NON-TARGET SPECIES SELECTION FOR HOST RANGE TESTING OF *COTESIA URABAE*

L.A. BERNDT¹, T.M. WITHERS¹, S. MANSFIELD² and R.J.B. HOARE³

¹Scion, Private Bag 3020, Rotorua 3046, New Zealand

²Faculty of Agriculture, Food and Natural Resources, University of Sydney, Camperdown, NSW 2006, Australia

³Landcare Research, Private Bag 92170, Auckland 1142, New Zealand

Corresponding author: lisa.berndt@scionresearch.com

ABSTRACT

Classical biological control is being attempted for *Uraba lugens* (Lepidoptera: Noctuidae: Nolinae), an Australian eucalypt pest established in New Zealand. The Australian solitary larval endoparasitoid *Cotesia urabae* (Hymenoptera: Braconidae) is the most promising agent under investigation. A non-target species list was compiled for host range testing. The endemic species *Celama parvitis* is the sole New Zealand representative of the Nolinae and was highest priority. The next most closely related subfamily is the Arctiinae, of which New Zealand has four endemic species (*Metacrias huttoni*, *M. erichrysa*, *M. strategica* and *Nyctemera annulata*) and one introduced biological control agent (*Tyria jacobaeae*). The merits of including other, more distantly related, members of the Noctuidae, and unrelated Lepidoptera filling a similar niche are discussed. **Keywords:** biological control, host specificity, Hymenoptera, Lepidoptera.

INTRODUCTION

Host range testing prior to introduction of a classical biological control agent is undertaken to determine the risk of negative impacts on non-target species. The means of selecting an appropriate non-target species list for arthropod biological control is less well established than for weed biological control (Messing 2001; Hoddle 2004). For weed biological control agents, the non-target species list is constructed based on phylogenetic relatedness to the target weed, with consideration of ecological and biogeographic issues to ensure species with the highest risk profiles are included (Briese & Walker 2008; Sheppard et al. 2005). This is not always appropriate for arthropod biological control agents, where the diversity of potential non-target species is much greater, and often arthropod taxonomy and phylogenetic relationships are less well known (Messing 2001; Kuhlmann et al. 2006). In addition, some parasitoids target hosts in a certain ecological niche, regardless of their taxonomic affinities (Messing 2001), whereas others are strongly host-specific (Godfray 1994).

Kuhlmann et al. (2006) proposed developing an initial testing list of non-target species based on phylogenetic or taxonomic affinities, ecological similarity to the target, and socioeconomic considerations. This list is then filtered by spatial, temporal and morphological attributes that might make a species inaccessible to the agent, and by the feasibility of obtaining the non-target species for testing. During the process of host range testing, any new information gathered (such as attack by the proposed agent on one of the non-target species) may alter the type or extent of testing required, and potentially the final list of non-target species selected (Kuhlmann et al. 2006). This approach is similar to that proposed by Hoddle (2004).

This paper describes the selection process used for obtaining the list of non-targets for host range testing of *Cotesia urabae* Austin & Allen (Hymenoptera:

Braconidae). *Cotesia urabae* is a solitary larval endoparasitoid only ever recorded from *Uraba lugens* Walker (Lepidoptera: Noctuidae: Nolinae) in Australia (Austin & Allen 1989). *Uraba lugens* is a eucalypt defoliator from Australia that has been present in New Zealand since the early 1990s.

METHODS

An analysis of the New Zealand Lepidoptera fauna and published phylogenies was conducted to establish which species were most closely related to *U. lugens*. The biology and distribution of these species were assessed, and consultation with Department of Conservation and Maori was undertaken to check conservation and Taonga (cultural treasure) status. Lepidopteran species present in overlapping habitats to *U. lugens* were also determined. From this process a non-target species list was compiled in order of priority for host range tests.

RESULTS AND DISCUSSION

Selection of non-target species

Uraba lugens was initially placed in the family Tortricidae (Walker 1863). After various changes, *U. lugens* is now placed in Noctuidae (subfamily Nolinae) (Edwards 1996; Lafontaine & Fibiger 2006). However, some authors have followed Kitching & Rawlins (1998) and Mitchell et al. (2006) in assigning the nolines family rank (e.g. Berry & Mansfield 2006; Kriticos et al. 2007). In the present investigation, Lafontaine & Fibiger (2006) was followed.

