Fecundity and germination of the invasive aquatic plant, Senegal tea (*Gymnocoronis spilanthoides* (D.Don) DC.)

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Summary

Senegal tea, *Gymnocoronis spilanthoides* (D. Don) DC., (Asteraceae) is an invasive perennial herb of aquatic and wetland habitats. In this study we investigated fecundity (per cent florets setting seed per inflorescence) of two populations in south-eastern Queensland (SEQ) and germination responses to light and temperature. Proportions of capitula that had set seed varied significantly between Ithaca Creek and Strathpine populations (Ithaca = 6.0%, Strathpine = 19.0%) (P <0.001) and both values were greater than previous unpublished estimates (mean number of seeds per capitula; Strathpine = 11.9 ± 1.3; Ithaca = 4.0 ± 0.96). Seeds largely failed to germinate under continuous darkness. Under a 12 h light:12 h dark regime, germination, occurred between five and 20 days after initiating the experiment. Mean germination reached a maximum of 83% under an alternating 12 h at 20°C and 12 h at 30°C regime and was significantly greater than under the other temperature treatments tested (P <0.05). Germination was still relatively high (63%) at lower (10/20°C) temperatures, suggesting that Senegal tea is capable of germinating over most seasons in SEQ. Results suggest that production of germinable seeds is high at the Strathpine infestation and that a seed bank is likely to exist at this site. The light requirement for germination suggests that Senegal tea recruitment would be favoured by soil or canopy disturbance that exposes seeds to light. We suggest that future management would be aided by an understanding of seed bank persistence and the relative importance of clonal and sexual reproduction in the population dynamics of this species.

Key words: aquatic weed, *Gymnocoronis spilanthoides*, Senegal tea, germination, seed set, sexual reproduction, wetland.

Introduction

Senegal tea, *Gymnocoronis spilanthoides* (D. Don) DC., is a semi-aquatic, perennial herb belonging to the Asteraceae (Parsons and Cuthbertson 2001). It is found growing in wet areas, along stream edges and extending from stream banks to form scrambling mats of floating stems 1–1.5 m in height. Senegal tea is native to the tropical and sub-tropical regions of South America between Mexico and Argentina (Parsons and Cuthbertson 2001).

The species was initially introduced to Australia as an aquarium plant in the 1970s (Parsons and Cuthbertson 2001). It has spread to natural ecosystems via dumping of unwanted aquarium material and the deliberate cultivation of plants in creeks and rivers. Once naturalized in creek, drainage and wetland situations, it spreads rapidly, forming dense mats (Sainty and Jacobs 1994), which can quickly cover waterways or wetlands and block water flows, leading to flooding problems. It has the ability to exclude submerged native flora species. The highly invasive nature of Senegal tea has led to it being declared a Class 1 Weed in Queensland and a declared weed in all states and territories, except the Northern Territory and Victoria (Gunasekera *et al*. 2002); it is also listed on the Northern Australia Quarantine Strategy Alert List and the national Weed Alert List – Environmental Weeds. Naturalized populations of this species in Australia have been found in several locations in coastal New South Wales, south-eastern Queensland, Tasmania and at three sites in Victoria. Cultivated plants have also been found and destroyed in south-western Western Australia (DEH 2003). The species is also problematic in New Zealand, where it was first found to have naturalized in 1991, and is now a target of an eradication campaign (NZ Regional Pest Management Strategy 2002).

Senegal tea is a bushy, often sprawling herb. Flowers are produced in clusters of terminal inflorescences and comprise white florets, subtended by a few green involucral bracts (Parsons and Cuthbertson 2001). The species reproduces vegetatively from stem fragments that root at the nodes, and by seed. Seeds are small, light brown achenes, 0.8–1.2 mm in length and 0.5 mm in diameter and weigh approximately 0.20 mg (air dried) (Vivian-Smith, unpublished data). They do not bear a pappus. Dispersal is thought to be primarily by water currents, as well as mud transported by animals, machinery and humans. Information describing the reproductive biology of the species is scant, in some cases inaccurate (e.g. seed size information), and largely anecdotal in nature. We were unable to find any published reports of seed set or germination requirements for the species.

This study was conducted to better understand sexual reproduction (fecundity and germination) of Senegal tea by determining: 1) levels of seed production in inflorescences collected at two infestation sites in south-eastern Queensland, and 2) germination responses to light and temperature.

