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DESERT PLANTS SEEDS MORPHOLOGY AND GERMINATION STRATEGY

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Abstract

Desert plant vegetation plays an important role in natural habitat, as its growth depends largely on germination of seeds. The growth of individual plants depends on how the seed germination responds to environmental conditions. Seeds of ten desert species were collected at the Red Sea road in Egypt. The purpose of this study is to provide a clear picture of some important factors (temperature, scarification, and soaking treatment) on the germination of the collected seeds. The temperature effect was found to play the greatest role in the germination rate for most of the species' seeds between 25℃ and 30℃. Reseda pruinosa and Ochradenus baccatus experienced the highest percentages of seed germination at 25℃ which were 100% and 93% respectively followed by Schouwia purpurea and Cotula cinerea which their seeds germination was 87% while at 30℃, R. pruinosa and S. purpurea represented the highest two values of germination which were 93% and 80% respectively. S. purpurea showed significant response to concentrated nitric acid treatment in both 30s and 1.0min. which were 100% and 87% respectively, while Asphodelus fistulosus made up about 65% germination. R. pruinosa showed slight growth of around 7% after soaking in boiling water.

***Keyword**: Acid scarification; Desert plants; Seed dormancy; Seed germination; Temperature*

Introduction

Egypt characterized by 96% of its area desert life, have little of interest, but Bedouins call the desert 'Sea without water' as it represents a huge beauty life consists of many plants that deserve more survey and study [1]. In Egypt, desert plants are an important and characteristic type of natural plant life, it covers the main areas, mainly composed of xerophytic shrubs and sub-shrubs. Marsa Alam region along the Red Sea coast in south Egypt contains a vast mountainous wilderness called the Eastern Desert, a small number of nomadic inhabitants, world-renewed marine resources, rare wildlife and numerous antiquities [2]. Egyptian desert plants, which grow naturally need important requirements to be conserved and propagated [3]. Desert plants are economically important. *Asphodelus fistulosus, Astragalus eremophilus, Cotula cinerea, Farsetia aegyptia, Launaea mucronata, Ochradenus baccatus, Pulicaria incisa, Reseda pruinosa, Schouwia purpurea and Taverniera aegyptiaca* are grown in arid and semi-arid regions and traditionally used as medicine and food. For example, Seeds of *A. fistulosus* are diuretic and applied externally to ulcers, while flower heads of *C. cinerea* is used against

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vomiting, nausea and scorpion bites, and also above-ground part of *P. incisa* is used as aromatic scent, carminative and stimulant [4]. Chemical constituents of desert plants like flavonoids, saponins, tannins and phenolic compounds play a significant therapeutic role. Saponins were extracted from stem and root barks of *T. aegyptiaca* used as an antibiotic and antifungal [4]. *Khan et al*. [5] reported that *A. eremophilus* methanol extracts are indeed sources of potential therapeutic compounds against antibacterial, antifungal and free radical associated disorders.

Seed germination is the first critical stage of growth, and its adaptation to different environmental conditions affects individual plants survival and the dynamics of community [6]. In extreme desert conditions, seeds do not germinate until the water supply is sufficient for seedling survival [7]. Thus, germination indications reflect the climatic conditions under which a species is the most likely to be established successfully [8]. Seeds have specific germination mechanisms that enable them adapt to different environments [9]. Many plants have dormancy mechanisms that prevent germination until the conditions for seed germination and seedling survival are favorable [10]. Thus, dormancy is crucial in the formation of soil seed banks, and long-lived seed banks maintained by annual desert plants are often regarded as evolutionary bet-hedging strategies against unpredictable environmental variations or harsh climatic regions [11]. Although dormancy may be completely broken, the seeds of many different species can germinate over a wide range of different conditions. However, the blocking of water access into the seed is the most general cause of delay in seed germination [12].

Temperature is the main factor for regulating seed dormancy, and germination rates [13]. On the other hand, temperature and humidity can limit species germination and tolerance to these variants may depend on the species [9]. Temperature affects germination in three main ways: moisture, hormone production, and enzyme activity [14]. Soil temperature can also affect seed viability mainly by regulating aging [15]. A warmer climate may increase evaporation and decrease moisture, which would negatively affect germination. Hence, knowing how temperature affects seed germination of species in different ecosystems is useful for understanding community structure and biodiversity maintenance.

