water limitation. Germination of *S.*

ciliata seeds was significantly affected by water limitation ($P<0.001$), where the highest final germination percentage (75.2%) was found in the control germination test (0.0 MPa) at optimal temperature (25°C). The decrease of osmotic potential of the PEG_{6000} solutions resulted in a gradual decrease of final germination percentage (average of 0.25%), and the decrease of final germination percentage was 2% at −2.0 MPa and at optimal temperature 25°C. With a reduction of osmotic potential of the PEG_{6000} solutions, the MTG was significantly ($P<0.001$, $F=268.067$) increased. The germination rate was also decreased as decreasing osmotic potential of the PEG_{6000} solutions at all tested temperatures (Fig. 2b).
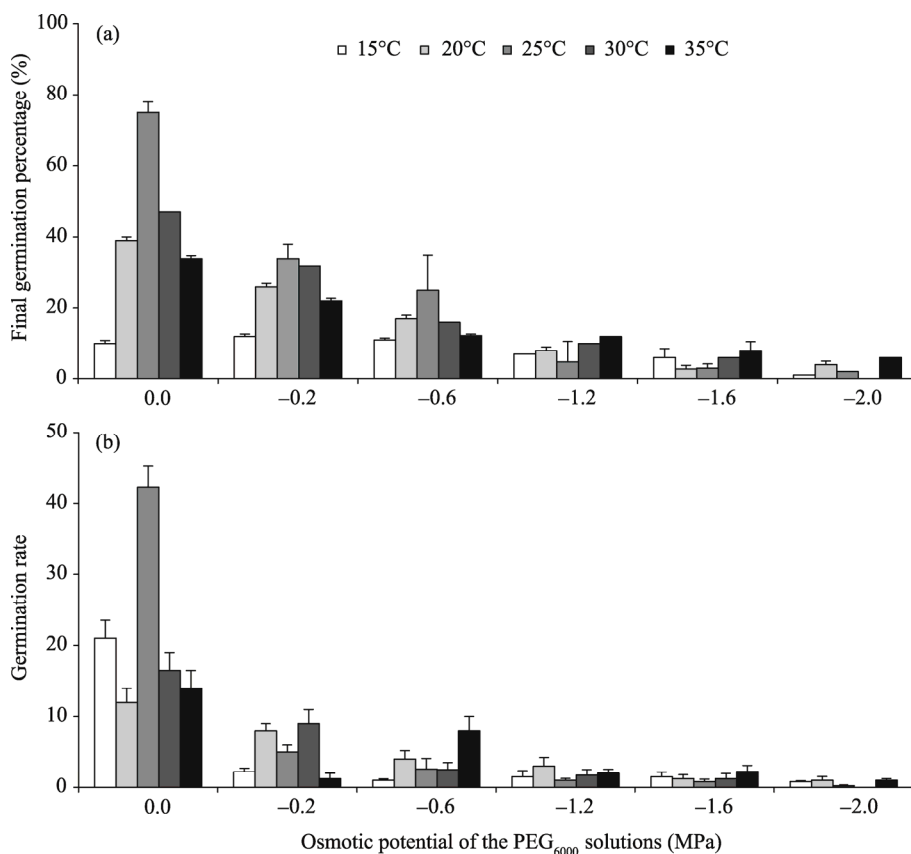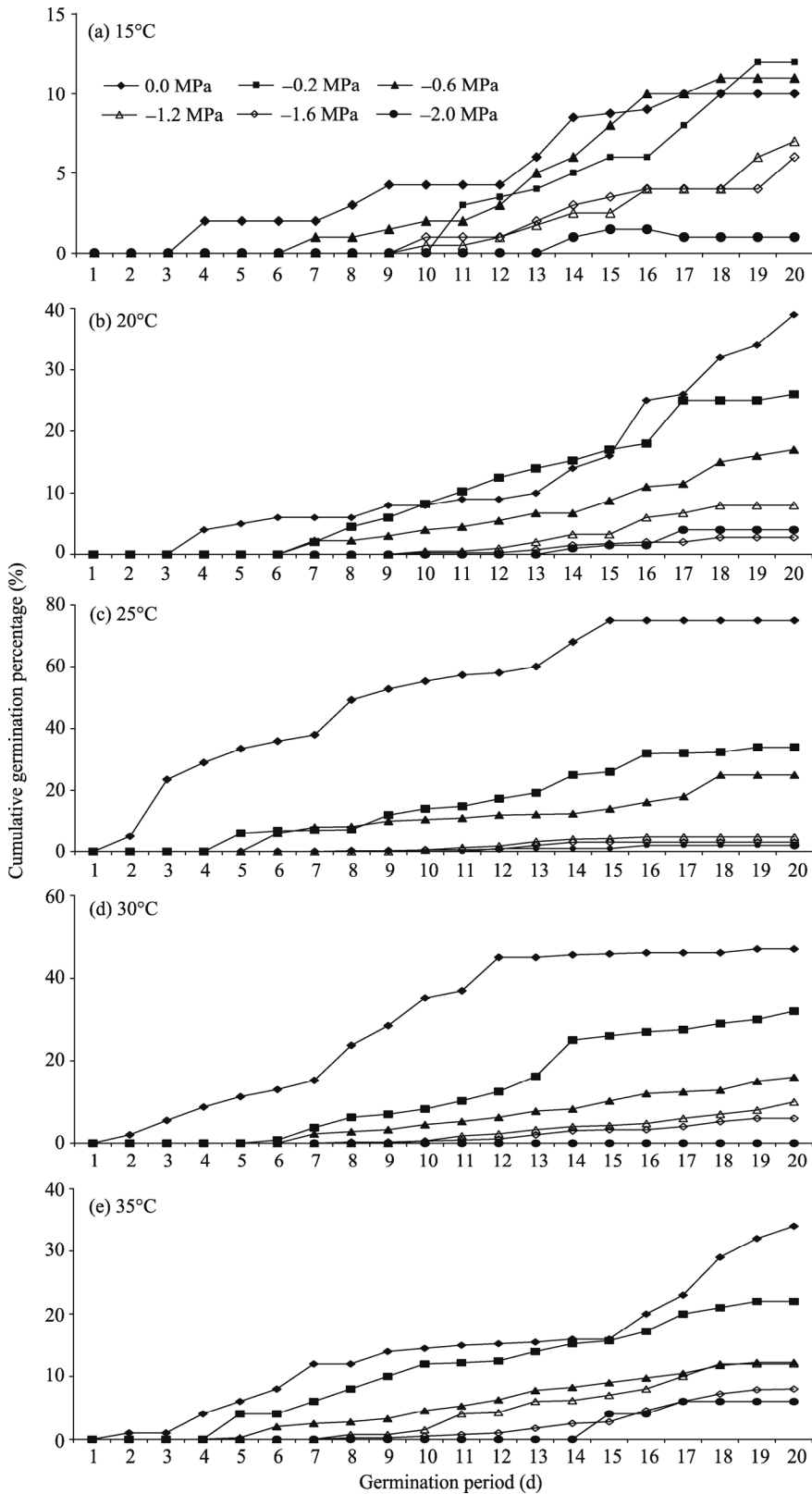

