HOW SAFE ARE BIOCONTROL AGENTS FOR WEEDS?

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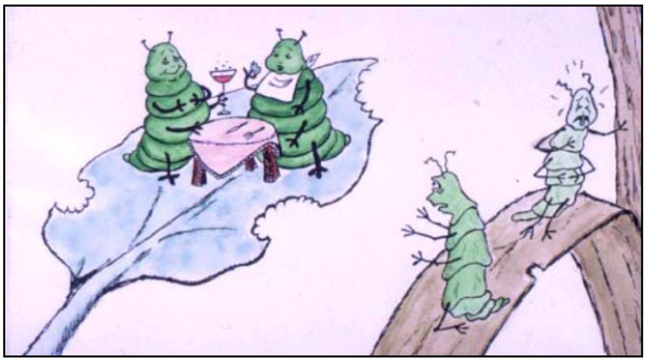
What are they going to eat next?

To some people, biological control sounds highly risky. The introduction of biocontrol agents for weeds is often directly compared with the introduction of rabbits or ferrets, leading to fears of further ecological disasters. In reality, fear of damage to crops has meant that host-specificity has always been a desired trait for weed biocontrol agents. Biocontrol of weeds consequently has an excellent safety record and has provided many benefits.

Safety issues are foremost in the minds of biocontrol of weeds researchers, and they usually only consider specialist feeders for introduction. These specialists have co-evolved with their host plants over a long period of time and have developed adaptations allowing them to only utilise that host plant and sometimes close relatives of that host plant. This specialisation makes it difficult for them to change host, and the chance of this happening has been calculated at between one in ten million, and one in one-hundred million (the risk of native species unexpectedly becoming a problem is the same).

Biocontrol agents are unlikely to ever run out of food because they are unable to eradicate their host plants. This is because it is difficult for them to find or severely harm every plant. If biocontrol is successful, plants become rarer and harder for agents to find, and the agent populations reduce accordingly.



A new equilibrium forms between the abundance of agents and their host plants.

How can you be sure that they won't eat anything else?

Researchers rigorously test all proposed agents to assess the risk of damage to non-target plants. It is not feasible to test every plant species in New Zealand, but a set of internationally accepted procedures has been developed to help researchers choose a suitable shortlist of test plants.

Plants that are closely related to the target weed are most at risk of non-target attack and, therefore, are the first plant species to be tested, followed by increasingly more distantly related species until the limits of a species' host range are established. When there are potentially many related species to test, factors such as plant morphology, biochemistry and distribution may be used to select the best representative plant species.

Researchers carefully consider the biology of an agent and its behaviour when deciding on the most appropriate kinds of tests to use. For agents such as fungi that disperse passively, no-choice tests (where agents are given the option of feeding on an alternative host or starving) are considered appropriate, because they are continually exposed to no-choice situations in real life. For agents that actively disperse, no-choice tests are still routinely used to determine what plants can support development. However, choice tests (where agents are given the option of feeding on their host and one or more alternative hosts) may also be used as they are considered more appropriate because the agents are able to choose in real life. Nevertheless, care is needed when interpreting the results of choice tests (see *Bruchidius villosus* example, below).

Some scientists believe that safety tests represent extreme and unnatural conditions and usually overestimate rather than underestimate the real host range of control agents. Often, tests can give "false positives" when the agents attack plants under artificial experimental conditions that they have never actually been known to attack in real life. This was the case with the gorse spider mite (*Tetranychus lintearius*), which during testing laid eggs on dwarf beans (*Phaseolus vulgaris*), although it never colonises bean plants under field conditions. For this reason, both indoors and outdoors tests (in the native range of the agent) may be carried out to build up a more comprehensive picture of the likelihood of attack.

If the testing suggests that a potential biocontrol agent is likely to damage other beneficial plants, then it is usually rejected. For example, an extremely promising stem miner (*Pirapion immune*) for broom was abandoned when tests showed that they might damage kowhai (*Sophora microphylla*). In other cases, some non-target attack may be acceptable if more damage may be caused by not controlling the weed. For example, the broom leaf beetle (*Gonioctena olivacea*) and broom shoot moth (*Agonopterix assimilella*) were cleared for release even though they may cause some damage to other exotic legumes such as tree lucerne (*Cytisus proliferus*).

See *Conflicts of interest*.

Pirapion immune was rejected

Have they ever got it wrong?