Methods

Site description

Mature inflorescences were collected from two populations at Strathpine, Pine Rivers Shire (27°18′S, 152°59′E) on 11 and 18 January, 2005; and Ithaca Creek, Bardon, Brisbane (27°27′S 152°58′E) on 19 January and 14 February, 2005. Both sites are disturbed urban creeks surrounded by suburban development that have been the target of Senegal tea eradication efforts in recent years. The Ithaca Creek population is considerably smaller (approximately 1 ha) than the Strathpine population (approximately 20 ha). Seeds were collected from plants that appeared healthy and had not been sprayed with herbicide during previous weeks. Initial infestations are thought to have arisen from the deliberate cultivation of Senegal tea for sale in the aquarium trade and subsequent expansion (T. Anderson, personal communication).

Seed production

Two mature inflorescences (capitula) per plant were selected from separate flowering stems collected from 19 plants at Strathpine and 14 plants at Ithaca. Each inflorescence was dissected using a dissecting microscope and the number of individual florets and mature seeds were recorded. The percentage florets that had produced seed was then determined for each capitulum.

Germination

Mature seeds from the Strathpine site were used in the germination study. Germination responses were measured using a factorial experiment (n = 5 replicates, each containing 20 seeds), consisting of light (12 h photoperiod) and continuous dark conditions over three temperature treatments (12 h alternating thermoperiods of 10/20°C, 15/25°C and 20/30°C). These thermoperiods were chosen to reflect the range of diurnal temperature conditions found in SEQ during most

seasons. Dark treatments involved wrapping Petri dishes in two layers of aluminium foil. The experiment was set up in growth cabinets, on 27 January 2005, with 20 seeds placed upon filter paper (Advantec 2) in each Petri dish, and moistened with 4 mL of tap water. All Petri dishes were placed in clear, sealed plastic bags to create similar conditions of humidity for both light and dark (wrapped) Petri dishes. Germination of seeds was recorded every 2–3 days for a period of six weeks. Seedlings were counted as germinated once their cotyledons had emerged; they were then removed. Dark treatments were inspected after 33 days to prevent unnecessary exposure to light.

Data analysis

Percentage seed set per inflorescence for the two populations was compared using the t-test following angular transformation to normalize the data. Total seed numbers per inflorescence at each population were compared using the Mann-Whitney U test. Final germination responses to temperature were analysed using ANOVA, with dark treatment data excluded from the analysis as only a single germination event was recorded under these conditions. Germination data were tested for normality using the Kolmogorov Smirnov test, with residuals examined for heteroscedasticity. Differences between individual treatments were tested for using the Bonferroni test adjusted for multiple comparisons.

Results

Seed production

A mean 19.0% of florets set seed at the Strathpine population, with a total of 452 seeds recorded from the 38 inflorescences examined. At the Ithaca population, the percentage of seed set was significantly lower ($t = 5.33$, $P < 0.001$) with a mean of 6.0% and a total of 121 seeds recorded from the 28 inflorescences examined. Mean seed production per inflorescence was greater at the Strathpine population, compared to the Ithaca population (Mann-Whitney U test statistic = 203.0, $P < 0.001$; mean ± SE: Strathpine = 11.9 ± 1.3, Ithaca = 4.0 ± 0.96). For both populations, considerable variability in seed set existed, with rates ranging from 1.3–51.3% at Strathpine and from 0–26.7% at Ithaca (Figure 1).

Germination

Germination was first recorded five days after initiating the experiment, and continued for a further 15 days. Germination was completely restricted to light treatments (only one seed germinated under dark conditions), with mean germination rates ranging from 63% to 83% depending on temperature treatment (Figure 2). There was a significant effect of temperature on germination (ANOVA $F_{2,12} = 6.195$, $P = 0.014$). Under the warmest treatment (20/30°C), germination was both more rapid (Figure 2) and significantly greater than the other treatments (Bonferroni test, 10/20°C vs 20/30°C, $P = 0.026$; 15/25°C vs 20/30°C, $P = 0.035$).

Discussion

Rates of seed set were significant for inflorescences collected at both sites and high frequencies of flowering plants were present at each site, with rough visual estimates of inflorescence densities at the time of sampling varying between 0–100 inflorescences m^{-2} at Strathpine and 0–10 inflorescences m^{-2} at Ithaca (G. Vivian-Smith personal observation). This suggests that although seed set may be highly variable between inflorescences and populations, it is of a magnitude that could well influence population dynamics at both sites. Therefore the presence of a seed bank and potential dispersal via seed should be considered when developing or refining eradication strategies.