Experimental evidence of the advantage of large seeds has been reported for establishment under low soil moisture conditions [16]. Large seeds may keep seedling from the negative effects of drought stress [17]. Acid scarification is considered as one of the most effective scarification methods used to melt seed coat and soften hard seed [18]. Sulfuric acid and nitric acid are common and effective chemicals to reduce hard seed coats [19]. Concentration of acid, duration of scarification and species and cultivars used are the main factors affecting the acid scarification efficiency [20]. For example, *Astragalus arpilobus* treated with concentrated sulfuric acid (98%) for 30 and 40 minutes caused the highest germination percentage (94% - 96%) while 50 minutes of acid-scarification significantly decreased the germination percentage [21]. Also, *Astragalus cicer* seeds treated with concentrated sulfuric acid (98%, 18M) for 20 minutes have been improved the germination [22] in contrast to acid scarified seeds for 5 minutes which resulted in low germination rate [23]. The aim of the present investigation to evaluate the effects of temperature, soaking in hot water, acid scarification treatments on the germination of the ten desert plants species from Red Sea area.

Experimental

Materials

Seed collections

Seeds of Ten species (*A. fistulosus, A. eremophilus, C. cinerea, F. aegyptia, L. mucronata, O. baccatus, P. incisa, R. pruinosa, S. purpurea and T. aegyptiaca*) were collected from the Red sea road in 2018 (Fig.1). Seed samples collected to obtain an adequate representation of genetic diversity. Seeds were stored in bags after being cleaned and air dried.

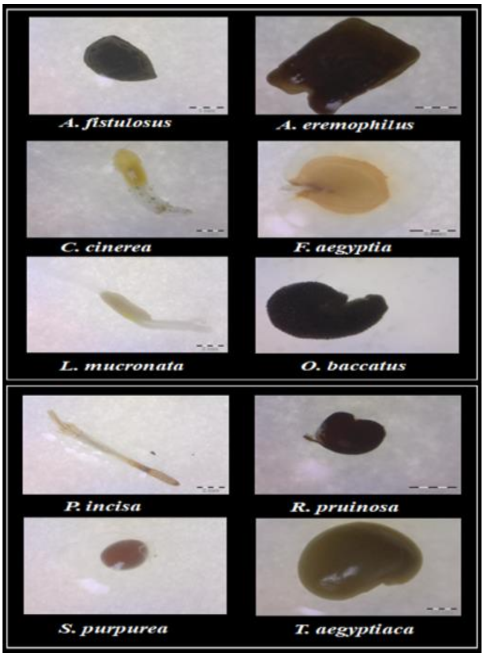

Fig. 1. Stereo Morphology photographs of studied seeds

Methods

Seed size measurements

Seed size was measured by the width and length of 5 randomly chosen seeds by using stereomicroscope (Olympus SZ61) LC micro software measurements and photographs were taken by Olympus soft imaging solutions GMBH camera model LC20 (Munster, Germany). The floristic composition, life-forms and seed size of studied desert plants species are presented in Table 1.

Table 1. Floristic composition, life-forms and seed size of studied desert plants species.

Species	Family	Seed size (Mm)	Life form	Vegetation type
Asphodelus fistulosus L.	Asphodelaceae	2.7×1.5	Therophytes	Perennials
Astragalus eremophilus Boiss.	Leguminosae (Fabaceae)	0.5×0.72	Therophytes	Annuals
Cotula cinerea Kotschy ex Benth. & Hook.	Asteraceae (Compositae)	0.8×0.3	Therophytes	Annuals
Farsetia aegyptia Turra.	Brassicaceae	3.3×3.7	Chamaephyte	Perennials
Launaea mucronata (Forssk.) Muschl.	Asteraceae (Compositae)	6.2×1.2	Hemicryptophyte	Perennials
Ochradenus baccatus Delile	Resedaceae	1.5×1.5	Phanerophyte	Perennials
Pulicaria incisa (Lam.) DC.	Asteraceae (Compositae)	4.7×1.1	Chamaephyte	Perennials
Reseda pruinosa Delile	Resedaceae	1.6×1.9	Therophytes	Annuals
Schouwia purpurea (Forssk.) Schweinf	Brassicaceae	1.9×1.7	Therophytes	Annuals
Taverniera aegyptiaca Boiss.	Leguminosae (Fabaceae)	2.1×2.5	Chamaephyte	Perennials

Germination experiments

Homogenized seeds were surface sterilized then washed several times in sterilized distilled water (SDW). Germination trials were done in 12cm sterile petri dishes lined with two Whatman filter papers No.1 and moistened with SDW to ensure adequate moisture for the seeds. Fifteen homogenous seeds were used in each treatment with three replicates for each species as well as the controls. For treatments except temperature treatment, petri dishes were labelled and maintained in a growth chamber with 25±2°C and 14/10h light/dark illumination. Germination was considered when the radicle protruded 2mm [24]. All experiments were carried out at Eco-physiology Laboratory, Unit of Environmental studies and Development, Aswan University, Aswan, Egypt. Only normal seedlings were counted daily for percent germination according to *H.A.A. El-Shaieny* [25].

