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Galerucella birmanica (Coleoptera: Chrysomelidae), a promising potential biological control agent of water chestnut, *Trapa natans*

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Abstract

Water chestnut, *Trapa natans*, has become a major invasive plant in shallow water bodies in the northeastern United States. The failure of chemical and mechanical means to provide long-term and economically sustainable suppression of the species resulted in interest in the development of biological control. Field surveys in Asia and Europe identified a number of potential biological control agents in the native range of *T. natans*. The most promising species appeared to be the leaf beetle *Galerucella birmanica*, which is considered a pest of farmed *T. natans* in China. However, initial attempts to develop biological control faltered when field observations in China suggested that *G. birmanica* may not be host specific. Of particular concern was attack on water shield, *Brasenia schreberi*, a species native to China and North America. We conducted a number of laboratory and field investigations in China to assess preference and performance of *G. birmanica* on *T. natans* and *B. schreberi*. Initial no-choice experiments using 19 different plant species in 13 different families demonstrated that *G. birmanica* oviposited and was able to complete development only on *Trapa* spp. and *B. schreberi*. In larval no-choice tests *G. birmanica* was able to complete development on *B. schreberi*, however, larvae showed a 20% increase in mortality and longer development time compared to larvae developing on *T. natans*. In laboratory and field choice tests adults strongly preferred *T. natans* and in the field only occasionally laid eggs on *B. schreberi*. In addition, adults emerging from larvae reared on *B. schreberi* were less fit with reduced feeding and a declining oviposition rate. Their strong preference for *T. natans* was maintained in the field, even when *T. natans* was completely defoliated and adults were forced to migrate. We found only occasional "spill-over" of beetles onto *B. schreberi* and our data indicate that *G. birmanica* is a more promising biological control agent of *T. natans* than previously thought, although additional host specificity tests with many more North American plant species need to be completed.

Keywords: *Galerucella birmanica*; Water chestnut; *Trapa natans*; Water shield; *Brasenia schreberi*; Biological weed control; Host specificity

1. Introduction

Trapa natans L. (Lythraceae), water chestnut, is a floating herb of Asian origin. It was first observed in North America in Concord, Massachusetts in the 1870s (Davenport, 1879) and shortly thereafter in Sanders Lake, Schenectady, NY, in 1884 (Wibbe, 1886). After its initial introduction as an ornamental, *T. natans* spread rapidly throughout the northeastern US and as far south as the Chesapeake Bay, and distribution and climate data from the native range suggest the species has potential to spread into subtropical North America (Crow and Hellquist, 2000; Pemberton, 2002). Invasion of *T. natans* into shallow water bodies replaces native macrophytes, alters associated foodwebs (Feldman, 2001; Strayer et al., 2003), and creates problems for recreation (boating, swimming, fishing, etc.). Current management techniques focus on chemical and mechanical means to

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suppress populations, however, treatments need to be maintained in perpetuity and currently no other long-term successful control technique is available to manage *T. natans* in North America (Pemberton, 2002).

Conventional management of *T. natans* is costly ($500,000 was spent for mechanical control in Lake Champlain, Vermont in 2000 alone, (Pemberton, 2002)), and lack of long-term suppression resulted in the initiation of a biocontrol program in the late 1980s (Pemberton, 1999). Surveys for potential biological control agents were conducted in China, Japan, eastern Russia, South Korea, and Western Europe, all areas with similarities in climate to the current range of *T. natans* in North America. Results of these surveys were discouraging because only 12 insects and 4 pathogens were found in Asia, and only 7 insects in Europe, and most of these species were known to have either broad host ranges or, if specific, had little impact on plant performance (Pemberton, 1999). The most promising species was the leaf beetle *Galerucella birmanica* Jacoby (Coleoptera: Chrysomelidae), which is reported as a widespread pest of cultivated *T. natans* in China (Lu et al., 1984). Adult and larval feeding can defoliate entire *T. natans* populations, however, the species was also reported to feed on unrelated plants, particularly water shield, *Brasenia schreberi* J. Gmelin (Cabombaceae), which is native to both China and North America, and appeared to use floating aquatic *Polygonum* species (Polygonaceae) in northern China (Lu et al., 1984; Pemberton, 1999, 2002). This lack of host specificity in *G. birmanica*, and absence of other promising potential biocontrol agents, led to the termination of biological control efforts in the late 1990s (Pemberton, 1999, 2002).

