Biological control of *Miconia calvescens* with a suite of insect herbivores from Costa Rica and Brazil

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**Summary**

*Miconia calvescens* DC. (Melastomataceae) is an invasive tree considered the most serious threat to the natural ecosystems of Hawaii and other Pacific islands. We evaluated nine species of natural enemies that feed on inflorescences or leaves of *M. calvescens* for their potential as biological control agents, comparing their impact on the target plant, host specificity, and vulnerability to biotic interference. Among herbivores attacking reproductive structures of *M. calvescens*, a fruit-galling wasp from Brazil, *Allorhogas* sp. (Hymenoptera: Braconidae), and a flower- and fruit-feeding moth from Costa Rica, *Mompha* sp. (Lepidoptera: Momphidae), were the most promising agents studied. The sawfly *Atomacera petroa* Smith (Hymenoptera: Argidae) from Brazil was thought to have the highest potential among the defoliators evaluated.

**Keywords:** herbivory, host specificity, biotic interference.

**Introduction**

*Miconia calvescens* DC. (Melastomataceae) is a small tree native to Central and South America that is considered a serious threat to natural ecosystems in Hawaii and other Pacific islands because of its ability to invade native forests (Medeiros et al., 1997). Its devastating effects are most evident in Tahiti, where it has displaced over 65% of the native forest and threatens many endemic species (Meyer and Florence, 1996). Herbicidal and mechanical removal are the main methods used to contain the spread of *M. calvescens*, but control is difficult and costly, especially in remote areas (Medeiros et al., 1997; Kaiser, 2006). Since *M. calvescens* is a tree of significant size (up to 15 m high) and prolific reproduction (Medeiros et al., 1997; Meyer, 1998), a combination of agents attacking vegetative and reproductive structures may be necessary to achieve effective biological control.

Several insects and pathogens have been identified as potential agents in surveys conducted in the native range of *M. calvescens* in Brazil and Costa Rica by Johnson (unpublished data) and others (Burkhart, 1995; Barreto et al., 2005; Picanço et al., 2005). In the interest of avoiding unnecessary introductions and making efficient use of limited resources to evaluate potential agents, we wish to prioritize future work and focus on highly host-specific agents that hold the greatest promise for impacting *M. calvescens* in Hawaii. Because biotic interference can be a significant obstacle to successful weed biocontrol in Hawaii, we have been attempting to predict which potential agents are most susceptible to parasites, predators and pathogens (Johnson, in this Proceedings). In this paper, we evaluate nine insect species that feed on inflorescences or leaves of *M. calvescens* based on impact on *M. calvescens*, host specificity and vulnerability to natural enemies.

**Methods and materials**

In Brazil, we studied four species attacking *M. calvescens*: a leaf-rasping sawfly, *Atomacera petroa* Smith (Hymenoptera: Argidae); a defoliating caterpillar, *Antiblemma leucocyma* Hampson (Lepidoptera: Noctuidae); a fruit-galling wasp, *Allorhogas* sp. (Hymenoptera:
Braconidae); and a fruit-boring weevil, *Apion* sp. (Coleoptera: Curculionoidea). In Costa Rica, we evaluated five species of Lepidoptera: an undescribed *Mompha* sp. (Momphidae), *Erra opisena* (Druce) (Lycaenidae), *Temeca paron* (Godman and Salvin) (Lycaenidae) and *Parrhasius polibetes* (Cramer) (Lycaenidae), all of which fed on inflorescences, and the leaf-roller *Ategumia lotanalis* (Crambidae).

To quantify the impact of the leaf feeders on *M. calvescens*, we observed the percentage of leaves attacked in the field, and we measured area damaged per leaf using WinFOLIA® leaf area analysis software (Regent Instruments Inc., 2003). To quantify the impact of the inflorescence feeders, the percentage of flower and fruit attacked by each species in the field were determined. Additionally, in the case of internal fruit feeding, we compared the number of seeds in infested versus healthy fruits. Host specificity of each insect was assessed through a combination of observations of plants growing in association with *M. calvescens* at field sites, laboratory feeding tests and knowledge of host ranges of related insects. Our evaluation of the potential for biotic interference was based upon evidence of attack by natural enemies in the native range and comparison with enemies known for related herbivores in Hawaii. For each insect, each criterion (impact on plant, host specificity, potential for biotic interference) was assigned a score from 1 (low) to 3 (high). An overall assessment of each potential biocontrol agent was made by summing scores across criteria.

**Results**

**Impacts**

Each of the fruit-feeding species caused variable levels of damage in the field, usually not attacking a high percentage of fruit but damaging moderate to high levels of seeds within the fruit they did attack, e.g. 80% and 60% reduction of seeds in attacked fruits for *Allorhogas* and *Apion* sp., respectively (Badenes-Perez and Johnson, 2007b). In addition, evidence of *Apion* sp. causing premature abscission of fruits suggests that this species could indirectly reduce viability and germination of seeds. Impacts by the three species of Lycaenidae can be very high because each larva completely consumed large portions of an inflorescence before flowering or many individual immature fruits after flowering (Badenes-Perez, unpublished data). Among defoliators, *A. leucocyma* and *A. lotanalis* were considered to have very high impact based on levels of damage seen in the field as well as leaf area consumed per insect (Badenes-Perez and Johnson, 2008b). Both of these lepidopterans attacked young foliage in addition to older leaves, with potentially high costs to plant fitness. In contrast, the sawfly *A. petroa* was found to attack primarily older leaves, and each larva removed relatively modest areas of leaf tissue (Badenes-Perez and Johnson, 2007a).

