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# Invasion strategies of the white ginger lily *Hedychium coronarium* J. König (Zingiberaceae) under different competitive and environmental conditions

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ABSTRACT

The success of an invasive plant depends on its competitive advantage in the new community. This advantage can be attributed to high phenotypic plasticity, which either allows the plant to develop under a broad variety of environmental conditions, or grants it with a higher fitness compared to native species. In the present study, we assessed the development of the invasive white ginger lily, *Hedychium coronarium*, and plant community through removal experiments, under different conditions of soil moisture in riparian areas. We observed that *H. coronarium* exhibited different invasion strategies according to soil moisture, plant community species life form, and intensity of intra- and inter-specific competition. In areas with high soil moisture and high competitive pressure, *H. coronarium* invests in height growth rather than new ramets. In areas with drier soils and lower competitive pressure, *H. coronarium* expands its population through new ramets. Our results suggest *H. coronarium* has a negative influence on the recruitment of plants from the plant community, with consequences to the biodiversity of invaded areas.

## 1. Introduction

Biological invasions can represent a threat to the ecological balance and conservation of native plant communities (Simberloff, 2005) because they can suppress native species (Pyšek et al., 2012). A species is considered invasive when it acquires a competitive advantage because natural obstacles to its proliferation disappear and this allows fast dispersal and colonization of new areas, where it can become dominant (Valery et al., 2008). This competitive advantage is frequently related to high phenotypic plasticity, which allows the invasive species to grow and reproduce under a broad variety of environmental conditions (Rejmánek et al., 2005). However, morphological or physiological plasticity only contributes to invasion success if it allows the invasive plant to develop under a broad range of environmental conditions or it provides a competitive advantage in favorable environments (Richards et al., 2006). Hence, to understand the success of invasive species, a knowledge of the role of morphological and phenotypic adaptations in the face of biotic (Burns and Winn, 2006) and abiotic interactions (Williams et al., 2008) is necessary.

Height is an essential component of ecological strategy for plants as individuals compete for light, favoring taller plants over shorter plants (Westoby et al., 2002). This competitive advantage depends on relative rather than absolute height (Falster and Westoby, 2003). Exotic species that grew slightly taller than those already present would have an advantage in light capture, presenting potential for invasion (Kollmann and Banuelos, 2004). Many herbaceous plants enhance elongation of stems, when the stand density or the leaf area index is high, as a shade avoidance strategy (Nishimura et al., 2010). However, any resources allocated to one function are unavailable for other functions, requiring investment trade-offs (Klinkhamer et al., 1990). Height investment incurs disadvantages in the transport of water (Midgley, 2003), increased risk of breakage (Williams and Douglas, 1995), and decreases of leaf investment (Givnish, 1982) and reproduction. Thus, the relationship between the accumulation of

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biomass and its allocation to structures and functions is the core of plant life-history strategies (Moles et al., 2009).

Riparian ecosystems have been identified as environments with a high risk of plant invasion (Richardson et al., 2007), partly because they are influenced by substantial human disturbance, from local to global scales. Such disturbance can result from dams and flow regulation (Shafroth et al., 2002), land use (Patten, 1998), deforestation (Iwata et al., 2003), trampling and extensive livestock farming (Meeson et al., 2002), water use for consumption (An et al., 2003), and leisure activities (Washitani, 2001), all of which can alter the physical and chemical characteristics of water. These disturbances, together with cyclic floods (Naiman and Décamps, 1997), which enhance rapid propagule dispersal through lotic environments (Planty-Tabacchi et al., 1996), can lead to extensive changes in wetland extension and its floristic composition, making these riparian environments highly susceptible to biological invasion (Richardson et al., 2007). Invasive species not only respond to environmental conditions, but can also modify the invaded sites (Wardle et al., 1998). Thus, knowledge of the intrinsic functional characteristics of an exotic invasive plant species provides a better understanding of its impact on the ecosystem, via changes in shading, soil temperature, and nutrient cycling (Westoby and Wright, 2006).

*Hedychium coronarium* is a perennial, rhizomatous, herbaceous macrophyte that occurs in wet environments and can reach up to two meters in height (Macedo, 1997). The species is self-incompatible, presenting low rates of fruit set and the flowering follows an annual pattern, showing asynchrony in the population level (Souza and Correia, 2007). It is native to tropical Asia and is commonly used as an ornamental plant due to its white and fragrant flowers (Kissmann and Groth, 1991). Because of its fast growth and rapid dispersal, *H. coronarium* is considered a weed in many tropical and subtropical areas worldwide (Kissmann, 1997; Villaseñor and Espinosa-Garcia, 2004; Vargas, 2009; Foxcroft and Richardson, 2003; Govaerts, 2015; PIER—Pacific Island Ecosystems at Risk, 2015). It invades wetlands, marshes, lake banks, streams, and drainage channels where it can form dense populations (Lorenzi, 1991) and replace native vegetation (Lorenzi and Souza, 2001). *H. coronarium* is difficult to control because of its extremely efficient vegetative reproduction through rhizome fragments (Kissmann and Groth, 1991).