New Zealand has representatives in two families in the same clade as the nolines within the quadrifine noctuids: one endemic noline, four endemic arctiines, and one arctiine introduced as a biological control agent (Table 1) (Dugdale 1988). Three additional arctiines are sporadic immigrants (*Nyctemera amica* (White), *Utetheisa lotrix* (Cramer), *Utetheisa pulchelloides vaga* Jordan) and have not been included in the non-target list (Dugdale 1988). The Hypeninae is the next New Zealand subfamily most closely related to the nolines (Lafontaine & Fibiger 2006). Mitchell et al. (2006) placed the nolines closer to the hypenines than to the arctiines, although this approach has been refuted by Lafontaine & Fibiger (2006). Given these taxonomic relationships, a non-target species list was constructed (Table 1) by prioritising relatedness to *U. lugens*, followed by endemicity and beneficial status. Two triline noctuids, more distantly related to *U. lugens* (*Spodoptera litura* (F.) and *Helicoverpa armigera* (Walker)), were selected as outgroup species.

Biology of selected species

In assessing possible risk to New Zealand species from *C. urabae*, spatial and temporal characteristics need to be considered (Kuhlmann et al. 2006). *Uraba lugens* is currently established in the upper part of the North Island, particularly in the Auckland region. A CLIMEX model predicted it will be capable of establishing through much of the North Island, and the eastern parts of the South Island, with an upper altitudinal limit of 600 m (Kriticos et al. 2007). In New Zealand, *U. lugens* is bivoltine, with larvae present from December to February, and May to October, similar to its phenology in Adelaide, South Australia (Allen 1990a). In its native range, *C. urabae* completes two generations for each generation of *U. lugens* (Allen 1990a).

Celama parvitis (Howes), the sole New Zealand noline (Dugdale 1988), occurs in Nelson, Lake Wakatipu and on the Otago Peninsula (Hudson 1928), as well as Wairarapa (B.H. Patrick, Alexandra Museum and Art Gallery, pers. comm.) and Lake Waikaremoana (NZAC Collection specimens) in the North Island. Larvae are active from April to November (B.H. Patrick, Alexandra Museum and Art Gallery, pers. comm.) so would overlap with winter generations of *C. urabae*, as well as the predicted geographic range of *U. lugens*.

The larvae of the *Metacrias* species are present from mid summer through to when they enter obligatory larval diapause over winter (Gibbs 1962). *Metacrias huttoni* (Butler) and the closely related *Metacrias erichrysa* Meyrick occur in open herb and tussock fields at

altitudes of 900 to 1200 m, predominantly in the South Island (Gibbs 1962). Thus these species are unlikely to overlap in habitat with *U. lugens* and its parasitoids. *Metacrias strategica* (Hudson) is restricted entirely to coastal regions of Canterbury, Otago and Southland in the South Island (Gibbs 1962). Its habitats range from coastal to forest-edge sites, up to the montane zone and include native grassland and exotic pastures (Gibbs 1962; Patrick et al. 2003), thus intersecting with the potential distribution of *U. lugens* and with summer generations of *C. urabae*.

TABLE 1: Non-target species list for host range testing of *Cotesia urabae*, a potential biological control agent for *Uraba lugens*. Species are listed in order of priority.

