Flora 220 (2016) 125–133

Contents lists available at ScienceDirect

Flora

journal homepage: www.elsevier.com/locate/flora

Germination and seedling performance of five native legumes of the Arabian Desert

Arvind Bhatt[a,*], María Mercedes Carón[b], Kris Verheyen[c], Esam Elsarrag[a], Yousef Alhorr[a]

[a] Gulf Organization for Research & Development, P.O. Box: 210162 Doha, Qatar
[b] Laboratorio de Investigaciones Botánicas (LABIBO), Facultad de Ciencias Naturales, Universidad Nacional de Salta-CONICET, Av. Bolivia 5150, 4400 Salta, Argentina
[c] Forest & Nature Lab, Ghent University, Geraardsbergsesteenweg 267, Melle-Gontrode B-9090, Belgium

ARTICLE INFO

Article history:
Received 11 July 2015
Received in revised form 26 February 2016
Accepted 3 March 2016
Edited by Hermann Heilmeier
Available online 5 March 2016

Keywords:
Dormancy break
Scarification
Seedling survival
Biomass allocation
Fabaceae
Arid desert

ABSTRACT

Introducing nitrogen-fixing legumes in desert land could enhance rangeland productivity and help in soil reclamation. However, detailed information about germination and seedling performance of many desert legumes species is still lacking. We investigated these plant characteristics for five native legumes of the Arabian Desert in Qatar: *Crotalaria aegyptiaca*, *Crotalaria persica*, *Rhynchosia minima*, *Senna alexandrina* and *Senna italica*. Germination of the species was tested under laboratory conditions using different temperature and light treatments: 15/25, 20/30 and 25/35 °C, in either continuous darkness or cycles of 12 h light/12 h darkness. The germination percentage recorded under the different temperature and light conditions was very low. Therefore, four scarification treatments, water soaking (12 and 24 h) and concentrated sulfuric acid application (5 and 10 min), were applied. The scarification treatments improved the germination of all the species. However, the different species did not equally respond to the scarification treatments tested. In general, the treatments with sulfuric acid were the most effective. Subsequent seedling survival and growth were evaluated under greenhouse and field (nursery) conditions. All the studied species exhibited higher seedling survival inside (69–96%) than outside the greenhouse (53–89%). Regarding growth, these species did not show much difference in terms of shoot and root length when placed in the greenhouse or the nursery. However, the species showed differences in biomass allocation (aboveground vs. belowground biomass) between greenhouse and nursery but with species-specific responses. The information provided here on scarification requirements and seedling survival and biomass allocation as dependent on the growth environment is helpful for conservation and landscape agencies interested in using these species for conservation, restoration and landscaping projects.

1. Introduction

The arid desert climate of the Arabian Peninsula is characterized by exceptionally high temperatures, low unpredictable rainfall and high evaporation rates (Abu Sukar et al., 2007). These environmental factors together with other factors such as drought, high irradiance and salinity allow the survival of only few plant species. Fabaceae is one of the most diverse and widespread plant families present in desert environments with the capacity of hosting N-fixing bacteria (e.g. *Rhizobium*) (Crews, 1999). The symbiotic relationship between legumes and rhizobium is the most important nitrogen-fixing system and has potential to increase N input in the soil (Wolde-Meskel et al., 2004). Moreover, the use of fertilizers to increase soil fertility is not a common practice in many areas around the world due to the high costs of this practice. Hence, the use of legumes can facilitate the conservation and restoration of soil functioning and biodiversity. Introducing the nitrogen-fixing legumes in desert land can be a viable technique to enhance rangeland productivity and help in soil reclamation (Skujins, 1991). Besides their relation with soil fertility, legumes are used for various purposes such as food, fodder, fiber, fuel wood, timber and medicine (Athar, 2005; Singh et al., 2013).

The production of good quality seedlings is essential for the successful establishment of any species that could be used for the rehabilitation of desert land. However, the presence of a hard seed coat is a characteristic feature of most of the legumes that often limits rapid and uniform germination in legume species. Dormancy imposed by a hard seed coat is part of the seed survival strategy in many species (Werker, 1981; Kelly et al., 1992). Seed coats play an important role in protecting the embryo against mechanical

* Corresponding author.
E-mail address: drbhatt79@gmail.com (A. Bhatt).

http://dx.doi.org/10.1016/j.flora.2016.03.002

injuries, attacks of pests and pathogens, and in the regulation of gas exchange between the embryo and the external environment (Weber et al., 1996; Morris et al., 2000). Furthermore, presence of phytotoxic compounds in the seed coat of some legume species also causes germination inhibition (Simões et al., 2008).

Previous studies reported that dormancy in the genera *Crotalaria*, *Senna* and *Rhynchosia* is mainly caused by a hard seed coat which makes the seeds impermeable to water and/or oxygen or causes mechanical resistance to radical protrusion (Baskin et al., 1998; Kak et al., 2006; Jurado and Flores, 2005; Tauro et al., 2009; Ali et al., 2011, 2012; De Paula et al., 2012). Until now, most of the studies on seed dormancy and germination were conducted under laboratory conditions. However, under nursery conditions seed germination can be affected by an altered ability of inhibitors (due to leaching) and by altered dynamics of micro-organisms available for decomposition (Burrows, 1997; Morpeth and Hall, 2000). Physical dormancy can result in erratic and low germination under field conditions. Therefore, various pretreatments, including mechanical (nicking or sandpaper), chemical (acid scarification) and heat (hot water soaking) treatments, have been widely used to improve seed germination of hard seed coat Fabaceae species to obtain uniform and fast germination (Hu et al., 2009; Büyükkartal et al., 2013).