Fig. 2 Final germination percentage (a) and germination rate of *S. ciliata* seeds (b) in the polyethylene glycol (PEG_{6000}) solutions with different osmotic potentials and at different temperatures. Bars mean standard errors.

Figure 3 shows the cumulative germination percentage of *S. ciliata* seeds at different temperatures as influenced by different osmotic potentials of the PEG_{6000} solutions. In the control test (0.0 MPa) at different temperatures, in particular at 25°C and 30°C, the kinetics of cumulative germination percentage showed three phases: latency phase, exponential acceleration phase, and finally the third phase characterized by the end of germination and radicle emergence. The effect of osmotic stress on the seed germination of *S. ciliata* occurred during these different phases, and it was depended on the osmotic potentials of the PEG_{6000} solutions (Fig. 3). Linear regression analysis was used to determine the relationship between final germination percentage of *S. ciliata* seeds and osmotic potential of the PEG_{6000} solutions (Fig. 4). A strong positive relationship was identified between these two parameters, with R^2 ranging from 0.5678 to 0.8761.

4   Discussion

4.1   Effects of temperature and water limitation on the seed germination of *S. ciliata*

In arid bioclimate of North Africa, the successful establishment of perennial grass depends on the

Fig. 3 Cumulative germination percentage of *S. ciliata* seeds during a 20-d germination period at different temperatures (15°C, 20°C, 25°C, 30°C and 35°C) as being influenced by the PEG$_{6000}$ solutions with different osmotic potentials (from –2.0 to 0.0 MPa) (*n*=8)
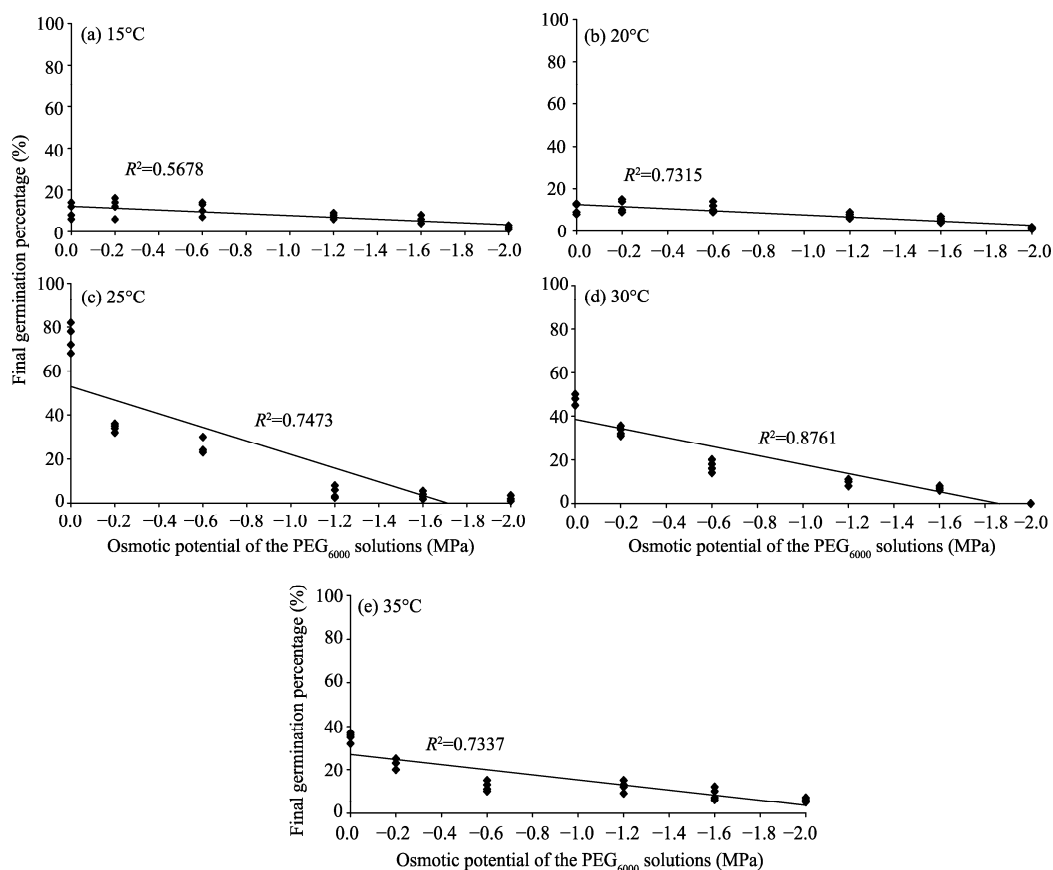
Fig. 4 Relationship between final germination percentage of *S. ciliata* seeds and osmotic potential of the PEG$_{6000}$ solutions at different temperatures (15°C, 20°C, 25°C, 30°C and 35°C)