Species	Family/ Subfamily	Status	Host	Reason for inclusion
<i>Celama parvitis</i> (Howes)	Noctuidae/ Nolinae	Endemic	<i>Heliochrysum lanceolatum</i> (Asteraceae)	Same subfamily
<i>Metacrias strategica</i> (Hudson)	Noctuidae/ Arctiinae	Endemic	Omnivorous on grasses and herbs	Closely related subfamily
<i>Nyctemera annulata</i> (Boisduval)	Noctuidae/ Arctiinae	Endemic	Oligophagous on <i>Jacobaea</i> , <i>Erechtites</i> , <i>Brachyglottis</i> , <i>Cineraria</i>	Closely related subfamily
<i>Metacrias huttoni</i> (Butler)	Noctuidae/ Arctiinae	Endemic	Omnivorous on grasses and herbs	Closely related subfamily
<i>Metacrias erichrysa</i> Meyrick	Noctuidae/ Arctiinae	Endemic	Omnivorous on grasses and herbs	Closely related subfamily
<i>Tyria jacobaeae</i> (L.)	Noctuidae/ Arctiinae	Introduced biocontrol agent	<i>Jacobaea vulgaris</i>	Closely related subfamily
<i>Rhaphsa scotosialis</i> Walker	Noctuidae/ Hypeninae	Endemic	Leaf litter and mosses	Related subfamily
<i>Spodoptera litura</i> (F.)	Noctuidae/ Acronictinae	Cosmopolitan pest	Clover, horticultural crops	Distantly related subfamily
<i>Helicoverpa armigera conferta</i> Walker	Noctuidae/ Heliethinae	Cosmopolitan pest	Horticultural grain crops	Distantly related subfamily

Nyctemera annulata Boisduval is common throughout New Zealand on native and exotic herbs and shrubs in the tribe Senecioneae (Asteraceae) (Singh & Mabbett 1976). There are at least two generations per year and in the North Island breeding may be continuous so that larvae can be found all year round. Thus this species would overlap with all generations of *C. urabae*. *Tyria jacobaeae* (L.) is native to England, Ireland and Europe and was introduced into New Zealand as a biological control agent of ragwort

(*Jacobaea vulgaris*) (Syrett 1983). Larvae are present from September to February, overlapping with summer generations of *C. urabae*. Both of these species are found on farms and in plantation forests where their hosts grow, and so may occur in the same habitat as *U. lugens*.

Rhapsa scotosialis Walker is very common throughout New Zealand and all stages are present over much of the year. Larvae are nocturnal feeders on leaf-litter in forests and suburban gardens (Bejakovich & Dugdale 1997), thus do not inhabit the same niche as *U. lugens*, although the two species are likely to overlap geographically and phenologically.

Spodoptera litura and *H. armigera* are cosmopolitan crop pests that were chosen because they were easy to obtain and rear for use in developing host range testing protocols (Berndt et al. 2007). In addition, the Department of Conservation (P. Craddock, pers. comm.) indicated that *H. armigera* should be tested as it acts as a proxy for the threatened species *Australothrips volatilis* Matthews & Patrick, the only endemic New Zealand representative of the Heliothinae (Matthews & Patrick 1998).

Preliminary host range tests on *S. litura* and *H. armigera* found that the parasitoid *C. urabae* only rarely attempted to attack these species when given maximum opportunity, and no evidence of successful attack was found from rearing or larval dissection (Berndt et al. 2007). Thus these tritine noctuids are outside the physiological host range of this parasitoid. In proposing a method for selecting a non-target species list, Kuhlmann et al. (2006) accept that phylogenetic relationships are an underlying consideration. This is particularly true for koinobiont parasitoid species thought to be highly host-specific in their native range (Godfray 1994). *Cotesia urabae* is a koinobiont species that has not been recorded attacking any species other than *U. lugens* (Austin & Allen 1989).

Consideration of other species

Although phylogenetic relationships formed the basis for selection of non-target species, an analysis of species sharing the ecological niche of *U. lugens* is also important (Kuhlmann et al. 2006). Parasitoids may select hosts based on physical characteristics and behaviour (Messing 2001). The hairy *U. lugens* larvae are exposed on the leaves day and night, and may drop on a thread if disturbed. Young larvae feed gregariously, while older larvae are solitary feeders, and *C. urabae* is capable of dealing with both larval behaviours (Allen 1990b). The niche of *U. lugens* was thus defined as hairy lepidopteran larvae feeding exposed on the leaves of trees and shrubs.

At least 51 species of eucalypts and closely related Australian Myrtaceae have been recorded as hosts of *U. lugens* in New Zealand, along with new host records on one New Zealand Myrtaceae and seven deciduous Northern Hemisphere tree species from a range of families (Berndt & Withers 2009). The Australian pest *Opodiphthera eucalyptii* (Scott) (Saturniidae) is the only lepidopteran species in New Zealand that shares the same niche and host plants with *U. lugens*, with no native or beneficial species in this niche feeding on the same host tree species. *Opodiphthera eucalyptii* is an exotic pest species from an unrelated family, and the larvae are significantly larger than those of *U. lugens*.

