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Germination of an invasive *Cenchrus ciliaris* L. (buffel grass) population of the Sonoran Desert under various environmental conditions

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ABSTRACT

Cenchrus ciliaris is one of the most important invasive plants in northwestern México and southwestern United States, threatening the conservation of desert and thorn scrub. Our knowledge about the mechanisms that underlie its capacity for invasion is limited. Here, we evaluate the effect of light, temperature, gibberellic acid, osmotic potential, heat shock and experimental fire on caryopses germination from an invader population, exploring the hypothesis that fast germination under a wide range of environmental conditions facilitates survival in a plant species that invades desert environments. Results showed that caryopses of invasive plants were light-indifferent, and germinate under a wide range of temperatures (10 °C–40 °C). Germination initiates in less than 24 h, reaching a maximum in 3–6 days at 25 °C, with lower germination recorded below 15 °C. Germination occurred at osmotic potentials ranging from 0 to −1.6 MPa. Some of the caryopses germinated only after the lemma and palea were removed and a fraction did not germinate even after covers were removed, suggesting the existence of physiological dormancy in these caryopses. Other seeds did not germinate even after gibberellins treatment. This variation in dormancy may promote a seed bank, increasing possibilities for persistence in time. Plasticity in germination responses to temperature and osmotic potential, as well as fast germination, might facilitate the invasion of buffel grass in arid and semiarid areas.

1. Introduction

Invasion of exotic plant species into native plant communities have been recognized as a serious ecological problem worldwide, affecting ecosystem function and threatening biological diversity (Ehrenfeld, 2010). Several studies have attempted to identify traits that make some species better invaders than others (Pysek and Richardson, 2007). Some features that may favor the invasiveness of exotic species are: high tolerance to stress conditions (Matzek, 2011), greater competitive ability in new habitats (Ren and Zhang, 2009), high rates of resource acquisition and growth (Baruch and Goldstein, 1999), greater ability to disperse to adjacent habitats and rapid germination under a wide range of environmental conditions (Bower et al., 2009). Therefore, ecophysiological studies of invaders at different phases of invasion, including their response to environmental stress, are important to understand invasion ecology (Williams and Baruch, 2000; Matzek, 2011).

In northern México and southwestern United States, buffel grass (*Cenchrus ciliaris*) is becoming one of the most serious invaders, threatening the conservation of desert scrub and thorn scrub vegetation (Franklin and Molina-Freaner, 2010). Buffel grass is an African native species that is drought-tolerant, resistant to heavy grazing and has fast growth, features that make this species valuable as a forage plant. For this reason, it was introduced into northwestern Mexico during the 1950s for cattle raising. Large-scale conversion of desert and thorn scrub to buffel grass pastures began in the 1970s and has continued with an almost exponential growth (Castellanos et al., 2002; Franklin et al., 2006). Thereafter, buffel grass has spread from pastures to disturbed habitats and into adjacent natural desert habitats (Olsson et al., 2012; Brenner and Kanda, 2013). Studies on the impact of buffel grass in ecosystems of NW Mexico have focused on the effect of conversion of natural vegetation to pasture for livestock grazing (Castellanos et al., 2002, 2010; Franklin et al., 2006). At the community and ecosystem levels, land conversion results in a significant decrease of plant species richness at local and regional scales, and important changes in primary productivity and vegetation structure (Franklin and Molina-Freaner, 2010). At the population level, land conversion produces significant changes in population structure and creates regeneration barriers for native species persisting on pastures (Morales-Romero and Molina-Freaner, 2008;

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Tinoco-Ojanguren et al., 2013). However, our knowledge about the ecophysiological features that might be involved in the invasion of desert areas by this species is quite limited (Marshall et al., 2012; Eits and Huxman, 2013).

Studies on caryopses dispersal, germination response to temperature, osmotic potential and caryopses longevity in soil, should be important to understand the capacity of this species to spread during the initial phase of invasion. The temperature and water availability of the surface of desert soils are subject to large diurnal and seasonal variation (Kigel, 1995) and the ability to germinate under such conditions may be important for the species' survival and invasion process. Because of its importance as a forage plant, ecophysiological studies on buffel grass germination have been more agronomically oriented, trying to improve its germination and establishment in specific areas (Jordan and Haferkamp, 1989; Sharif-Zadeh and Murdoch, 2001; Bhattarai et al., 2008). Although these studies are an important antecedent, very few studies have been conducted using caryopses derived from invasive populations. For the Sonoran Desert, Ward et al. (2006) found that invasive buffel grass has low water requirements for emergence, and argued that this feature might explain its success as an invader. The invasion of buffel grass into desert habitats also produces a high fuel load that supports more frequent and intense fires (Marshall et al., 2012). However, our knowledge on how buffel grass caryopses respond to water availability and the high temperatures reached during buffel fires is limited.

In this study, we use caryopses from an invasive population from a Sonoran desert scrub, to characterize the germination response to different environmental factors. We evaluated the effect of the following environmental factors on germination: light, temperature, osmotic potential, heat shock and experimental fires, exploring the hypothesis that seeds of invasive buffel have a rapid germination under a wide range of experimental conditions that facilitates survival in arid environments. We also tried to identify the caryopses dormancy by adding gibberellins and testing if the lemma and palea restrict the germination of physiologically dormant caryopses.