The species *Crotalaria aegyptiaca* Benth., *C. persica* (Burm. f.) Merr., *Rhynchosia minima* (L.) DC., *Senna alexandrina* Mill. and *Senna italica* Mill. are important legumes of the Arabian Desert. They are widely used for fodder, fuel wood and medicine (Franz, 1993; Jongbloed, 2003; Norton et al., 2009; Molares and Ladio, 2011; Phondani et al., 2015). Furthermore, the species have several features (e.g. attractive foliage and flowers, evergreen character) that make them good candidates for use in landscaping in arid regions according to the criteria measures of global sustainability assessment system (GSAS, 2014). They also have the potential to establish successfully in a water deficient desert environment due to their drought tolerance and to perform well in nitrogen deficient soils due to the ability to fix atmospheric nitrogen. All these species commonly occur in different desert habitats such as wadis and sand and gravel plains (Jongbloed, 2003). Furthermore, these species can facilitate creating suitable habitats for other species by improving soil conditions. However, there is a lack of knowledge about their germination and establishment behavior, limiting their use in e.g. restoration and landscaping projects. Thus, detailed information on methods to improve seed germination, seedling survival and growth is needed. The present study was carried out to (a) determine the effect of temperature and light on the germination of these five species under laboratory conditions; (b) test dormancy breaking treatments using acid scarification and water soaking under greenhouse conditions; and (c) evaluate seedling survival and growth under greenhouse and nursery conditions.

2. Materials and methods

2.1. Study species

Crotalaria persica is a perennial small branched herb (up to 40 cm), mostly occurring on low sand dunes areas. *S. alexandrina* and *S. italica* are perennial medium sized herbs (50–90 cm) with a woody stem that produces yellow flowers. The species grow in compact sand, sandy gravel plains and wadis. Finally, *C. aegyptiaca* and *R. minima* are perennial and relatively big branched herbs that reach up to 100 cm. Both species produce yellow flowers and mostly occur in sandy and gravel plain habitats.

2.2. Seed collection and storage

Seeds of *C. aegyptiaca*, *C. persica*, *R. minima*, *S. alexandrina* and *S. italica* were collected in July 2014 from plants growing on Shahniya Nursery (25°27′39″N, 51°11′22″E), Doha, Qatar. Seeds were randomly collected from approximately 50 plants of each species to represent genetic diversity. Immediately after collection, the seeds were cleaned and stored in brown paper envelopes at room temperature (20 ± 2 °C).

2.3. Germination under laboratory conditions

The effects of temperature and light and their interaction on seed germination was assessed in incubators set at daily 15/25, 20/30 and 25/35 °C temperature regimes in either continuous darkness or 12 h light/12 h darkness. These temperature regimes are close to those that occur between December and March when the conditions for germination and seedling establishment are better due to higher chances of rainfall in the study area (Böer, 1997). The incubators were set with light coinciding with the higher temperatures. For the dark treatment, the dishes were wrapped in aluminum foil to prevent any exposure to light. Four replicates of 25 seeds were used for each treatment. Radicle emergence was the criterion for germination. Germinated seeds were counted every alternate day for 22 days following seed soaking. Germination of seeds incubated in the dark was evaluated only after 22 days. The experiment was stopped after 22 days because no new germination occurred for a consecutive five days period.

2.4. Germination after scarification

Because the germination percentages of all the species were very low under laboratory conditions, subsamples of seeds (four replicates of 25 seeds of each species) were treated with one of the following treatments: water soaking for 12 and 24 h and sulfuric acid (100%) application for 5 and 10 min. Seeds treated with sulfuric acid were rinsed five times using distilled water. After scarification, four replicates of 25 seeds of each species were sown in 8.0 cm plastic pots at 0.5 cm depth (one replicate per pot) using a mixture of farm soil, beach sand and potting soil (160–280 mg/l N, 190–320 mg/l P and 200–340 mg/l K), organic matter 85–90% and salt level (KCl) of 1.6 g/L (SAB potting soil, Germany). The proportion between farm soil, sand and potting soil was 1:1:1. After sowing the pots were placed in a greenhouse. The control for this experiment consisted of seeds without any treatment. The number of germinated seeds was counted every alternate day for 28 days. After 28 days, no new germinated seed occurred for a consecutive five days period; therefore germination was considered to be completed. The criterion used to define germination in this case was first leaf emergence. Pots were watered every alternate day with 50 ml water. To keep track of the environmental conditions in the greenhouse, the minimum/maximum air temperature and relative humidity were recorded using a Thermo-Hygrometer (Electronic Temperature Instrument Ltd, UK).

2.5. Survival and growth performance under nursery and greenhouse conditions

The average temperature was higher inside the greenhouse (39.6 °C maximum and 35.7 °C minimum) compared to the nursery (36.3 °C maximum and 28.6 °C minimum). The relative humidity varied from 81.8 to 63.5% inside the greenhouse and from 84.5 to 26.9% in the nursery. To test the effect of these climatological differences on seedling survival and performance, after 28 days of the beginning of the experiment the germinated seedlings were pooled separately for each species (irrespective of the scarification treatment) and half of them were kept inside the greenhouse and half were transplanted to the nursery. Seedling survival percentage and growth parameters (shoot height, root length, above and belowground dry weight) under greenhouse and nursery (open) conditions were measured after 90 days. Twelve randomly selected