GP = (No. of seeds germinated/total No. of seeds sown) × 100

Temperatures treatments

To determine temperature effect, the seeds were incubated at a wide range of germination temperatures of 25, 30, 35 and 40°C. The experiments were carried out in light-controlled growth chambers for 7 days.

Acid scarification Treatments

To study the effect of nitric acid (HNO_3), scarification on germination and early seedling growth in the studied species, seeds were immersed for three levels times (0.30s and 1.0min.) in concentrated HNO_3 followed by thorough rinsing 4 times with SDW at room temperature to remove all traces of acid.

Hot and boiling water treatment

The seeds were soaked in hot water (65°C) and boiling water (100°C) for 30min. Then seeds cleaned with SDW four times. The untreated seeds were used as control.

Statistical analysis

For each species, effects of temperature, acid scarification and soaking in hot and boiling water on final germination percentage (GP) were analyzed. All statistical analyses were performed using one way analysis of variance (ANOVA) from Minitab 18 and GraphPad Prism 8.0.2 for Windows software. Data is represented as mean with standard deviation of three replicates.

Results and Discussion

Species and seed size

The ten studied species (4 annuals and 6 perennials) included single species *L. mucronata* is Hemicryptophyta, other one species *O. baccatus* is Phanerophyte and the three species (*F. aegyptia*, *P. incisa, and T. aegyptiaca*) are Chamaephyte, while the rest are Therophytes (Table 1). Species from wide range of plant families, life cycle, and plant communities exhibited the difference in germination characteristics of seed collected from different location [26]. Seed length varied from 0.72mm for *A. eremophilus* to 6.2mm for *L. mucronata*, and seed width from 0.3mm for *C. cinerea* to 3.7mm for *F. aegyptia*. *F. Yi et al.* [27] reported the relationship between seed germination and seed size is important for predicting future community structures and concluded the relationships between germination under drought stress and seed size might differ among ecosystems.

Temperature effect on seed germination rate

Temperature is the most important factor in seed germination and played a vital role in breaking seed dormancy. Each desert plant species has its own set of mechanisms that enable it to germinate under a wide range of conditions. No specific germination mechanism has been found for each examined seeds inhabiting the Red Sea coast. Germination stages of studied seeds and formation cotyledonary leaves are showed in figure 2. The results indicated that high temperatures delayed the seeds germination in all studied species (Fig. 3). At 25°C, seeds of *S. purpurea* and *O. baccatus* started germination from the second day but in case of *C. cinerea* and *R. pruinosa* was delayed from the second day to the fourth day and *L. mucronata* was delayed to the six days while the rest of species began to germinate from the third day (Fig. 3). High temperature (30°C) delayed the seeds germination as radicle was appeared only in the fifth day in case of *S. purpurea* and *O. baccatus* in the fifth day, while it was emerged in the second day in 25°C. The germination percentage of *O. baccatus* is 100% at 25°C, in contrast *Bhatt and Pérez-García* [28] reported that fresh matured seeds of *O. baccatus* are dormant at maturity and are unable to germinate under different temperature and light conditions. In *T. aegyptiaca*, the germination rate was increased by 35°C (Fig. 3). The germination rate was decreased with increasing temperature (Fig. 3). *Pérez-Sánchez et al*. [29] and *Daws et al.* [15] reported that exposure seeds to high temperatures resulted in lower germination of the seeds probably by the impact of high temperatures denaturing cellular structures.

