



Seed mucilage effect on water uptake and germination in five species from the hyper-arid Arabian desert



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ABSTRACT

The effect of mucilage removal on germination percentages and velocity (Timson's index) was studied for five Arabian desert species (*Lavandula subnuda*, *Lepidium aucheri*, *Boerhavia elegans*, *Plantago ciliata* and *Plantago amplexicaulis*) under two photoperiods (0, 12 h of light daily) and three thermoperiods (night/day temperatures of 15/25, 20/30 and 25/35 °C). Mucilage presence increased water uptake in all species, and was associated with higher germination percentages in *L. subnuda*, *B. elegans* and *P. ciliata*, but not *L. aucheri* and *P. amplexicaulis*. Germination velocity response to mucilage presence was mixed, being increased in *L. aucheri* and reduced in *L. subnuda*. In all species germination was increased by light and affected by temperature, but species' response to temperature varied. Interactions of mucilage presence with temperature were more frequent than with light. Seed mucilage plays a role in germination regulation of these species, but the effects are species-specific. Mucilage presence inhibited germination at lower temperatures in *L. subnuda* and *P. ciliata*, at higher temperatures in *B. elegans*, and increased germination velocity but not percentage in *L. aucheri*. It had no influence on germination in *P. amplexicaulis*. The differences detected demonstrate as perhaps mucilage in seeds of some desert species serves also to other ecological purposes.

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1. Introduction

The arid desert climate of the Arabian Peninsula is characterized by high temperatures, low unpredictable rainfall and high evaporation rates (Abu Sukar et al., 2007). These and other factors, such as high irradiance and soil salinity, strongly condition the survival of plant species. Each desert species has its own adaptations to increase reproductive success in this severe environment (Guterman, 1993). Morphological adaptations include variation in seed size and seed dispersal mechanisms, while physiological adaptations include seed dormancy to cope with unpredictable seasons (El-Keblawy et al., 2013). Another adaptation is myxodiaspory, in which seeds produce a pectinaceous mucilage in response to water imbibition (Yang et al., 2012). Myxodiaspory has been reported in 110 families, but is particularly found in

Brassicaceae, Lamiaceae, Nyctaginaceae and Plantaginaceae (Van Oudtshoorn and Van Rooyen, 2013). Several studies have confirmed its advantage to survival of desert species, including *Artemisia sphaerocephala* (Yang et al., 2012), *Plantago minuta* (Zhang et al., 2014) and *Plantago albicans* (Veiga-Barbosa and Pérez-García, 2014).

The presence of mucilage on the seed coat may protect the seed against drying, promote seed germination and facilitate early seedling growth, by retaining a film of water around the seed and near the seedling (Yang et al., 2010). When dehydrated, the mucilage forms strong adherence to soil particles, which may increase the physical barrier for water loss from the seed (Lu et al., 2010). It may discourage predation (Engelbrecht and García-Fayos, 2012) and anchor smaller seeds in the soil, thus reducing seed removal by wind and rain erosion (Sun et al., 2012). During dormancy in arid environments, mucilage can harvest sufficient dew for seed cells to repair DNA damage, and thus maintain genetic integrity for longer periods (Yang et al., 2011). However, the specific role of seed mucilage varies with species and environmental context (Western, 2012).

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Previous studies indicate that seed mucilage may have a positive or inhibitory effect on seed germination (Yang et al., 2012). Mucilage secretion may enhance germination by increasing contact between seeds and soil particles, thus attracting available moisture (Lu et al., 2010), but diffusion of water and oxygen into the seed is also reduced, which may suppress germination (Gutterman and Shem-Tov, 1996). The role in arid ecology is perhaps clearer, where in general, seed mucilage assists germination and early seedling growth through the attraction of limited water resources (Sun et al., 2012). Desert species studied include *Artemisia monosperma* (Huang et al., 2000), *Artemisia sphaerocephala* (Yang et al., 2010), *Alyssum minus* (Sun et al., 2012), *Henophyton deserti* (Gorai et al., 2014), *Plantago minuta* (Zhang et al., 2014) and *Plantago albicans* (Veiga-Barbosa and Pérez-García, 2014).

Light and temperature are the most important environmental signals for regulating seed germination, species distribution and ecological interactions when sufficient moisture is available (Chauhan and Johnson, 2008). Seeds are sensitive to intensity, spectral composition, and duration (photoperiod) of light (Baskin and Baskin, 2014) via phytochrome (Smith, 1982). Temperature is strongly implicated in determining the timing of seed germination in the field (Fenner and Thompson, 2005), but temperature cues can interact with light and other factors, possibly by modifying the rate of phytochrome metabolization (Pons, 2000). Plant establishment in arid regions is often limited by temperature when moisture conditions are favourable (Evans and Etherington, 1990). Desert ecosystems typically exhibit a large diurnal temperature variation in addition to seasonal variation (Baskin and Baskin, 2014). Diurnal variation is greatest at the ground surface where germination occurs.

