

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

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Summary

Miconia calvenscens 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. calvenscens* 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. calvenscens*, 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 calvenscens 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. calvenscens*, but control is difficult and costly, especially in remote areas (Medeiros *et al.*, 1997; Kaiser, 2006). Since *M. calvenscens* 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 repro-

ductive 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as potential agents in surveys conducted in the native range of *M. calvenscens* in Brazil and Costa Rica by Johnson (unpublished data) and others (Burkhart, 1995; Barreto *et al.*, 2005; Picanço *et al.*, 2005).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. calvenscens* 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 parasitoids, predators and pathogens (Johnson, in this Proceedings). In this paper, we evaluate nine insect species that feed on inflorescences or leaves of *M. calvenscens* based on impact on *M. calvenscens*, host specificity and vulnerability to natural enemies.

Methods and materials

In Brazil, we studied four species attacking *M. calvenscens*: a leaf-rasping sawfly, *Atomacera petroa* Smith (Hymenoptera: Argidae); a defoliating caterpillar, *Antiblemma leucocyma* Hampson (Lepidoptera: Noctuidae); a fruit-galling wasp, *Allorhogas* sp. (Hymenoptera:

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Braconidae); and a fruit-boring weevil, *Apion* sp. (Coleoptera: Curculionidae). In Costa Rica, we evaluated five species of Lepidoptera: an undescribed *Mompha* sp. (Momphidae), *Erora opisena* (Druce) (Lycaenidae), *Temecle 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, 2008). 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-Floate, 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: Curculionidae) 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

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 acclinalis* 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* (Guenée) (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 *Euselasia 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.

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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.

Insect species	Plant part attacked	Impact on plant	Host specificity	Probability of biotic interference in Hawaii	Overall potential for biological control
<i>Allorhogas</i> sp.	Inflorescences	High (3)	High (3)	Low ^b (-1)	High (5)
<i>Mompha</i> sp.	Inflorescences	High (3)	High (3)	Low ^{b,c} (-1)	High (5)
<i>Apion</i> sp.	Inflorescences	High (3)	Unknown ^a (3)	Moderate ^{b,c} (-2)	Moderate-High (4)
<i>Erora opisena</i>	Inflorescences	High (3)	Unknown ^a (2)	Moderate ^b (-2)	Low-Moderate (3)
<i>Temecla paron</i>	Inflorescences	High (3)	Unknown ^a (2)	Moderate ^b (-2)	Low-Moderate (3)
<i>Parrhasius polibetes</i>	Inflorescences	High (3)	Low (1)	Moderate ^b (-2)	Low (2)
<i>Atomacera petroa</i>	Leaves	Moderate (2)	High (3)	Low ^a (-1)	Moderate-High (4)
<i>Antiblemma leucocyma</i>	Leaves	High (3)	High (3)	High ^{b,c} (-3)	Low-Moderate (3)
<i>Ategumia lotanalis</i>	Leaves	High (3)	Moderate ^a (2)	High ^{b,c} (-3)	Low (2)

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

^b Based on field and/or laboratory observations.

^c Based on published studies with same and/or related species.