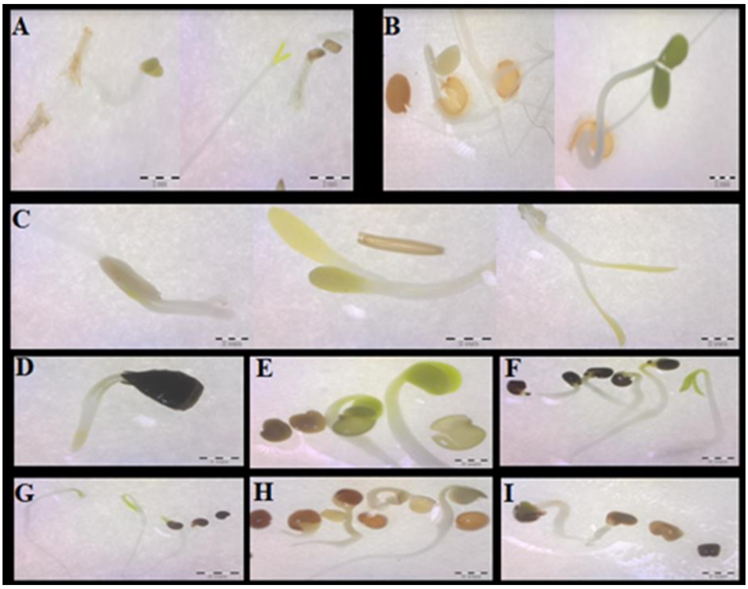

Fig. 2. Germination stages of studied seeds and formation of cotyledonary leaves:
A) *C. cinerea* at 25°C; B) *F. aegyptia* at 30°C; C) *L. mucronata* at 30°C;
D) *A. fistulosus* only at 25°C with appearance only radicle; E) *T. aegyptiaca* at 30°C;
F) *O. baccatus* at 30°C; G) *R. pruinosa* at 25°C; H) *S. purpurea;* I) *A. eremophilus*

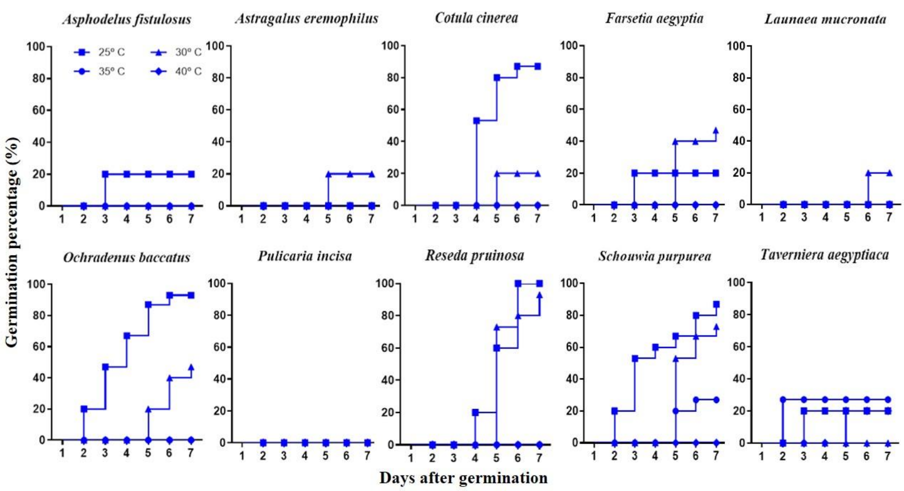

Fig. 3. Effect of different levels of temperatures on seed germination rate of the studied species

Temperature effect on final percentage of seed germination

Seeds germination percentage of the studied species after 7 days in different temperatures is presented in figure 4. Germination rate was differed significantly among species ($p < 0.05$) and temperature regimes. Germination percentage decreased with increasing temperatures. Data indicates that seeds of the ten species showed reduction in germination at the highest temperature 35 and 40°C, with little variation in the seeds behavior of *T. aegyptiaca*.