**Host specificity**

Gall-forming *Allorhogas* spp. represent a highly diverse group with each species being quite host specific (Hanson, personal comment), like most gall-formers tend to be (Julien and Griffiths, 1998; Dennill et al., 1999; Hoffmann et al., 2002). Specificity of *Apion* sp. has not been tested, but adults were found only on *M. calvescens* in the field. *Apion* sp. tend to be host specific and have been used with some success in weed biocontrol (Julien and Griffiths, 1998; McClay and De Clerck-Flaute, 1999; Norambuena and Piper, 2000). *Mompha* sp. has been reared only from fruits of *M. calvescens* in Costa Rica, where fruits of several *Miconia* spp. and other Melastomataceae have been repeatedly sampled (Chacón, 2007). *E. opisena*, *P. polibetes* and *T. paron* were only seen on *M. calvescens* in our field surveys (Badenes-Perez, unpublished data), but no focussed host specificity studies have been conducted. Larvae of *P. polibetes* have also been found feeding on Euphorbiaceae (Zikan, 1956), Leguminosae (D’Araujo e Silva et al., 1968), Malpighiaceae (http://janzen.sas.upenn.edu/) and Vochysiaceae (Diniz and Morais, 2002). Larval food plants of neotropical lycaenids are poorly known, but most are thought to be polyphagous (Downey, 1962; Robbins and Aiello, 1982). Studies in the laboratory and the native habitat of *A. leucocyma* and *A. petroa* indicated that they only attacked *M. calvescens*, while *A. lotanalis* attacked other Melastomataceae besides *M. calvescens* in the laboratory (Badenes-Perez and Johnson, 2007a; Badenes-Perez and Johnson, 2008).

**Biotic interference**

*Allorhogas* sp. was sometimes attacked by a eulophid parasitoid (*Hymenoptera: Eulophidae: Tetrastichinae*) in its natural habitat in Brazil, but there are no *Allorhogas* sp. present in Hawaii, and it appears likely that specialized enemies of this gall wasp are absent (Badenes-Perez and Johnson, 2007b). No natural enemies of *Apion* sp. were observed in the field in Brazil, but opportunities to assess biotic interference were limited by low densities of this insect (Badenes-Perez and Johnson, 2007b). A fungal pathogen is thought to limit the effective range of biocontrol by the gorse herbivore *Apion ulicis* (Forsters) (Coleoptera: Curculionoidea) in Hawaii (Julien and Griffiths, 1998). It is therefore possible that our species from *M. calvescens* might be similarly affected. Despite the presence of several parasitoids of *Mompha* sp. in Costa Rica, rates of parasitism were relatively low (Alfaro-Alpizar, unpublished data). A relative occupying a very similar niche, *Mompha trithalama* Meyrick (Lepidoptera: Momphidae), introduced from Trinidad to Hawaii, is well established and attacks a high percentage of *Clidemia hirta* (L.) D. Don. (Melastomataceae) fruits in Hawaii (Conant, 2002), although its population dynamics and overall efficacy have not been evaluated.
assessed in detail. In general, insects feeding internally in *M. calvescens* fruits are expected to escape impacts from generalist enemies in Hawaii. The probability of biotic interference in Hawaii was considered moderate to high for *E. opisena*, *P. polibetes* and *T. paron* because, feeding externally, they would be exposed to a variety of generalist enemies of Lepidoptera. Although they have not been well studied, there are a few species of native and introduced lycaenids in Hawaii that may already have specialized enemies. The mimetic appearance of our three species on *M. calvescens* may, however, help them avoid some predators and parasitoids. In fact, parasitism of these species in their native Costa Rican range was low (Badenes-Perez and Johnson, 2007a).

Biotic interference was considered highly probable for *A. leucocyma* because of the high levels of parasitism found in Brazil (Badenes-Perez and Johnson, 2008) and because of high parasitism of *Antiblemma acclinilis* Hübner (Lepidoptera: Noctuidae), established but apparently ineffective as a biological control agent of *C. hirta* in Hawaii (Conant, 2002). Biotic interference also seems likely for *A. lotanalis* because several species of parasitoids and a hemipteran predator were observed attacking it in Costa Rica (Castillo-Castillo, unpublished data) and because another biocontrol agent of *C. hirta*, *Ategumia matutinalis* (Guenee) (Lepidoptera: Crambidae), also appears to be highly parasitized in Hawaii (Conant, 2002). In contrast to these lepidopterans, the sawfly *A. petroa* was considered less likely to be attacked in Hawaii because no parasitoids and predators were observed in the natural habitat of *A. petroa* in Brazil and because there are no native species of Argidae and only two other introduced sawflies in Hawaii (Badenes-Perez and Johnson, 2007a).