The genus *Galerucella*, and particularly *Galerucella nymphaeae* L., is notorious for morphologically similar sibling species that show host-plant specialization in Europe and North America (Cronin et al., 1999; Hippa and Koponen, 1986; Nokkala and Nokkala, 1994, 1998; Nokkala et al., 1998; Pappers et al., 2002a; Pappers et al., 2002b). An assessment of the evolution within the genus *Galerucella* suggested that species separated from a common ancestor via host plant specialization (Manguin et al., 1993) and developed morphological differences after reproductive isolation. A similar situation, where specimens found on different host plants may be reproductively isolated and constitute specific host races, may exist for the Asian *G. birmanica*, which is ecologically and morphologically similar to *G. nymphaeae* (Pemberton, 2002). If individuals collected from *T. natans* show high specificity, the potential for developing biological control in North America may be more promising than currently realized.

We used a combination of field observations, laboratory, and common garden experiments in southeastern China to assess the host specificity and performance of *G. birmanica*. Different populations may display distinct feeding preferences and performances (Cronin et al., 1999), and we therefore compared the host-specificity of *G. birmanica* collected from *T. natans* in northeastern (outside the Asian distribution of *B. schreberi*) and southeastern China (*B. schreberi* and *T. natans* occur in sympatry). We initially evaluated host acceptance in no-choice tests using 19 different plant species in 13 different families and, in additional experiments, placed a particular emphasis on evaluation of preference and performance of *G. birmanica* on *B. schreberi* and *T. natans* using no-choice and multiple choice oviposition, and no-choice larval development tests.

2. Material and methods

2.1. Experimental organisms

Trapa natans emerges as an annual rosette in spring from seeds that overwinter in shallow water bodies. Plants anchored in the hydrosoil are kept afloat by spongy inflated leaf petioles. Plants produce a branched flexuous stem often with 10–15 daughter rosettes. Inconspicuous whitish flowers develop in leaf axils by mid summer and each rosette can produce 15–20 woody nuts (each containing a single seed), which ripen over time, dislodge from the plant, and sink to the bottom where they overwinter. Seeds can remain viable in water for up to 12 years (Kunii, 1988; Winne, 1935). Water chestnut grows best in nutrient rich and moderately alkaline waters 0.3–2 m deep, but can grow in water up to 5 m deep (Papastergiadou and Babalonas, 1993). In the introduced range in North America, *T. natans* is able to completely cover ponds, shallow lakes, and river margins with up to 50 rosettes/m^2, displacing native vegetation. At infested sites, most recreational activities such as swimming, fishing from the shoreline and the use of small boats are eliminated or severely impeded. Over much of its native range in Asia, the starchy nut-like fruits of *T. natans* and its various cultivars (often referred to as *T. bispinosa*) are used as food and the species is widely cultivated (Pemberton, 2002).

B. schreberi is a perennial rhizomatous plant typically found in stagnant to slow moving water (20–180 cm deep). The species is native and widely distributed throughout the northern hemisphere including North America (where it is considered a weed in certain regions), Asia and Australia but is absent from Europe (Elakovich and Wooten, 1987; Scott, 2004). Elongated purple petioles attach to the center of the oval 10–20 cm long leaves, and petioles and leaf undersides are coated with a mucous substance that distinguishes this plant from most other macrophytes. Single purplish flowers develop in mid summer and the developing seeds are considered a valuable food for waterfowl in North America. The species is widely cultivated in Asia, where