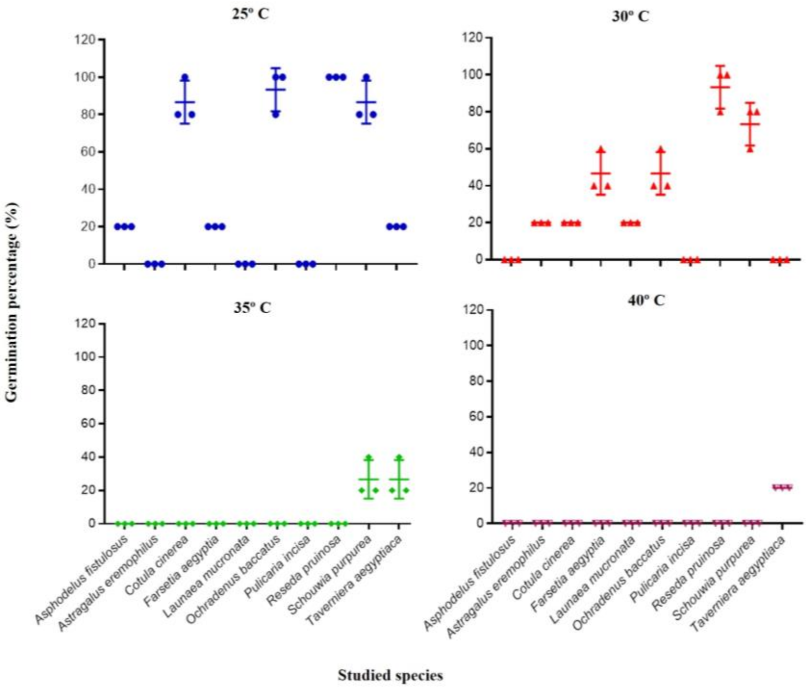

Fig. 4. Effect of different levels of temperatures on seeds germination percentage of ten studied species

Only *T. aegyptiaca* germinated at 40°C compared as the rest species, while *S. purpurea* and *T. aegyptiaca* germinated at 35°C. Results showed that *T. aegyptiaca* germinated at all different temperature levels except 30°C. However, all the studied species displayed higher records of germination percentages at the treatments of 25 and/or 30°C, except *P. incisa* (Fig. 4). *R. pruinosa* displayed the maximum response of germination to the highest percentage 100% and 93% at 25 and 30°C respectively. *A. fistulosus* germinated only at 25°C and no germination was recorded at 30°C. This agrees with. *Khan et al*. [30] where germination of *A. tenuifolius* was significantly affected by the temperature and dormancy breaking chemicals. *A. eremophilus* and *L. mucronata* germinated only at 30°C.

The effect of temperature on germination varied according to the species, but generally all the studied species germinated rapidly at intermediate temperatures between 20°C and the germination was inhibited above 30°C [30]. The suitable day/night temperatures for germination of *Agropyron cristatum* and *Artemisia halodendron* ranged from 20/10°C to 30/20°C [31]. Seed germination of *Melilotus suaveolens* was stimulated under medium temperatures and inhibited under the highest or lowest temperatures according to *Lai et al.* [31].

Nitric acid effect on seed germination rate

The results indicated the seeds germination rate of the tested species are shown in figure 5. Acid scarification is known to be highly effective in improving germination of species with hard seed coats [32].

A. fistulosus germinated after the second day after scarifying seeds with acid in both treatments (Fig. 5). Nitric acid improved both the rate of seed germination and the total germination of many seeds but a few of seeds still germinated unsatisfactorily following HNO_3 treatment. Nitric acid delayed the seeds germination in *T. aegyptiaca* in both treatments to the fourth day (Fig. 5).

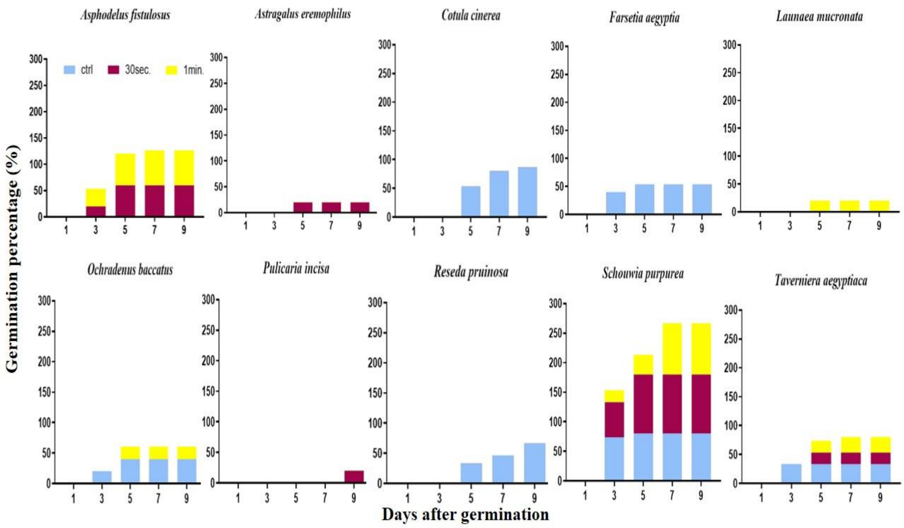

Fig. 5. Effect of nitric acid scarification on seed germination rate of ten tested species

