SAFETY IN NEW ZEALAND WEED BIOCONTROL: A NATIONWIDE SURVEY FOR IMPACTS ON NON-TARGET PLANTS

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ABSTRACT

The safety record of weed biocontrol was questioned recently when examples of damage to non-target plants were reported overseas. Until now, systematic investigations of non-target feeding have not been performed in New Zealand. Results of surveys looking for evidence of non-target damage caused by 20 biological control agents released against weeds in New Zealand are presented. Most agents (16) are apparently host-specific. However, two species (*Tyria jacobaeae* and *Phytomyza vitalbae*) were recorded attacking native plants, although their attack was very minor and predictable from host-range testing performed prior to release. For two other species, *Bruchidius villosus* and *Cydia succedana*, non-target attack was not predicted from host-range testing. Larval feeding by these species was confined to mainly weedy, exotic plants that are closely related to their target plants. The reliability of host-specificity testing and overall safety record of weed biological control in New Zealand are discussed.

Keywords: biological control, specificity, risk, environmental safety.

INTRODUCTION

Although biological control is often perceived as an environmentally benign alternative to chemicals, there have been recently reported cases of damage to non-target plants (e.g. Louda et al. 1997; Pemberton 1995). This prompted research into the safety record of weed biocontrol in New Zealand.

Fowler et al. (in press) presented a retrospective analysis of host range testing quality for 19 arthropod biocontrol agents released and established against alien weeds in New Zealand to determine whether testing methods used and the range of plant species tested were adequate by modern standards. Their analysis revealed weed biocontrol agents were subjected to generally appropriate host range tests, although there were several examples where, by modern standards, significant plant species were not tested. For example, although, the first three agents released in the 1920s and 30s were tested against several key native plant species, it was not until 1990 that native species became consistent components of all test plant lists. This analysis was used to predict the potential for biological control agent species to attack non-target plants. However, when Fowler et al. (in press) presented their data, field surveys to assess potential non-target attack had only been performed for six species (*Bruchidius villosus* Fabricius, *Exapion ulicis* L., *Cydia succedana* Denis & Schiffermüller, *Lochmaea suturalis* Thompson, *Tyria jacobaeae* L., and *Longitarsus jacobaeae* Waterhouse).

The lack of monitoring of non-target impacts in most weed biocontrol programmes has led to the suggestion that the few examples of non-target impacts must be "a miniscule fraction of those that have occurred" (Simberloff & Stiling 1996). For this reason, surveys were conducted to test for non-target feeding from 14 additional biological control agents that had not previously been surveyed (13 species, to complete the surveys of Fowler et al. (in press), plus one additional species). Results of these surveys and recent developments regarding the gorse pod moth, *C. succedana,* are also discussed.

METHODS

Surveys were conducted throughout New Zealand, focused on plants that are closely related to the target weeds which are most at risk of non-target attack (Pemberton 2000; Briese & Walker 2002; Louda et al. 2003). These surveys tested for non-target feeding from the following 14 species.

(i) Thistle-feeding agents. New Zealand has no native thistles and the only valued plant in the tribe Cardueae in New Zealand is the minor crop *Cynara scolymus* L. (globe artichoke). Therefore, to test for non-target attack from the nodding thistle receptacle weevil *Rhinocyllus conicus* Fröhlich, the nodding thistle crown weevil *Trichosirocalus mortadelo* Alonzo-Zarazaga & Sánchez-Ruiz, the nodding thistle gall-fly *Urophora solstitialis* L. and the Scotch thistle gall fly *Urophora stylata* Fabricius growers of *C. scolymus* were contacted. All growers reported that they experience no insect damage on their crops (despite being in areas where thistle biocontrol agents are present). A grower in Ohinewai (37°29'S 175°09'E) who had abandoned his crop, which was therefore untreated with pesticides, was also located. Foliage from 30 *C. scolymus* plants at this site was examined for signs of damage by *T. mortadelo* and 100 flower heads were examined for galls and *R. conicus* eggs. A further 30 flower heads were removed and dissected in the laboratory.

(ii) The old man's beard leaf-miner *Phytomyza vitalbae* was searched for on the following native clematis species: *Clematis foetida* Raoul, *C. paniculata* J.F.Gmel, *C. forsteri* J.F.Gmel, *C. petriei* Allan, *C. marata* J.B.Armstr, *C. cunninghamii* Turcz and *C. quadribracteolata* Colenso. Leaf mines were collected from old man's beard and native clematis species throughout New Zealand and flies were reared out and identified.

(iii) The alligator weed flea-beetle, *Agasicles hygrophila* Selman & Vogt, and stem-mining moth, *Arcola malloi* Pastrana, were searched for on *Alternanthera sessilis* (L.) Roem. & Schult., the only plant congeneric with alligator weed (*A. philoxeroides* (Mart.) Griseb.) in New Zealand, growing at Lake Waiporohita (34°54'S 173°20'E) in Northland.

(iv) The gorse spider mite, *Tetranychus lintearius* Dufour, was searched for on commercial bean crops growing near Lincoln, Canterbury, within 5 m of gorse hedges infested with these mites.