To date there have been more than 2000 biocontrol programmes for more than 260 weed species worldwide, using over 600 different agents (insects, mites and fungi), and for the vast majority no unpredicted host change has occurred. There are only eight reports of insect agents attacking non-target plants that were not predicted by safety-testing prior to release, (which was generally inadequate by modern standards), including two cases in New Zealand (Table 1). Most of these attacks were only transitory, 'spill-over' attack, a phenomenon that is occasionally seen when plant-feeding species colonise a new habitat and have not caused significant economic losses.

Of the 58 fungal pathogens that have been released for weed biocontrol worldwide, none have caused unexpected non-target damage.

Overall, the benefits gained from releasing biological control agents have far outweighed any damage caused. Weed biocontrol researchers are continually reviewing the knowledge gained from both past experience and new studies to refine best practice, develop more sophisticated tests that reflect more accurately real-life situations, and improve their interpretation of the results obtained.

There are every now and then cases of mistaken identity where damage to plants is not caused by biocontrol agents, but something that looks similar.

There appear to be only two recent examples of potentially significant effects on native non-target plant species from biological control agents. The receptacle weevil *Rhinocyllus conicus* attacks native thistles (*Cirsium* spp.) in the USA. The potential impact on native thistles was anticipated in the 1960s but not considered important. This example highlights the fact that classical biocontrol is irreversible, and values can change.

The moth *Cactoblastis cactorum* attacks endangered native *Opuntia* spp. in Florida, which was also predicted by host-testing. The moth arrived in Florida either by natural dispersal following the deliberate release of the agent in several Caribbean islands, or was an accidental introduction, perhaps on ornamental *Opuntia*. This example highlights the need for cross-border effects of biocontrol releases to be considered.

See *Insects commonly mistaken for biocontrol agents*, *Fungi commonly mistaken for biocontrol agents.*

Table 1: Predicted and observed non-target attack in New Zealand

Species	Predicted	Observed
Alligator Weed beetle, *Agasicles hygrophila*	None	Minor spill-over
Broom Seed Beetle, *Bruchidius villosus*	None	Full utilisation on tree lucerne (minor consequences)
Californian Thistle Rust, *Puccinia punctiformis*	None	No
Gorse Pod Moth, *Cydia succedana*	None	Full utilisation on other exotic legumes (minor consequences)
Gorse Seed Weevil, *Exapion ulicis*	None	No
Hieracium Rust, *Puccinia hieracii* var. *piloselloidarum*	None	No
Mist Flower Gall Fly, *Procecidochares alani*	None	No
Mist Flower Fungus, *Entyloma ageratinae*	None	No
Mexican Devil Gall Fly, *Procecidochares utilis*	None	No
Nodding Thistle Crown Weevil, *Trichosirocalus horridus*	None	No
Nodding Thistle Gall Fly, *Urophora solstitialis*	None	No
Nodding Thistle Receptacle Weevil, *Rhinocyllus conicus*	None	No
Ragwort Seedfly, *Botanophila jacobaeae*	None	No
Scotch Thistle Gall Fly, *Urophora stylata*	None	No
Alligator Weed Moth, *Arcola malloi*	Potentially minor	No
Blackberry Rust, *Phragmidium violaceum*	Potentially minor	Minor spill-over
Cinnabar Moth, *Tyria jacobaeae*	Potentially minor	Minor spill-over
Gorse Spider Mite, *Tetranychus lintearius*	Potentially minor	No
Heather Beetle, *Lochmaea suturalis*	Potentially minor	No
Old Man's Beard Leaf Fungus, *Phoma clematidina*	Potentially minor	No
Old Man's Beard Leaf Miner, *Phytomyza vitalbae*	Potentially minor	Minor spill-over
Ragwort Flea Beetle, *Longitarsus jacobaeae*	Potentially minor	No
Greater St John's Wort Beetle, *Chrysolina quadrigemina*	Potentially major	No
Lesser St John's Wort Beetle, *Chrysolina hyperici*	Potentially major	Persists tenuously on native *Hypericum involutum* at one site. Impact appear minor
St John's Wort Gall Midge, *Zeuxidiplosis giardi*	Potentially major	No

Non-target surveys in New Zealand

In New Zealand, extensive follow up surveys have been undertaken to check for non-target damage. Non-target attack can be defined as transitory 'spill-over' feeding on plant species that cannot support agent populations and full utilisation.

