Seed germination may explain differences in invasiveness and prevalence: a case study using cat's claw creeper (*Dolichandra unguis-cati*)

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Summary High germination rates and rapid germination behaviour in response to different environmental cues are traits that may be associated with invasiveness. Cat's claw creeper (*Dolichandra unguis-cati* (L.) Lohmann (syn. *Macfadyena unguis-cati* (L.) Gentry), a Weed of National Significance has two forms, a long-pod (LP) form and a short-pod (SP) from. The LP form occurs in only a few localities in south-east Queensland while the SP form is widely distributed in Queensland (Qld) and New South Wales (NSW). The aims of this investigation were: to evaluate whether there are significant differences in germination traits between the two forms of cat's claw creeper; and if there are any significant differences, to find out whether the differences in germination can be related to prevalence and invasiveness levels for the two forms. Long pod and short pod seeds collected in 2009, 2010, 2011, 2012 and 2013 from various localities in Qld were germinated in growth chambers in early 2013. The growth chambers were set to 10/20°C, 15/25°C and 20/30°C temperature cycles. Seeds from 2009−2012 of either form did not germinate, while for the fresh seeds (2013), SP exhibited significantly higher total germination percentage and rates than LP. Assuming that the two forms were introduced in Australia at around the same period, these results could explain why SP is widely distributed (and therefore more invasive) in Qld and NSW while LP is only confined to a few localities in south-east Qld.

Keywords Invasive, non-specific, germination rate, germination percentage, temperature.

INTRODUCTION

Traits such as high reproductive capacity are normally correlated with invasiveness (Baker 1965). Seed germination is a very crucial developmental stage in the establishment of species (El-Keblawy and Al-Rawai 2005, Li *et al.* 2008) as it governs the ecological success and distribution patterns of plants. Time of germination, rate of germination and total germination percentage are measurable characteristics that can enable ecologists to predict the level of success and recruitment of a species in a new environment (Ranal and Santana 2006). High versatility in germination characteristics can be selected for because the evolutionary success of any organism is directly proportional to the number of individuals in existence and the range of environmental conditions under which they can survive and proliferate in (Baker 1974).

Cat's claw creeper is a Weed of National Significance (Dhileepan *et al.* 2013). It is native to the Greater and Lesser Antilles, Mexico, South and Central America to Argentina, including Trinidad and Tobago (Gentry 1983). Cat's claw creeper was introduced to Australia as an ornamental plant and naturalised in Queensland by the 1950s (Downey and Turnbull 2007). In south-east Qld, two forms of cat's claw creeper have been found to occur (Shortus and Dhileepan 2011). These forms have been informally referred to as long pod (LP) and short pod (SP) based on their average fruit length at maturity. Herbarium records from the Queensland Herbarium (BRI) indicate that LP specimens were initially collected in Qld as early as 1972. In Australia, SP is the most prevalent form of cat's claw creeper occurring widely in Qld and NSW while LP only occurs in a few isolated localities in south-east Qld. Since LP occurs only in a few sites of south-east Qld, it does not seem to be as invasive as SP. The cause for the apparent difference in prevalence between the two forms is not known. This study was carried out to compare germination behaviour of LP and SP seeds subjected to different environmental cues. The occurrence of two forms of cat's claw creeper provides an ideal system for such a comparative study.

MATERIALS AND METHODS

Seeds of LP and SP were collected from different sites in 2009, 2010, 2011, 2012 and 2013. Seeds of the SP were collected at maturity from the following infestation sites in March 2013: South Bank (27°55'S, 153°01'E), Ipswich Forest Reserve (27°32'S, 152°42' E), Chelmer (27°47' S, 152°58' E), Bardon (27°30' S, 152°60' E), Boonah (27°60' S, 152°41' E) and

Carindale (27°30'S 152°41'E). Seeds of the LP were collected at maturity from Bardon (27°30'S, 152°60'E) and Carindale (27°30'S 152°41'E) in September 2013. Another LP site, Oxley (27°60'S, 152°59'E) did not have fruits in 2013. All the sites mentioned above are in the greater Brisbane area, south–east Queensland. Seeds were stored at room temperature in paper envelopes in containers with silica gel to facilitate drying. Seeds were physically screened so that those that were destroyed by insects or did not have content were discarded and not used in the experiments.