It is unknown if *C. urabae* shows strong habitat fidelity or uses host plant cues in host location, so the possibility of it moving through other native or exotic habitats cannot be ruled out. Thus native Lepidoptera with exposed leaf feeding larvae could also be considered, particularly those that might occur adjacent to eucalypts. *Uresiphita polygonalis maoralis* Felder & Rogenhofer (Pyralidae) is a very common endemic species with hairy larvae that feed exposed on the leaves of kowhai (*Sophora* spp.) and other leguminous shrubs (Somerfield 1984). *Pseudocoremia suavis* Butler (Geometridae) is an example of a suite of endemic geometrids that feed exposed on trees and shrubs. *Pseudocoremia suavis* is a very common species with larvae feeding on a wide range of native and exotic tree species (Emberson 1984). Should resources allow for host range testing of these species, it would enable assessment of the response of *C. urabae* to a potential novel host or host-plant complex.

CONCLUSIONS

The proposed non-target list includes nine species related to *U. lugens* from five subfamilies of the Noctuidae. It is hypothesised that if any non-target hosts are identified during host range testing, they will be from the species most closely related to *U. lugens* in the Nolines and Arctiines. Thus species in these subfamilies are of highest priority, particularly those species that feed while exposed on the leaves of trees, shrubs or herbs, and whose spatial and temporal distribution overlaps with that predicted for *U. lugens* in New Zealand. The non-target species list presented here may not be the final list of species tested, as this will be influenced by findings of the host range tests as these are conducted, as well as insect availability, phenology and resources.

ACKNOWLEDGEMENTS

Thanks to Karina Potter, Brian Patrick and Richard Hill for their assistance.

REFERENCES

- Allen GR 1990a. The phenologies of *Cotesia urabae*, *Dolichogenidea eucalypti* (Hymenoptera: Braconidae) and their host *Uraba lugens* (Lepidoptera: Noctuidae) in the Adelaide region. Australian Journal of Zoology 38: 347-62.
- Allen GR 1990b. Influence of host behaviour and host size on the success of oviposition of *Cotesia urabae* and *Dolichogenidea eucalypti* (Hymenoptera: Braconidae). Journal of Insect Behaviour 3(6): 733-749.
- Austin AD, Allen GR 1989. Parasitoids of *Uraba lugens* Walker (Lepidoptera: Noctuidae) in South Australia, with description of two new species of Braconidae. Transactions of the Royal Society of South Australia 113(4): 169-184.
- Bejakovich D, Dugdale JS 1997. Keys to late-instar larvae and adults of Noctuidae (Lepidoptera) encountered in field surveys and border control in New Zealand. MAF Quality Management and Landcare Research Manaaki Whenua, Wellington. 55 p.
- Berndt LA, Mansfield S, Withers TM 2007. A method for host range testing of a biological control agent for *Uraba lugens*. New Zealand Plant Protection 60: 286-290.
- Berndt LA, Withers TM 2009. Challenges in assessing risk posed by new forestry incursions: *Uraba lugens* as a case study. In: Richardson M, Hodgson C, Forbes A (compilers). IUFRO International Forest Biosecurity Conference, Popular Summaries. NZFRI Bulletin No 233 [ISBN 0-478-11023-5]. Pp. 37-40.
- Berry JA, Mansfield S 2006. Hyperparasitoids of the gum leaf skeletoniser, *Uraba lugens* Walker (Lepidoptera: Nolidae), with implications for the selection of a biological control agent for *Uraba lugens* in New Zealand. Australian Journal of Entomology 45(3): 215-218.
- Briese DT, Walker A 2008. Choosing the right plants to test: The host-specificity of *Longitarsus* sp. (Coleoptera: Chrysomelidae) a potential biological control agent of *Heliotropium amplexicaule*. Biological Control 44: 271-285.
- Dugdale JS 1988. Lepidoptera – annotated catalogue, and keys to family-group taxa. Fauna of New Zealand No.14. DSIR, Wellington, New Zealand.
- Edwards ED 1996. Chapter 89 Noctuidae. In: Nielsen ES, Edwards ED, Rangsi TV ed. Checklist of the Lepidoptera of Australia. Monographs on Australian Lepidoptera: No. 4. Pp. 292 & 314.
- Emberson RM 1984. Forest and Timber Insects. Chapter 11. In: Scott RR ed. New Zealand Pest and Beneficial Insects. Lincoln University College of Agriculture, Canterbury, New Zealand. Pp. 191-204.
- Gibbs GW 1962. The New Zealand genus *Metacrias* Meyrick (Lepidoptera: Arctiidae) systematics and distribution. Transactions of the Royal Society of New Zealand (Zoology) 2(19): 153-167.
- Godfray HCJ 1994. Parasitoids: Behavioural and Evolutionary Ecology. Princeton University Press, Princeton, New Jersey, USA. 473 p.