The poor germination of seeds may be due to the age of seeds [33]. Also, germination differs depending on the time of treatment in the nitric acid. Germination was delayed to the fourth day in *A. eremophilus* when 30 seconds and *O. baccatus* in 1 minute treatment (Fig. 5). In our study, germination of the studied species found to be accelerated on treatment with concentrated nitric acid under the different periods. These agree with *R.C. Hare* [33] which reported that HNO_3 promotes the growth of Pine Seeds. Also, our results indicated that Nitric acid led to the cessation of seed germination in the case of *R. pruinosa* and *F. aegyptia* and showed reduction in germination in case of *O. baccatus* and *T. aegyptiaca*. *Bhardwaj et al*. [34] reported that poor germination or no germination in case of concentrated HCl and HNO_3 respectively might be due to the inability of these treatments to break the physical dormancy. *Cassia spp*. suffers from dormancy owing to the presence of water impermeable thick seed coat that prevents water and oxygen from reaching and activating the embryo, or due to the presence of germination-inhibitor chemical compounds and they require specific treatments for breaking dormancy. Hence, acid scarification like H_2SO_4 for different periods was the most effective treatment in softening the seed coat of *Cassia* seeds [35]. Our results showed the opposite, exposing the seeds for nitric acid decreased significantly the germination capacity because nitric acid being corrosive might have damaged the embryos of some seeds like *rose* seeds exposed to nitric acid [36].

Nitric acid effect on final germination percentage

The effect of nitric acid on the examined seeds is given in figure 6. There was increase in the germination percentages in case of *S. purpurea*, *A. fistulosus*, *P. incisa*, *A. eremophilus* and *L. mucronata* varies depending on the time of treatment in the nitric acid. *S. purpurea* showed the highest germination percentage 100% when scarified for 30 seconds with the nitric acid. *A. fistulosus* showed 60% germination for 30 seconds treatment with nitric acid and 67% for 1 minute treatment with nitric acid and this is probably due to its seed stiffness.

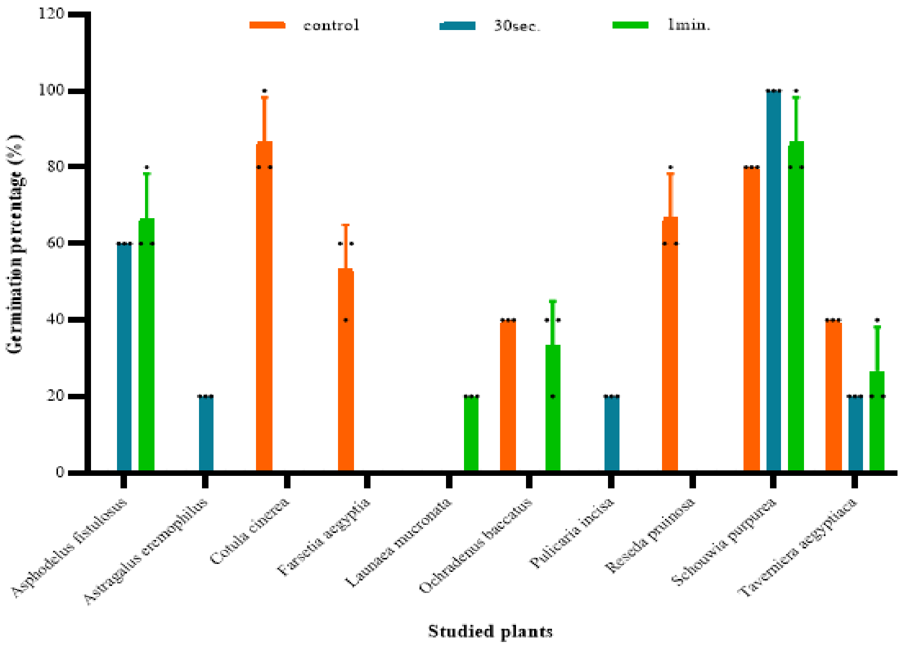

Fig. 6. Effect of nitric acid at different periods of time on the germination rates of ten tested species

A. eremophilus and *P. incisa* and exhibited slight percentage germination (20%) in case of 30 seconds treatment with nitric acid as well as *L. mucronata* in case of 1 minute treatment with nitric acid. In the other hand, treatment with nitric acid led to the cessation of seed germination in the case of *F. aegyptia* and *R. pruinosa* but showed reduction in germination in case of *O. baccatus* and *T. aegyptiaca*. However, there was no change in seed germination in case of *C. cinerea*. Nitric acid improved both the rate of seed germination and the total germination of many seeds but a few of seeds still germinated unsatisfactorily following HNO_3 treatment.