Germination experiments were conducted in growth chambers (model ADAPTIS A1000) set to cool (10/20°C), intermediate (15/25°C) and warmer (20/30°C) temperature regimes for 12 hours at each temperature. These temperature regimes followed the conditions applied by Vivian-Smith and Panetta (2004). Fifteen (15) replicates of 20 seeds each were used for each cat's claw creeper form (LP and SP) in each treatment. Seeds were considered to have germinated with the emergence of the radicle.

Total germination percentage for each form at each temperature regime was calculated from total number of germinated seed divided by the total number of seeds. The rate of germination was estimated using a modified Timson's (1965) Index of germination velocity: Germination index = $(\sum G)/t$, where G is seed germination percentage at 1 week intervals and t is the total germination period (Sun *et al.* 2012). From the cumulative germination % curves, time to start of germination (T_1) and time to 50% germination (T_{50}) was extracted.

Data collected were checked and found to be normally distributed. Data were analysed using Analysis of Variance (ANOVA) on SPSS Statistics Version 21 with cat's claw creeper forms (LP vs. SP) as main factors and temperature as a random factor. All statistical tests were carried out at $P < 0.05$. One-way ANOVA was used to compare means of total percentage germination for each form, and a two-way ANOVA was used to determine the interaction between temperature and form and their effects on the germination parameters.

RESULTS

Seeds of LP and SP from 2009 to 2012 did not germinate. SP seeds collected in 2013 required significantly less time to start of germination than the 2013 long pod (LP) seeds at all the temperature cycles investigated (Figure 1). At all the temperature regimes except 10/20°C, SP required three to 21 days (mean performance = 11.7 days) while it took LP an average of 28 days to start of germination (T_1). T_{50} is significantly lower for SP seed germination (22–34 days; averaging 28.6 days) when compared to LP seed germination (30–>84 days; averaging approximately 67.7 days) at the same temperature cycles.

Seeds of the SP form depicted significantly higher final germination percentages than that of LP at all the temperature regimes. Long pod did not germinate at the cool temperature cycle of 10/20°C. At 15/25 °C, a one-way ANOVA indicates that the final germination percentage of LP seeds was significantly lower than the final germination % of the SP form ($F_{1,28} = 13.486$, $P = 0.022$). A one-way ANOVA did not show any significant difference on final germination percentage at warmer temperatures (20/30°C) between LP and SP forms ($F_{1, 38} = 0.674$, $P = 0.757$).

A two-way ANOVA shows that temperature had a significant effect on final germination percentage ($F = 16.175$, $P < 0.005$). A post hoc Tukey HSD analysis indicates that the final germination percentage of SP seeds at 10/20°C is not statistically different from SP germination percentage at 15/25°C and 20/30°C ($P = 0.274$ and $P = 0.528$ respectively). A post hoc HSD test also shows that at 10/20°C, final germination percentage for SP seeds is not statistically different from final germination percentage for LP seeds at 15/25°C and 20/30°C ($P = 0.992$ and $P = 0.966$ respectively).

DISCUSSION

The results clearly indicate that there are significant differences between LP and SP forms of cat's claw creeper in relation to temperature regimes. Rapid germination response, higher germination percentages and rates recorded for SP than LP do lend support to the observations that SP is more prevalent than LP in Queensland (Shortus and Dhileepan 2011). Short pod evidently exhibits high germination plasticity and high germination percentages at all temperatures (robustness) than LP (Figure 1). Exotic invasive species have been found to exhibit high germination plasticity and robustness than native plant species (Wainwright and Cleland 2013). The results of this study suggest that germination requirements of SP are non-specific while LP germinates optimally only under warmer temperatures (20/30°C). This implies that both forms have the potential to invade warm climates in the long term while SP would colonise both cool and warm climates. This may explain the fact that SP form is the one that is reported in the entire introduced range (Prentis *et al.* 2009). In the case of Australia, this trend may also explain why SP is more prevalent in Queensland and New South Wales when compared with LP which only occurs in a few localized sites in south-east Queensland (Shortus and Dhileepan 2011).