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References

- Allen, P. (2007) *Demografia, patrón de supervivencia y efectos de tamaño de grupo en larvas gregarias de Euselasia chrysippe (Lepidoptera: Riodinidae), un potencial agente de control biológico de Miconia calvenscens (Melastomataceae) en Hawai*. MSc Thesis. Escuela de Biología, Universidad de Costa Rica, San Jose, Costa Rica, 51 pp.
- Badenes-Perez, F.R. and Johnson, M.T. (2007a) Ecology, host specificity and impact of *Atomacera petroa* Smith (Hymenoptera: Argidae) on *Miconia calvenscens* DC (Melastomataceae). *Biological Control* 43, 95–101.
- Badenes-Perez, F.R. and Johnson, M.T. (2007b) Ecology and impact of *Allorhogas* sp. (Hymenoptera: Braconidae) and *Apion* sp. (Coleoptera: Curculionidae) on fruits of *Miconia calvenscens* DC (Melastomataceae) in Brazil. *Biological Control* 43, 317–322.
- Badenes-Perez, F.R. and Johnson, M.T. (2008) Biology, herbivory, and host specificity of *Antiblemma leucocyma* (Lepidoptera: Noctuidae) on *Miconia calvenscens* (Melastomataceae) in Brazil. *Biocontrol Science and Technology* 18, 183–192.
- Barreto, R.W., Seixas, C.D.S., Killgore, E. and Gardner, D.E. (2005) Mycobiota of *Miconia calvenscens* and related species from the neotropics, with particular reference to potential biocontrol agents. Technical Report 132 pp. 24. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Honolulu, HI.
- Burckhardt, D., Hanson, P. and Madrigal, L. (2005) *Diclidophlebia lucens*, n. sp. (Hemiptera: Psyllidae) from Costa Rica, a potential control agent of *Miconia calvenscens* (Melastomataceae) in Hawaii. *Proceedings of the Entomological Society of Washington* 107, 741–749.
- Burkhart, R.M. (1995) Natural enemies of *Miconia calvenscens*. Hawaii Department of Agriculture, Honolulu, HI.
- Chacón, M.E.J. (2007) *Historia natural de Anthonomus monostigma (Coleoptera: Curculionidae) y su potencial como agente de control biológico de Miconia calvenscens (Melastomataceae)*. MSc Thesis. Escuela de Biología, Universidad de Costa Rica, San Jose, Costa Rica, 85 pp.
- Conant, P. (2002) Classical biological control of *Clidemia hirta* (Melastomataceae) in Hawaii using multiple strategies. In: Smith, C.W., Denslow, J.S. and Hight, S. (eds) *Workshop on biological control of invasive plants in native Hawaiian ecosystems. Technical Report 129*. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Honolulu, HI, pp. 13–20.
- D'Araujo e Silva, A.G., Gonçalves, C.R., Galvao, D.M., Gonçalves, J.L., Gomes, J., do Nascimento Silva, M. and de Simoni, L. (1968) *Quarto Catalogo dos Insetos que Vivem nas Plantas do Brasil, seus Parasitos e Predadores* (ed. M. d. Agricultura), Rio de Janeiro, Brasil, 622 pp.
- Dennill, G.B., Donnelly, D., Stewart, K. and Impson, F.A.C. (1999) Insect agents used for the biological control of the Australian Acacia species and *Paraserianthes lophantha* (Willd.) Nielsen (Fabaceae) in South Africa. *African Entomological Memoir* 1, 45–54.
- Diniz, I.R. and Morais, H.C. (2002) Local pattern of host plant utilization by lepidopteran larvae in the cerrado vegetation. *Entomotopica* 17, 115–119.
- Downey, J.C. (1962) Host-plant relations as data for butterfly classification. *Systematic Zoology* 11, 150–159.
- Hoffmann, J.H., Impson, F.A.C., Moran, V.C. and Donnelly, D. (2002) Biological control of invasive golden wattle trees (*Acacia pycnantha*) by a gall wasp, *Trichilogaster* sp. (Hymenoptera: Pteromalidae), in South Africa. *Biological Control* 25, 64–73.
- Julien, M.H. and Griffiths, M.W. (1998) *Biological control of weeds: a world catalogue of agents and their target weeds*. CAB International, Wallingford, UK, 223 pp.
- Kaiser, B.A. (2006) Economic impacts of non-indigenous species: *Miconia* and the Hawaiian economy. *Euphytica* 148, 135–150.
- McClay, A. and De Clerck-Floate, R. (1999) Establishment and early effects of *Omphalopion hookeri* (Kirby) (Coleoptera: Curculionidae) as a biological control agent for scentless chamomile, *Matricaria perforata* Merat (Asteraceae). *Biological Control* 14, 85–95.
- Medeiros, A.C., Loope, L.L., Conant, P. and McElvaney, S. (1997) Status, ecology and management of the invasive plant *Miconia calvenscens* DC (Melastomataceae) in the Hawaiian Islands. *Bishop Museum Occasional Papers* 48, 23–36.
- Meyer, J.-Y. (1998) Observations on the reproductive biology of *Miconia calvenscens* DC (Melastomataceae), an alien invasive tree on the island of Tahiti (South Pacific Ocean). *Biotropica* 30, 609–624.
- Meyer, J.-Y. and Florence, J. (1996) Tahiti's native flora endangered by the invasion of *Miconia calvenscens* DC (Melastomataceae). *Journal of Biogeography* 23, 775–781.
- Morais, E.G.F. (2007) *Diclidophlebia smithi* (Hemiptera: Psyllidae) como agente de controle biológico da planta invasora *Miconia calvenscens*. MSc Thesis. Universidade Federal de Viçosa, Viçosa, Brazil, 68 pp.
- Norambuena, H. and Piper, G.L. (2000) Impact of *Apion ulicis* Forster on *Ulex europaeus* L. seed dispersal. *Biological Control* 17, 267–271.
- Picanço, M.C., Barreto, R.W., Fidelis, E.G., Semeao, A.A., Rosado, J.F., Moreno, S.C., de Barros, E.C., Silva, G.A. and Johnson, M.T. (2005) Biological control of *Miconia calvenscens* by phytophagous arthropods. Technical Report 134 pp. 31. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Honolulu, HI.
- Regent Instruments Inc. (2003) *WinFOLIA® 2003d*, Quebec, Canada, 70 pp.
- Reichert, E. (2007) *Cryptorhynchus melastomae* (Coleoptera: Curculionidae) as a potential biocontrol agent for *Miconia calvenscens* (Melastomataceae) en Hawaii. MSc Thesis. Department of Natural Resource Sciences, McGill University, Montreal, Canada, 66 pp.
- Robbins, R.K. and Aiello, A. (1982) Foodplant and oviposition records for Panamanian Lycaenidae and Riodinidae. *Journal of the Lepidopterists' Society* 36, 65–75.
- Zikan, J.F. (1956) Beitrag zur biologie von 12 Theclinen-arten. *Dusenía* 7, 139–148.