- Hoddle MS 2004. Analysis of fauna in the receiving area for the purpose of identifying native species that exotic natural enemies may potentially attack. In: Van Driesche RG, Reardon R ed. Assessing host ranges for parasitoids and predators used for classical biological control: a guide to best practice. Forest Heath Technology Enterprise Team, Morgantown, West Virginia, USA.
- Hudson GV 1928. The Butterflies and Moths of New Zealand. Ferguson & Osborn Ltd., Wellington, New Zealand.
- Kitching IJ, Rawlins JE 1998. Chapter 19: The Noctuidae. In: Kristensen NP ed. Handbook of Zoology Vol. IV Arthropoda: Insecta. Lepidoptera, Moths and Butterflies. Vol. 1: Evolution, Systematics and Biogeography. Walter de Gruyter, Berlin, New York. Pp. 355-402.
- Kriticos DJ, Potter KJB, Alexander NS, Gibb AR, Suckling DM 2007. Using a pheromone lure survey to establish the native and potential distribution of an invasive Lepidopteran, *Uraba lugens*. Journal of Applied Ecology 44(4): 853-863.
- Kuhlmann U, Schaffner U, Mason PG 2006. Selection of non-target species for host specificity testing. In: Bigler F, Babendreier D, Kuhlmann U ed. Environmental impact of invertebrates for biological control of arthropods. CABI International, Wallingford, UK.
- Lafontain JD, Fibiger M 2006. Revised higher classification of the Noctuoidea (Lepidoptera). Canadian Entomologist 138: 610-635.
- Matthews M, Patrick B 1998. A new diurnal species of Heliethinae (Lepidoptera: Noctuidae) endemic to New Zealand. Journal of Natural History 32(2): 263-271.
- Messing RH 2001. Centrifugal phylogeny as a basis for non-target host testing in biological control: is it relevant for parasitoids? Phytoparasitica 29: 187-189.
- Mitchell A, Mitter C, Regier JC 2006. Systematics and evolution of the cutworm moths (Lepidoptera: Noctuidae): evidence from two protein-coding nuclear genes. Systematic Entomology 31: 21-46.
- Patrick BH, Patrick H, Edwards E 2003. Tiger moths and pheromones. The Weta 25: 14-17.
- Sheppard AW, van Klinken RD, Heard TA 2005. Scientific advances in the analysis of direct risks of weed biological control agents to non-target plants. Biological Control 35: 215-226.
- Singh P, Mabbett FE 1976. Note on the life history of the magpie moth, *Nyctemera annulata* (Lepidoptera: Arctiidae). New Zealand Journal of Zoology 3: 277-278.
- Somerfield KG 1984. Greenhouse and Ornamental Pests. Chapter 4. In: Scott RR ed. New Zealand Pest and Beneficial Insects. Lincoln University College of Agriculture Canterbury, New Zealand. Pp. 65-92.
- Syrett P 1983. Biological control of ragwort in New Zealand - a review. Australian Weeds 2: 96-101.
- Walker F 1863. List of the specimens of lepidopterous insects in the collection of the British Museum Part XXVIII. Tortricites and Tineites. British Museum (Natural History), London. Pp. 287-561.