Our fecundity results contrast with earlier unpublished information from the Ithaca population that indicated <1% of florets set seed (D. Panetta personal communication). A number of possible explanations exist to explain the discrepancy reported. First, considerable inter-annual, seasonal or environmental variation in seed set may exist for populations of Senegal tea, with conditions during the Summer of 2005 leading to the somewhat higher rates of seed set (6%) than during previous observations at the Ithaca site. Environmental variables influencing reproductive success, such as water, disturbance and nutrient regimes, may have also contributed to the differences observed between the two populations. Second, it is possible the considerably greater fecundity at the Strathpine population may be in part due to its larger size (20 ha). Reproductive output of plants can be strongly influenced by the patch size, a phenomenon recognized by invasion biologists (Lewis and Karieva 1993). In some cases greater reproductive success of large populations has been shown to be due to a superior

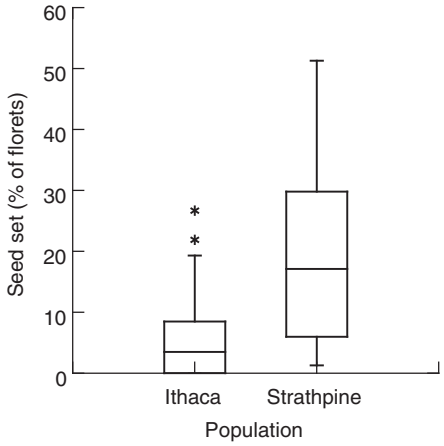

Figure 1. Box and whisker plots of median seed set values (% of florets with seed) for Ithaca (n = 28 inflorescences) and Strathpine populations (n = 38 inflorescences) of *Gymnocoronis spilanthoides*.

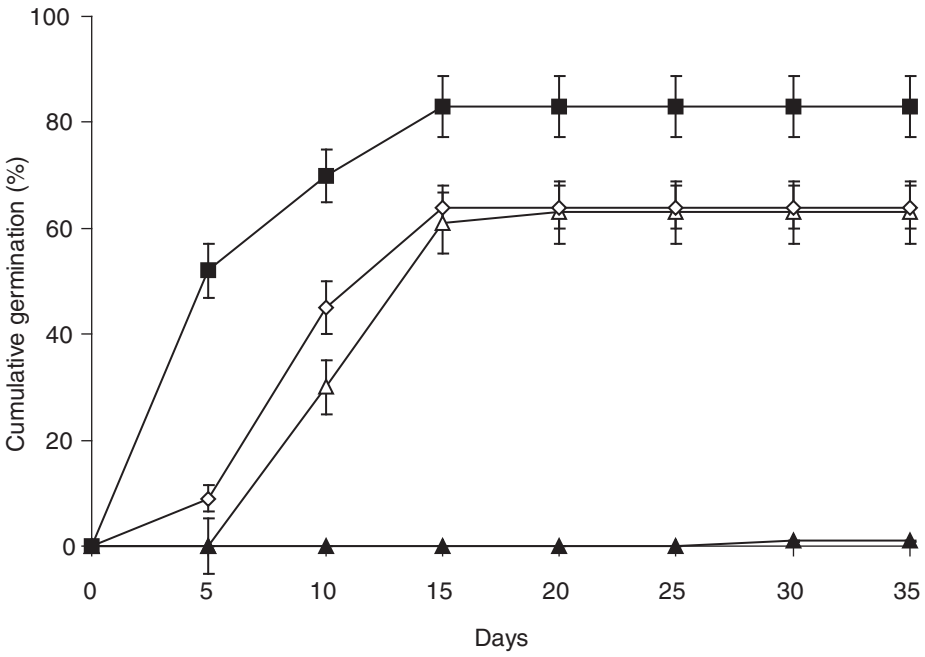

Figure 2. Mean cumulative germination (%) (± standard error) of *Gymnocoronis spilanthoides* seeds under different light and temperature treatments (filled squares = light, 20/30°C; open diamonds = light, 15/25°C; open triangles = light, 10/20°C; filled triangles = continuous darkness for all temperature treatments) over 35 days.

ability to suppress the growth of competitors (Cappucino 2004). In other cases low reproductive success of small populations has been attributed to inbreeding (Menges 1991) or pollination limitation (Groom 1998).

In our study, germinability of seeds was high (63–83%) across the range of temperatures tested, provided that there was light available. The virtual absence of germination under continuous darkness suggests that management activities resulting in disturbance to the soil or canopy that could expose Senegal tea seeds to light could stimulate germination and seedling emergence. This indicates that disturbance to the soil surface, by mechanical removal or non-selective herbicide application, leading to the exposure of bare soil, requires careful attention to follow-up control of any emerging seedlings.

Future weed management or eradication efforts targeting Senegal tea would benefit from a greater understanding of the reproductive ecology of this species, in particular, seed bank persistence, seed dormancy, and dispersal biology. Other aspects, such as pollination biology (e.g. whether pollination is via specialist or generalist pollinators or selfing) and population dynamics (e.g. the relative importance of clonal and sexual reproduction in population maintenance) of this species would also aid management efforts.

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