success of seed germination. In arid zones of Tunisia, understanding the germination capacity of threatened species is significant to get insights into the major cause of restoration in the degraded ecosystems (Ouled Belgacem et al., 2006). The outcomes of the germination tests allowed for knowing more about the seed responses to environmental factors such as high temperature, salinity and water limitation, which characterize the bioclimate of arid zones (Tlig et al., 2008). In the same context, Khan and Unger (2001) showed that the successful establishment of perennial grasses under arid condition depends on the optimal temperature for germination. de la Barrera and Castellanos (2007) also reported the significance of temperature in the seed germination of *S. ciliata*. Results obtained in this study suggested that seed germination of *S. ciliata* occurs over a temperature range of 25°C–30°C in darkness. The optimum temperature for the seed germination of *S. ciliata* is 25°C, with 75.2% final germination percentage. This behavior may explain the high adaptation of this C$_4$ species to the ecological conditions in arid environments characterized by relatively high temperatures. Thanos et al. (1995) and Baskin and Baskin (1998) considered this behavior as a typical survival strategy of Mediterranean plants with optimum temperatures ranging from 15°C to 30°C. They also suggested that the success of germination recorded at elevated temperatures allows the seeds to escape the risks of rapid desiccation of the upper soil horizons during the period of germination, and that higher temperatures, such as 25°C, are considered to be very favorable to the species of the photosynthetic type C$_4$ (Niu et al., 2005). These species germinate in dry climate characterized by high temperature and water limitation. An ecological and physiological study conducted on *Stipagrostis obtusa* and *Stipagrostis ciliata* concluded that the germination of seeds can be influenced by temperature (Skinner, 1964). The optimal temperature for the germination of *S. ciliata* seeds was in the range of 20°C–25°C. Decrease in germination potential with heating of seeds was also reported by Skinner (1964). In

the same context, previous research on the other *Stipagrostis* species showed that temperature is an important factor in seed germination in laboratory conditions and in seedling recruitment in field conditions (Ronnenberg et al., 2008). *Stipagrostis bungeana* seeds were reported to germinate at a temperature range of 10°C–30°C, and it was suggested that these seeds could germinate from spring to autumn in the local environment (Xiao et al., 2013).

This study also demonstrated that the MTG can be affected by the changes in the temperature regimes. The lowest MTG was recorded at 25°C. At this temperature, the seeds took less time to germinate. Liu et al. (2013) reported that *Stipagrostis pennata* seeds may take a longer time to initiate germination at high temperatures, and that the highest MTG can be recorded at low temperatures. This is probably due to the decrease in water absorption associated to a low diffusion of respiratory gas. Changes in the temperature were reported to affect the vital processes of plant species that in turn control seed germination, enzyme activity and membrane permeability (Khan et al., 2001). Low temperatures were reported to significantly impact the performance of C_4 plant species by negatively affecting the functioning of enzymes involved in the C_4 pathway enzymes (Naidu et al., 2003). Notably, the Sahara-Mediterranean plants have a typical seed germination strategy with optimal temperatures ranging from 15°C to 30°C (Thanos et al., 1995). The highest germination percentage was obtained at optimal temperature 25°C.