Hot water effect on seed germination rate

The results indicated that effect of hot water scarification on germination rate of the tested species is presented on figure 7. The treatment of seeds with hot water to improve germination is safe and cost-effective method, which is recommended by the Brazilian Ministry of Agriculture [37]. Hot and boiling water treatments resulted in delay in the germination rate in all studied species except *A. fistulosus*. In case of *F. aegyptia*, *O. baccatus*, *R. pruinosa* and *S. purpurea*, the germination seeds were delayed to the ninth day when compared with control in boiling water scarification while *T. aegyptiaca* germination was delayed from the second day to the fourth day after exposure to hot water treatment. The reasons behind the increased seedling growth parameters after hot water treatment at 50-52°C than control are increased imbibition and stimulated germination related activities such as gibberellic acid synthesis, RNA synthesis, protein synthesis and DNA replication and finally weakening of the endosperm and thereby increasing germination [38-40].

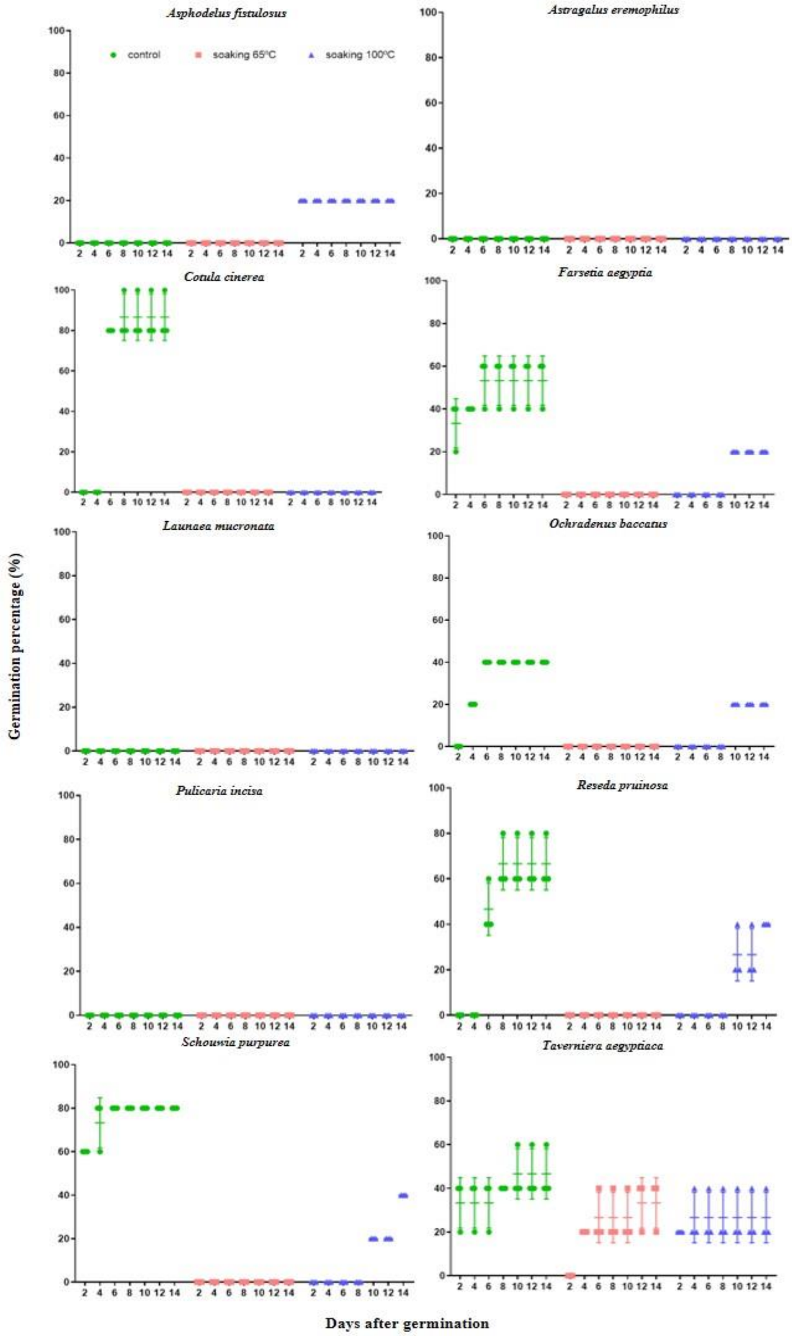

Fig. 7. Effect of hot and boiling water treatments on seed germination rate of ten tested species