Testing the response of native plants to invasion experimentally, with a focus on the first stages of its development, can provide information on both the degree of influence of the invasive plant on the community, and how the ecosystem responds to a reduction or removal of the invasion (Cushman and Gaffney, 2010). Understanding the mechanisms leading to an invasive species success is, therefore, key to comprehend and mitigate their impacts (Byers et al., 2002). In this study, we used a removal experiment to assess development in height and numbers of new individuals of the invasive white ginger lily *H. coronarium* J. König (Zingiberaceae) and other plants within the plant community in riparian areas under different competitive and environmental conditions. Our hypothesis was there would exist a trade-off between investments in vegetative (plant height) and clonal reproductive growth (new ramets) by *H. coronarium* in response to (1) different soil moisture levels and (2) differing levels of plant competition produced by removing different groups of species. We expected greater invasive success in soils with higher moisture levels, expressed by the number of *H. coronarium* recruits. Regarding removal treatments, with higher competition (i.e., with fewer plants removed), we expected taller *H. coronarium* recruits and lower recruitment.

**Table 1**
Species and life-forms recorded within the species-removal experiment under two moisture regimes (dry and wet moisture treatments) in the four months between September to December 2013. Key to: H = herbaceous, S = shrubs, T = trees and E = exotic.

| Family | Dry sub-blocks | | | Wet sub-blocks | |
|---|---|---|---|---|---|
| | Species | Life form | Family | Species | Life form |
| Araceae | *Philodendron* sp. | H | Asteraceae | *Ageratum conyzoides* L. | H |
| | *Monstera deliciosa* Liebm.$^{E}$ | S | | | |
| Asteraceae | *Chromolaena* sp. | S | | *Bacharis* sp. | S |
| | *Eupatorium* sp. | S | | *Campuloclinium macrocephalum* (Less.) DC. | H |
| | *Tithonia diversifolia* (Hemsl.) A. Gray $^{E}$ | S | | *Mikania cordifolia* (Linnaeus f.) | H |
| Bignoniaceae | *Handroanthus heptaphyllus* (Vell.) Mattos | T | | *Chromolaena* sp. | S |
| Clusiaceae | *Clusia criuva* Cambess. | T | Balsaminaceae | *Impatiens walleriana* Hook. f. $^{E}$ | H |
| | *Clusia* sp. | T | Convolvulaceae | *Merremia* sp. | H |
| Convolvulaceae | *Merremia* sp. | H | Cyperaceae | *Cyperus* sp. | H |
| Dennstaedtiaceae | *Pteridium aquilinum* (L.) Kuhn in Kersten | H | | *Cyperus surinamensis* Rottb. | H |
| Euphorbiaceae | *Sapium glandulatum* (Vell.) Pax | T | | *Eleocharis acutangula* (Roxb.) Schult | H |
| Fabaceae | *Crotalaria incana* L. | S | | *Eleocharis interstincta* (Vahl) Roem. & Schult. | H |
| Melastomataceae | *Miconia chamissois* Naud. | T | | *Eleocharis sellowiana* Kunth. | H |
| | *Tibouchina granulosa* (Desr.) Cogn. | S | Dennstaedtiaceae | *Pteridium aquilinum* (L.) Kuhn in Kersten | H |
| | *Tibouchina* sp.1 | S | Euphorbiaceae | *Sapium gladulatum* (Vell.) Pax | T |
| | *Tibouchina* sp.2 | S | Fabaceae | *Crotalaria incana* L. | S |
| Meliaceae | *Guarea guidonia* (L.) Sleumer | T | Lamiaceae | *Hyptis atrorubens* J.A.Schmidt | H |
| Phyllanthaceae | *Phyllanthus tenellus* Roxb. | H | Onagraceae | *Ludwigia leptocarpa* (Nutt.) H. Hara | H |
| Poaceae | *Panicum* sp. | H | Poaceae | *Urochloa subquadripara* (Trin.) R.D.Webster $^{E}$ | H |
| | *Cenchrus purpureus* (Schumach.) Morrone $^{E}$ | H | Pontederiaceae | *Eichhornia azurea* (Swartz) Kunth | H |
| | *Urochloa decumbens* (Stapf) R.D.Webster $^{E}$ | H | Primulaceae | *Rapanea gardneriana* (A. DC.) Mez. | T |
| Rubiaceae | *Spermacoce* sp. | S | Salviniaceae | *Salvinia auriculata* Aubl. | H |
| | Indet. 4 | H | Typhaceae | *Typha domingensis* (Pers.) Steud. | H |
| | | | Xyridaceae | *Xyris* sp. | H |
| | | | | Indet 1 | T |
| | | | | Indet 2 | H |
| | | | | Indet 3 | T |
| | | | | Indet 4 | H |