When the criteria of impact, specificity and biotic interference were considered together, *Allorhogas* sp. and *Mompha* sp. emerged as the strongest candidates among herbivores attacking reproductive structures of *M. calvescens* (Table 1). Other insects showing relatively high overall potential for biological control were the defoliator *A. petroa* and the inflorescence feeder *Apion* sp. Less likely to become effective biological control agents of *M. calvescens* were *A. leucocyma*, *A. lotanalis*, *E. opisena*, *T. paron* and *P. polibetes* because of their high probability of experiencing biotic interference in Hawaii and/or the possibility of low host specificity.

**Discussion**

Our assessment of the potential of the insects studied as biological control agents of *M. calvescens* may be preliminary but is still helpful as an initial evaluation. Other insects being evaluated as biocontrol agents of *M. calvescens* that have not been included here are: the fruit-feeding weevil *Anthonomus monostigma* Champion (Coleoptera: Curculionidae) (Chacón, 2007), the stem/leaf-feeding weevil *Cryptorhynchus melastomae* Champion (Coleoptera: Curculionidae) (Reichert, 2007), the sap-sucking *Diclidophlebia* spp. (Hemiptera: Psyllidae) (Morais, 2007; Burckhardt et al., 2005), and the defoliating caterpillar *Euelsia chrysippe* Bates (Lepidoptera: Riodinidae) (Allen, 2007). As additional information becomes available, insects will need to be re-evaluated. Other practical factors that affect prioritization are the viability of insect rearing and the difficulty to obtain permits to export insects from native areas.

**Acknowledgements**

We thank Drs Robert Barreto and Marcelo Picanço as well as people working in their laboratory groups at the Universidade Federal de Viçosa. We also thank Drs

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**Table 1.** Nine insect species selected as potential biological control agents of *Miconia calvescens* based on impact, host specificity and probability of biotic interference in Hawaii. For each insect, each criterion was assigned a score from 1 to 3 indicated in parenthesis: 1 = low, 2 = moderate or 3 = high. Risks of biotic interference were assigned negative scores. Finally, an overall assessment of each potential biocontrol agent was made by summing scores across criteria.

<table>
<thead>
<tr>
<th>Insect species</th>
<th>Plant part attacked</th>
<th>Impact on plant</th>
<th>Host specificity</th>
<th>Probability of biotic interference in Hawaii</th>
<th>Overall potential for biological control</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Allorhogas</em> sp.</td>
<td>Inflorescences</td>
<td>High (3)</td>
<td>High (3)</td>
<td>Low (−1)</td>
<td>High (5)</td>
</tr>
<tr>
<td><em>Mompha</em> sp.</td>
<td>Inflorescences</td>
<td>High (3)</td>
<td>High (3)</td>
<td>Low (−1)</td>
<td>High (5)</td>
</tr>
<tr>
<td><em>Apion</em> sp.</td>
<td>Inflorescences</td>
<td>High (3)</td>
<td>Unknown* (3)</td>
<td>Moderate (−2)</td>
<td>Moderate-High (4)</td>
</tr>
<tr>
<td><em>Eura opisena</em></td>
<td>Inflorescences</td>
<td>High (3)</td>
<td>Unknown** (2)</td>
<td>Moderate (−2)</td>
<td>Low-Moderate (3)</td>
</tr>
<tr>
<td><em>Temexia paron</em></td>
<td>Inflorescences</td>
<td>High (3)</td>
<td>Unknown** (2)</td>
<td>Moderate (−2)</td>
<td>Low-Moderate (3)</td>
</tr>
<tr>
<td><em>Parrhasia polibetes</em></td>
<td>Inflorescences</td>
<td>High (3)</td>
<td>Low (1)</td>
<td>Moderate (−2)</td>
<td>Low (2)</td>
</tr>
<tr>
<td><em>Atomacera petroa</em></td>
<td>Leaves</td>
<td>Moderate (2)</td>
<td>High (3)</td>
<td>Low (−1)</td>
<td>Moderate-High (4)</td>
</tr>
<tr>
<td><em>Antiblemma leucocyma</em></td>
<td>Leaves</td>
<td>High (3)</td>
<td>High (3)</td>
<td>High (−3)</td>
<td>Low-Moderate (3)</td>
</tr>
</tbody>
</table>

* Only observed on *M. calvescens* and based on host specificity of related insects.

** Based on field and/or laboratory observations.

* Based on published studies with same and/or related species.
Paul Hanson and Kenji Nishida at the Universidad de Costa Rica, Dr Robert Robbins at the Smithsonian Institution, Dr Ichiro Nakamura at the University of Buffalo and Dr Isidro Chacón at the Instituto Nacional de Biodiversidad of Costa Rica for their help with insect identification. Funding was provided by the Hawaii Invasive Species Council and Forest Service International Programs.

References