(v) The ragwort seed-fly *Botanophila jacobaeae* was searched for on *Senecio bipinnatisectus* and *Senecio vulgaris* growing sympatrically at a range of sites near Rotorua.

(vi) The Mexican devil weed (*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.) gall fly, *Procecidochares utilis* Stone, was searched for on Mist flower, *Ageratina riparia*(Regel) R.M.King & H.Rob.

(vii) The mist flower gall fly *Procecidochares alani* Steyskal was searched for on *Ageratina adenophora* (Spreng.) R.M.King & H.Rob.

(viii) St Johns wort biocontrol agents, the lesser and greater St John's wort beetles (*Chrysolina hyperici* Forster and *Chrysolina quadrigemina* Suffrian, respectively) and the St John's Wort gall midge (*Zeuxidiplosis giardi* Kieffer), were searched for on *Hypericum japonicum* Murray and *H. gramineum* G. Forst.

In addition to the above surveys, recent developments regarding the gorse pod moth, *Cydia succedana* Denis & Schiffermüller are presented. This included extensive surveys of plants, such as *Sophora microphylla* Ait., *Clianthus puniceus* (G. Don) Sol. Ex Lindl., and several *Carmichaelia* R. Br. species, that are not closely related phylogenetically to the main host plant, gorse (*Ulex europaeus* L).

The various detection methods employed mirrored those used successfully to detect establishment of the agents on their target weeds and will be reported in detail elsewhere. Generally, sites were selected where the agent, the target weed and the potential non-target species were all present. Where records indicated the agent dispersed well, it was assumed that any substantial stand of the non-target plant was exposed to the agent, even if the target weed occurred several kilometres away. For more cryptic agents, plant material was collected and/or dissected for larvae. Where the identity of dissected larvae could be confused, they were reared through to adults to confirm identifications.

RESULTS AND DISCUSSION

Testing adequate/no or minor non-target effects predicted

There were 11 species where specificity testing was considered adequate (i.e. appropriate tests were conducted and key test plants were tested) and the tests reliably predicted agent safety (Table 1). Indeed, predictions erred on the side of caution in three out of four cases where minor non-target attack was predicted but none was observed. In the fourth case, old man's beard leaf-miner flies (*Phytomyza vitalbae*) were reared from *Clematis foetida* growing at one site on the Banks Peninsula. However, the level of attack was considered unlikely to have any impact on *C. foetida* populations. Furthermore, no attack was recorded at another Banks Peninsula site and at seven sites on the North Island, including one site where *P. vitalbae* was abundant and *C. foetida* and Old Man's Beard (*Clematis vitalba* L.) were growing intertwined. The sporadic nature and low level of attack appears to justify the prediction that *P. vitalbae* may occasionally mine other *Clematis* species, but can only persist on *C. vitalba* (Hill et al. 2001).

Testing inadequate/no non-target effects predicted

There were four species where specificity testing was considered inadequate and the tests had predicted no non-target effects (Table 1). The Scotch broom (*Cytisus scoparius* L. (Link)) seed-beetle (*Bruchidius villosus*) was recorded attacking tagasaste *Cytisus proliferus* L. f., an introduced minor fodder crop. In 'choice tests', beetles laid eggs on broom in preference to tagasaste. However, in New Zealand, tagasaste produces pods before broom so beetles emerging early from hibernation are given a 'no choice' scenario in the field. This scenario was not tested in pre-release feeding trials and indicates that choice tests alone are inappropriate when there is asynchrony in phenology between the test and target plants (Haines et al. in press).

Similarly, gorse pod moth (*Cydia succedana*) larvae were also found attacking other introduced legumes, such as Scotch broom and tree lupin (*Lupinus arboreus* Sims.). Our extensive surveys have indicated no native legume species are attacked by *C. succedana* (or *B. villosus*). The reasons for this attack are currently being investigated, but appear complex; like the broom seed-beetle, it may be due to asynchrony between the target plant and other species. However, moths introduced into New Zealand were sourced from both England and Portugal. There may be issues regarding the provenance of insects since *C. succedana* was recently split into two species on the basis of differences in the structure of the genitalia of male moths (Razowski 2002). The other species is *C. ulicetana* Haworth). Moths resembling both of these species were collected in New Zealand, during our non-target surveys. Furthermore, there are forms of difficult assignation present in the Iberian Peninsula that would require some research to determine their taxonomic status (J. Baixeras, pers. comm.).

In contrast, the ragwort seed fly (*Botanophila jacobaeae*) and alligator weed beetle (*Agasicles hygrophila*) were only recorded feeding on their target plants (Table 1). However, laboratory feeding-tests indicated the naturalised exotic species *Alternanthera sessilis* should be an acceptable food plant for the alligator weed beetle (Q.E. Paynter, unpubl. data). Absence of attack in field conditions may be due to the alligator weed beetle being restricted to very humid sites, so that it is only effective on floating mats of alligator weed (Julien et al. 1992). *Alternanthera sessilis* does not form floating mats. Specificity here seems to depend on ecological, rather than physiological host-range.