2. Materials and methods

2.1. Caryopses collection

For this study, caryopses of buffel grass which are covered with several layers derived from the flower (palea, lemma, glumes, and a soft burr-like structure), were collected in 2010 from plants invading hill slopes in Siete Cerros, a mountain located about 60 km west of Hermosillo, Sonora (28°51.32'N, 111°21.84'W, 101 m a.s.l.), an area with desert scrub vegetation. The site receives an annual rainfall of 168 mm, with 80% of the total during summer (Peacc BC), whereas soils are aridisoils. Caryopses produced in the summer were collected from at least 60 individuals at the beginning of October 2010.

2.2. General procedures

After collection, caryopses were air-dried and stored for one week in paper bags under laboratory conditions at 23 °C–25 °C and 30%–50% relative humidity. For the different treatments, caryopses were sown in Petri dishes on 1% agar, wrapped in plastic bags to avoid desiccation, and germinated in growth chambers (Lab-Line 455 Instrument, Inc.; Melrose Park, Illinois), provided 20 W fluorescent cool light (Sylvania, USA) and a photoperiod of 12/12 h light/darkness. All the germination treatments were done in Petri dishes (5 replicas per treatment) with 50 seeds per dish, unless otherwise indicated. Germination (protrusion of radicle) was registered daily, unless otherwise stated.

2.3. Light and temperature effects

Naked caryopses (caryopses − glumes, lemma and palea) were germinated at different constant temperatures and under white light or darkness conditions to determine light and temperature requirements; darkness was obtained by wrapping the Petri dishes in two layers of aluminum foil (Vázquez-Yanes and Orozco-Segovia, 1990). Constant temperature treatments were: 5 °C, 10 °C, 20 °C, 25 °C, 30 °C, 35 °C and 40 °C. The experiment used 2 light and 7 temperature treatments. The number of germinating caryopses under light was counted every day until germination was completed, whereas the dark treatments were counted under green safe light every other day to minimize accidental exposure to light.

2.4. Effect of gibberellins, hydro-priming and seed cover

Germination was evaluated in response to gibberellic acid (GA_3) at 1000 ppm, hydro-priming and seed covering. We evaluated the effect of seed covers contrasting the germination of covered caryopses (caryopses + glumes, lemma and palea) with the germination of naked caryopses (caryopses − glumes, lemma and palea). For hydro-priming, seeds were immersed in tap water for 12 h; afterwards, they were allowed to dry for a period of 12 h on paper towels in a dark room (at 23 °C–25 °C and 20%–50% of relative humidity, respectively). The procedure was repeated 3 times (three hydration–dehydration cycles) before they were incubated at 25 °C. Control was covered caryopses without any treatment.

2.5. Osmotic potential effect

Naked caryopses were germinated in solutions with different osmotic potentials: 0, −0.2, −0.4, −0.6, −0.8, −1.0, −1.2, −1.4, −1.6, −1.8 MPa. Solutions were prepared with polyethylene glycol (PEG 8000, Baker, USA); the osmotic potential of PEG solutions was calculated using the program SPMM (Michel and Radcliff, 1995). The caryopses were sown in Petri dishes on a small organza mesh circle to allow seeds to be in contact with the solution and avoid oxygen deprivation. Each Petri dish contained 5 mL of the osmotic solution and was incubated at 25 °C and a photoperiod of 12/12 h light/darkness.

2.6. Heat shock treatments

Naked and covered caryopses were exposed to high temperature treatments: 60 °C, 80 °C, 100 °C and 120 °C (dry heat shock) for two periods (1 or 60 min). The experimental design was: 2 seed coverage conditions × 8 heat shock treatments, and the control (covered caryopses incubated at 25 °C). For the treatments, caryopses were placed in an aluminum foil and covered with preheated dry sand for 1 or 60 min; afterwards, the treated caryopses were allowed to cool down to ≈25 °C, and then were sowed in Petri dishes for germination at 25 °C and a photoperiod of 12/12 h light/darkness.

2.7. Experimental fires

Experimental fires were conducted in aluminum trays (size: 43 cm long × 33 cm wide × 10 cm depth) filled with a layer of 7 cm of sand. Four replicates of 25 covered caryopses were enclosed in aluminum foil containers at the surface, 1 cm and 2 cm below the surface. Trays were covered with dry tissue of buffel grass simulating the standing biomass of invading populations (≈2 kg of dry biomass/m^2). Three K-type thermocouples connected to data loggers HOBO U-12014 (HOBO U12-013 Onset Computer Corporation, Pocasset, MA) were placed at the surface, 1 and 2 cm below the surface to document temperature during controlled fires. Experimental fires were replicated four times documenting the time until consumption. After the fire, caryopses were sowed in Petri dishes and germinated at 25 °C and at a photoperiod of 12/12 h light/darkness, to explore the impact of fire on buffel grass caryopses at different depths.