Hot water effect on final germination percentage

The final germination percentage (14 days post treatments) was recorded for the ten species (Fig. 8). Soaking in both hot and boiling water didn't induce seeds of *A. eremophilus, C. cinerea, L. mucronata* and *P. incisa* to germinate. *T. aegyptiaca* was the only plant that responded to the effect of soaking in both hot and boiling water and the germination percentage decreased from 40% to 27% in both treatments while the rest examined plants germinated only in case of boiling water. In the case of *A. fistulosus*, germination was increased over the control from 0% to 20% in boiling water scarification. The final germination levels of *F. aegyptia*, *O. baccatus*, *R. pruinosa* and *S. purpurea* were decreased after boiling water treatment from 53, 40, 67 and 80% to 20, 20, 27, 20% respectively. *Younis et al*. [36] revealed that the treating rose seeds with hot water may unable to penetrate the endosperm to enhance the germination. Treatment of *Acacia polyacantha* by hot water was found one of the best pre-treatment seed methods for the increased growth seedlings similarly to *Missanjo et al.* [41]. In addition, the seeds of pepper are sensitive to hot water treatment. The soaking of pepper seeds in hot water at convenient temperature promote the germination rate *Lewis Ivey and Miller* [43] had revealed that. Similarly effects of hot water seed treatment on improved seed percentage germination in other plants like *Pinus pinnata* according to *Ramamoorthy et al.* [43]. Also, *Pasiecznik et al*. [44] noted the *Prosopis* seeds treated by boiling water increased germination.

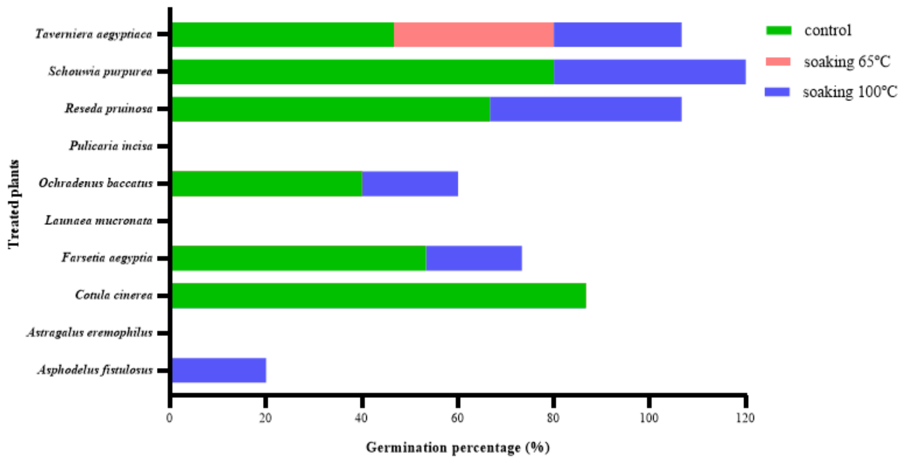

Fig. 8. Effect of hot and boiling water treatments on germination percentage of ten species of desert plants

Conclusions

The roles of applied germination factors including temperature, water soaking and nitric acid were elucidated. Desert seeds varied for their requirements of temperature for germination, some seeds exhibited a wide temperature range for germination from 25 to 40°C, while others showed narrow range such as *Schouwia purpurea* and *Taverniera aegyptiaca*.

The obtained data of present study demonstrated that germination decreased with increased temperature. The percentage of germination and the rate and of soaked desert plants seeds varied between soaked seeds and those of control seeds, *Farsetia aegyptia* showed high germination rate with soaking in hot water at 65 and 100 °C. Nitric acid effect on desert seed germination rate positively increased germination rate of *Schouwia purpurea* at the two-treatment period of time (30 and 60s).

This initial study and the obtained findings will give elucidation strategy and ways to select ideal growth aspects for these studied species further for restoration and conservation purposes.

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