Seed burial depth affects exposure to both temperature and light. Many deserts have an incoherent substrate (e. g. sand) which may frequently become mobile, resulting in regular changes to seed depth. Diurnal temperature variation declines with increasing depth, while ecologically significant amounts of light rarely penetrate more than 4–5 mm (Tester and Morris, 1987). Species establishment in an arid habitat is therefore affected by interactions among several abiotic factors (Minissale et al., 2011; Baskin and Baskin, 2014). A further example is that of salinity and temperature (Ungar, 1995). Germination percentages decline with increasing salinity, but the decline is generally less severe at optimum temperature for the species (Murru et al., 2015; Santo et al., 2014a, 2014b).

In the present study, the role of mucilage in regulating seed germination and dormancy of five species adapted to the hyper-aridity of the Arabian Gulf coast was studied. A better

understanding of germination requirements could inform conservation and rehabilitation programs. Two perennial species adapted to gravel hillsides, and three annual species adapted to low sandy dunes (Jongbloed et al., 2003) were selected for the study (Table 1). Seeds of all species lack dispersal structures, and produce mucilage after contact with moisture. Presence and removal of seed mucilage on germination response (percentage and velocity) were studied under different photoperiods and temperature regimes.

2. Material and methods

2.1. Seed collection

Seeds of each species were collected in Qatar in 2014 in a month representing phaenological maturity (Table 1). The location is hyper-arid, with a sporadic annual precipitation of 152 mm occurring mostly between November and March (International EMECs Center, 2003), and evapotranspiration of 2–10 mm/day in December to June respectively (Abu Sukar et al., 2007). Midsummer is hot and humid, with daytime temperatures peaking above 50 °C in August and humidity approaching 100% in May.

Seeds were separated from fruits, and seeds that visually appeared healthy were stored in paper bags at room temperature (20 ± 2 °C) until needed (1–4 months). Mass ± SD (standard deviation) of each species was determined by weighing three replicates of 50 seeds each.

2.2. Mucilage removal

Seeds were soaked in distilled water for 10 min, and then daubed on filter paper until mucilage production ceased (Yang et al., 2010; Gorai et al., 2014). To determine the effect of mucilage on water uptake, three replicates of 50 de-mucilaged, and three of 50 intact seeds were placed on filter paper in 9-cm plastic Petri dishes, given 10 ml distilled water, and weighed before and after incubation for 19 h at 20 °C in total darkness (Gorai et al., 2014).

2.3. Germination

Germination was studied for 20 days under three thermo-periods and two photoperiods using three LMS (UK) incubators. Thermoperiods were night/day temperatures of 15/25, 20/30, and 25/35 °C, chosen to simulate 12-h temperature averages for mid-winter (January) and surrounding months (December and

Table 1
Descriptive and collection data for the five studied species, and mass of seeds in storage conditions (20 ± 2 °C), after soaking (19 h at 20 °C), and after de-mucilagination and soaking. Percentage change of the latter from storage seed mass is also provided.

Species Family	Plant height (cm)	Lifespan/habitat/collection point (decimal degrees)	Seed collection (2014)	Storage seed mass (mg ± SD)	Mass of intact, soaked seeds (mg ± SD; % change ± SD)	Mass of de-mucilaged, soaked seeds (mg ± SD; % change ± SD)
<i>Lavandula subnuda</i> Lamiaceae	120	Perennial/Gravel hillsides/Shahniya nursery, Qatar (25.4412 N, 51.2701 E)	May	0.94 ± 0.02	5.94 ± 0.26 531.79 ± 18.63	1.51 ± 0.14 60.54 ± 18.54
<i>Lepidium aucheri</i> Nyctaginaceae	50		August	0.43 ± 0.01	0.68 ± 0.06 59.24 ± 10.54	0.47 ± 0.01 10.97 ± 2.88
<i>Boerhavia elegans</i> Brassicaceae	30	Annual/ Low sand dunes/Roadside, Qatar	April	1.38 ± 0.04	6.61 ± 0.45 378.86 ± 18.76	2.53 ± 0.15 83.04 ± 7.68
<i>Plantago ciliata</i> Plantaginaceae	10	(24.8167 N, 51.0851 E)		0.99 ± 0.03	3.21 ± 0.13 225.37 ± 20.62	2.11 ± 0.14 114.49 ± 18.62
<i>Plantago amplexicaulis</i> Plantaginaceae	20			3.31 ± 0.06	17.0 ± 0.66 413.99 ± 10.67	7.05 ± 0.27 113.22 ± 11.32

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