So far, 20 invertebrate agents and five fungal agents (including three self-introduced species) have been surveyed and results have provided additional assurance that current best practice host-testing is a good indicator of what will happen in the field. Non-target attack was generally absent, even when some might have been expected (Table 1). The alligator weed beetle was observed feeding on *Alternanthera denticulata* and *A. nahui* at one site in Northland, causing minor spill-over damage. Non-target attack on native plants was not anticipated for this species because *Alternanthera denticulata* and *A. nahui* were not considered native to New Zealand when *A. hygrophila* was released. These plants are recent colonists that have been listed as native to New Zealand because it is possible that they arrived as seeds attached to birds migrating between Australia and New Zealand. Where minor non-target attack was anticipated, none was found in four out of eight cases. In the remaining four cases, minor non-target damage was expected and has been seen. Cinnabar moth (*Tyria jacobaeae*) larvae will occasionally spill-over onto attack native fireweeds *Senecio minimus* and *S. biserratus* when they have defoliated ragwort (*S. jacobaea*). Eight native *Senecio* species were tested before cinnabar moth was released in 1929, but recent advances in phylogenetics using molecular techniques have shown these plants to be quite distantly related to ragwort and inappropriate species to use for host-testing. Molecular plant phylogenetics has since revolutionised host-plant selection making such omission of key test plants unlikely nowadays.

Old man's beard leaf miner (*Phytomyza vitalbae*) will occasionally spill-over onto a species of native *Clematis* (*C. foetida*) (and on one occasion C*. forsteri*) but the damage is not significant. This non target attack mostly occurred within 4 km of old man's beard (*C. vitalba*), which is further than you would normally expect for such spill-over attack, owing to the exceptional dispersal abilities of this agent.

Minor non-target damage was predicted for the old man's beard fungus (*Phoma clematidina*) on closely-related ornamental *Clematis*. Studies have shown that fungi found damaging native and ornamental *Clematis* are not the fungus deliberately released against old man's beard and in fact there is no evidence that this fungus is still present in New Zealand.

Blackberry rust (*Phragmidium violaceum*) has self-introduced to New Zealand. Testing carried out before the rust fungus was released in Australia suggested that native *Rubus* and some cultivated thornless blackberry species here might be attacked. Some minor 'spill-over' damage has been observed on bush lawyer (*R. cissoides*) and a few blackberry species.

Of the three instances where potentially major non-target attack was expected with the St John's wort agents, because of what had occurred with these agents in the USA, surveys have so far confirmed one case where this may be true. The lesser St John's wort beetle (*Chrysolina hyperici*) does feed and lay eggs on the native *Hypericum involutum*, but the impacts appear to be minor. This agent was introduced in the 1940s without any testing of New Zealand plants beforehand, which would never happen now.

Only two agents have unexpectedly attacked other plants in New Zealand and we now understand the reasons why this occurred. Broom seed beetles (*Bruchidius villosus*) are attacking tree lucerne (*Cytisus proliferus*) seed, although again this is not significant to the plant. In New Zealand, tree lucerne produces pods before broom. This 'no choice' scenario was not tested in pre-release feeding trials, as 'choice' tests at the time were considered to be more useful. 'No choice' tests are always included now when there is potential for such a 'no choice' situation to arise. The gorse pod moth (*Cydia succedana*) is attacking several introduced closely-related legumes, including Scotch broom (*Cytisus scoparius*), French broom (*Genista monspessulana*), tree lupin (*Lupinus arboreus*) and trefoils (*Lotus* spp.). Field studies have revealed that gorse pod moth activity in New Zealand is often poorly synchronised with gorse flowering and non-target attack was most prevalent when gorse flowers and pods were absent. Although original specificity tests were performed on moths sourced from England, moths of Portuguese provenance were also released into New Zealand to improve genetic diversity. Testing has since revealed that the Portuguese moths have a slightly wider host-range that the UK moths. As a result, no agents would ever be released from a population that had not been thoroughly tested, even if it is the same species.

Cinnabar caterpillar on *S. bisseratus*

See *Cinnabar moth*, *Old man's beard leaf miner*, *Old man's beard leaf fungus*, *Blackberry rust*, *Broom seed beetle*, *Gorse pod moth*

Downstream effects

As well as direct effects where the biocontrol agent damages another plant, it is possible that there could be indirect non-target effects on ecosystems when the biocontrol agent becomes a food source, competitor, or disease vector. These are also referred to as 'ripple' or 'downstream' effects and may be positive or negative.

Currently, many believe that such intricate and often subtle effects are impossible to assess given the current level of knowledge of ecosystem function, but they are considered before biocontrol agents are released. Research into food webs is being undertaken and may allow predictive models to be developed in the future.

Successfully controlling a weed could be a negative outcome if it led to soil erosion or replacement by a worse weed. However, we know of no examples in New Zealand where this has occurred, and it has been rarely reported globally. The largest indirect effect caused by biocontrol agents is likely to be the restoration of native habitats as a result of a reduction in the problem weed.

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