TABLE 1: Predicted and observed non-target feeding for 20 arthropod biological control agent species established in New Zealand. Testing standard: G=good or acceptable host-specificity testing; I=inadequate host-specificity testing. N=no non-target feeding predicted; M= minor and/or sporadic non-target feeding predicted; S=potentially serious impacts on non-target plants.

Species	Testing standard	Potential non-target feeding predicted	Non-target feeding observed
Exapion ulicis[1]	G	N	None
Procecidochares utilis	G	N	None
Procecidochares alani	G	N	None
Rhinocyllus conicus	G	N	None
Trichosirocalus mortadelo	G	N	None
Urophora solstitialis	G	N	None
Urophora stylata	G	N	None
Agasicles hygrophila	I	N	None
Botanophila jacobaeae	I	N	None
Bruchidius villosus[1]	I	N	Yes
Cydia succedana[1]	I	N	Yes
Lochmaea suturalis[1]	G	M	None
Longitarsus jacobaeae[1]	G	M	None
Phytomyza vitalbae	G	M	Yes, minor and rare
Tetranychus lintearius	G	M	None
Arcola malloi	I	M	None
Tyria jacobaeae[1]	I	M	Yes, sporadic
Chrysolina hyperici	I	S	None
Chrysolina quadrigemina	I	S	None
Zeuxidiplosis giardi	I	S	None

[1]Data from Fowler et al. (in press).

Testing inadequate/non-target damage predicted

For two species, minor non-target damage was predicted and specificity testing was considered flawed (Table 1). However, there was no non-target feeding by the alligator weed moth *Arcola malloi* detected on *A. sessilis*. In contrast, cinnabar moth larvae, *Tyria jacobaeae*, were recorded eating native fireweeds, such as *Senecio minimus* Poir and *S. biserratus* Belcher (Fowler et al. in press). Unusually for such an early biological control programme, eight native *Senecio* species were tested before the moth's release in 1929 (Miller 1970). Unfortunately, at the time both *Senecio minimus* and *S. biserratus* were placed in a different genus, *Erechtites* (Allan 1961), and were not tested. Furthermore, only one of the original eight *Senecio* species, *S. lautus* Willd., is still classified in the genus *Senecio* (Webb et al. 1988), so it is perhaps not surprising that the risk to *Senecio* species was underestimated. Fortunately, adult moths do not oviposit on *Senecio minimus* and *S. biserratus*, so the non-target attack is very sporadic 'spill-over' that occurs when wandering larvae are forced to search for more food, following defoliation of their normal host-plant, ragwort (*Senecio jacobaeae* L.).

Finally, there were three species where severe non-target damage was predicted and specificity testing was considered flawed (Table 1). Two native plants related to St John's wort (*Hypericum perforatum* L.), *Hypericum japonicum* Murray and *H. gramineum* G. Forst., were not tested before release of the lesser and greater St John's wort beetles (*Chrysolina hyperici* Forster and *Chrysolina quadrigemina* Suffrian, respectively) and the St John's Wort gall midge (*Zeuxidiplosis giardi* Kieffer), so there is the potential for serious non-target damage to these species. Surveys are ongoing but to-date several

H. japonicum sites in both the North Island and South Island and one *H. gramineum* population in the South Island have been visited and no non-target damage was recorded. However, in Australia, greater St John's wort beetles have been recorded feeding on *H. gramineum* growing close to St John's wort (A.J. Willis, pers. comm.). This may not occur in New Zealand, because the greater St John's wort beetle is adapted to warmer climates and the lesser St John's wort beetle is consequently the most abundant agent. However, since there is only data from one *H. gramineum* locality, it is too early to assess the impact of these agents on native *Hypericum* species in New Zealand.

CONCLUSIONS

Past investigations of non-target effects of weed biocontrol agents in New Zealand have been sporadic, with systematic surveys typically carried out only at a local scale if a report of suspected non-target damage was received. Investigation of non-target effects is now an integral part of biological control practice in New Zealand. With more rigorous regulatory legislation in place, it is important that a good past safety record for weed biocontrol agents can be demonstrated, and that the methods used for host specificity testing deliver a reliable assessment of risk. This survey indicates that the overall reliability of host-range testing in past weed biocontrol programmes for New Zealand has been high. Furthermore, the two cases of non-target attack recorded on native plant species were predictable and their impacts minor. The risk of non-target attack to native species appears negligible for targets that are only distantly phylogenetically related to native New Zealand flora (e.g. gorse and Scotch broom). However, lessons have been learnt – particularly from the unpredicted impacts of the broom seed-beetle and the gorse pod-moth. Future testing protocols can be improved to enhance safety as follows:

1. Ensure that no-choice tests are performed, especially where there is asynchrony in phenology (e.g. timing of flowering) between the target weed and non-target plants.
2. Use molecular techniques to reduce the possibility of cryptic species or different host-races being inadvertently introduced.

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