This study also found that both forms of cat's claw creeper have very low longevity of seeds since

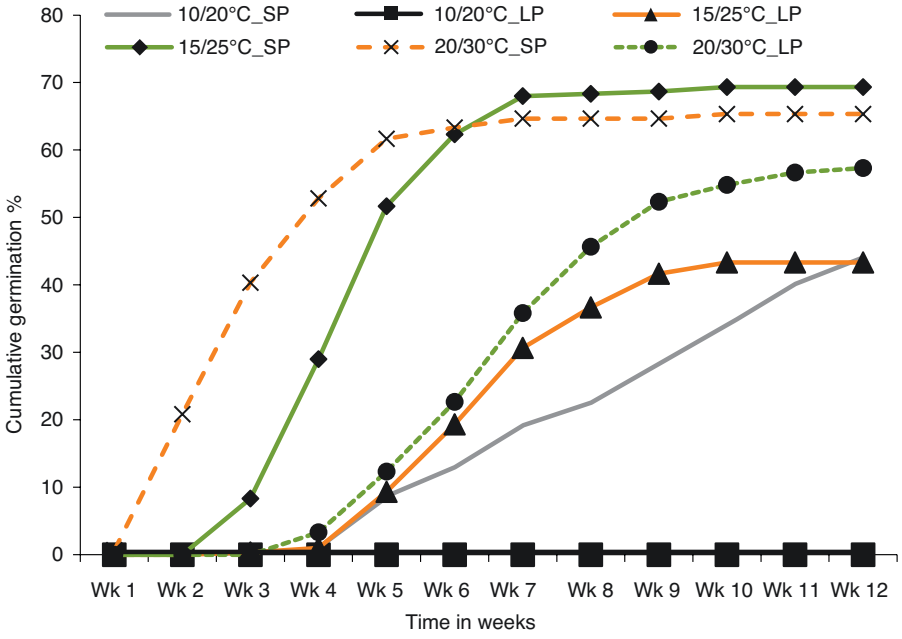

Figure 1. Effects of temperature on the germination process of two forms of cat's claw creeper. LP = long pod, SP = short pod.

cohorts of seeds collected from 2009−2012 did not germinate at all the temperature regimes. Short pod was previously reported to have low seed longevity, usually less than 12% and 1% at 12 months for soil-surface (<1 cm depth) and 5 cm depth buried seeds respectively (Vivian-Smith and Panetta 2004).

This study demonstrates that SP germination is rapid with higher rates than LP under a wide range of temperature conditions. Assuming that LP and SP were introduced to Australia around the same time as suggested by BRI records, this rapid germination response may confer a fitness advantage on the SP form in terms of the long term seedling establishment and weed spread (Tweddle *et al.* 2003). Although BRI records indicate about 20 year difference between collection of the two forms in Queensland, we suspect that SP became more prominent earlier than LP owing to the rapid and high germination tendencies. Additionally, most of the literature on cat's claw creeper prior to Shortus and Dhileepan (2011) referred to SP only (e.g. Downey and Turnbull 2007).

The rapid germination response of SP is typical of invasive species (Wainwright and Cleland 2013). So germination behaviour may be useful in explaining the differences that are observed in invasiveness and prevalence of related taxa. This should be taken into account when developing management and control strategies for the two forms of cat's claw creeper. Further germination of the two forms of cat's claw creeper seeds under other temperature regimes may shed more light into their performance.

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