Water potential and temperature are considered as two of the important environmental factors regulating grass germination (Chauhan and Johnson, 2008). In arid environment of Central Tunisia, water necessary for germination is available only for short periods during winter. Therefore, a successful establishment of plant species depends not only on the rapid and uniform germination, but also on the ability of the seed to germinate under low water availability (Fischer and Turner, 1978). In the present study, *S. ciliata* seeds exhibited about 75% final germination percentage under water limitation conditions; however, the decrease of osmotic potential of the PEG_{6000} solutions to –2.0 MPa completely inhibited the seed germination. The reported high germination capacity of *S. ciliata* may be strongly related to the better ecological adaptation of this C_4 perennial grass to water limitation. The variation in osmotic potential of the PEG_{6000} solutions significantly affected the MTG and germination percentage. As it is true also with other plants, water is bound to have important effects on the seed germination (versus temperature). This is because water is an initial factor for seed imbibition and, directly and indirectly, is involved in the subsequent germination-associated metabolic stages under arid bioclimates (De Mendonça Barreto Cavalcante and Perez, 1995). However, imbibition has also been considered as another essential prerequisite of germination, and the surrounding soil water potential and the resistance to movement of water can govern its percentage and extent in the soil-seed system (Evans and Etherington, 1990). It has also been proved that the critical threshold for the germination of *S. ciliata* seeds is not high as compared to other perennial species (such as *Cenchrus ciliaris*) growing in arid environment (Emmerich and Hardegree, 1991). Earlier, *Stipa neaei* was reported to require high solution water potentials for its germination, while almost no germination was evidenced below 0.59 MPa (Bonvissuto and Busso, 2007). In the areas with dry and hot summers, seed germination is mainly triggered by temperature-precipitation interaction (Gutterman, 2002). Water availability, rather than temperature is also considered as an important factor driving the germination of *Stipagrostis* species in Jordan in the field conditions (Hamasha and Hensen, 2009).

4.2   Thermal time and hydrothermal time models

S. ciliata seed germination is strongly influenced by temperature and water limitation. Advancement in the radicle emergence under various combinations of temperature and water potential can be described using the thermal time and hydrothermal time models (Gummerson, 1986). Germination behavior of seeds under laboratory conditions can be regulated by the interaction of physiological and environmental factors, which can be proved by the thermal time and hydrothermal time models (Bradford, 1990, 1995). However, the seed dormancy is a reflection of high value of $\varPsi_{b(g)}$ threshold of the conditions that break the seed dormancy and shift the $\varPsi_{b(g)}$ distribution to higher values (Meyer et al., 2000). Subsequently, *S. ciliata* exhibited a low

$\Psi_{b(g)}$ value that may be a condition breaks the seed dormancy and leads to the high T_c value. The $\Psi_{b(50)}$ increased linearly with increasing incubation temperature. Further, the low T_c values can also be associated with seed dormancy (Bradford and Somasco, 1994). It is clear that plant species might be in dormancy at high temperatures. The consistency of the seed dormancy points towards a close relation of the water potential threshold with the dormancy and germination status (Dutta and Bradford, 1994). Arid zones are usually characterized by a long period of water limitation, high evapotranspiration and low rainfall. Hence, the establishment of perennial grass is an important and rare event in these zones. In the current study, the establishment of *S. ciliata* would be possible during the years with normal and well-distributed rainfall. It was earlier argued that rainfall exceeding 10 mm is a requirement for the seed germination of *S. ciliata* (Günster, 1995).

5   Conclusions

The seeds of *S. ciliata* can germinate at temperatures ranging from 25°C to 30°C, with an optimum temperature of 25°C; whereas, temperature of 15°C can limit the germination. Seed germination of *S. ciliata* can also be affected by water limitation with a limit of osmotic potential –2.0 MPa, where germination can be completely inhibited. *S. ciliata* is considered to be tolerant to water limitation, and can also present an adaptive capacity to aridity. Seeds of *S. ciliata* were able to tolerate high temperatures and water stressful habitats in arid ecosystems. These results would be of an important utility for the ecological restoration of degraded environments in arid zones. The most important result showed that the germination capacity of this species under the environmental constraint factors is sufficiently assured to consider this species for a restoration program and consequently extend its distribution area. This species can especially be introduced for the other regions with arid bioclimates.

Acknowledgements

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