

WHAT'S NEW IN

Biological Control of Weeds?

Issue 57 Aug 11

Broom Gall Mite, Lincoln

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Landcare Research
Manaaki Whenua

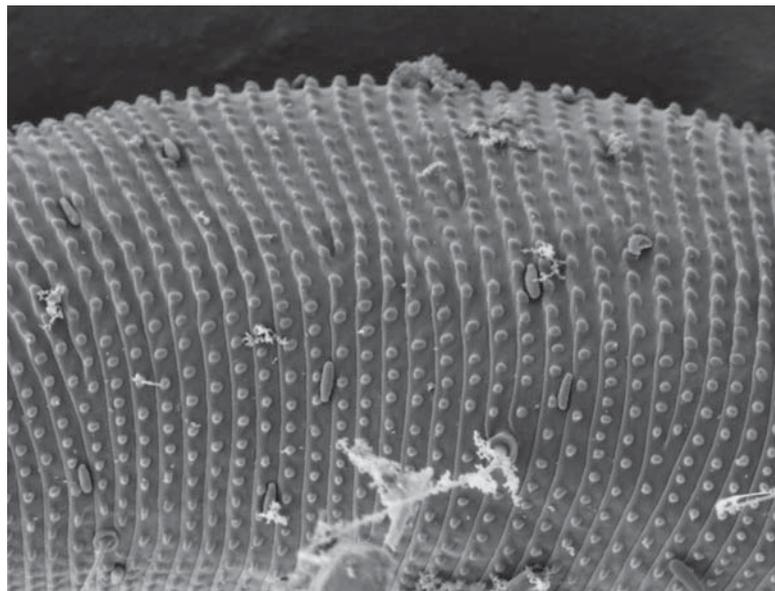
Untangling a Food Web on Broom

A gall mite (*Aceria genistae*) was introduced to New Zealand in 2008 to control broom (*Cytisus scoparius*) and has established readily at many sites. The mites, which are so tiny you can't easily see them with the naked eye, cause broom plants to form cancer-like galls instead of healthy tissues. The death of whole branches and even entire broom bushes has been observed already at some sites, leading to much optimism and excitement. We suspect that an interaction between the mites and one or more plant pathogen may be responsible. Galls are occasionally seen on broom here, which are thought to be caused by plant pathogens, but little is known about them. These galls can be distinguished from gall mite galls as they are soft when squeezed rather than solid.

When a biocontrol agent establishes, it is inevitable that it will interact with many more organisms than just its target weed as it becomes part of a food web. Post-release field studies have revealed that the galls produced by the mite have become home already to a community of other mites and plant pathogens (bacteria and fungi). Spores that probably belong to a bacterium species have also been found on the bodies of the gall mite. This raises many interesting questions, which have become the basis of a new project, now underway:

- What pathogens are already responsible for galls on broom?
- Can the mite move pathogens between host plants?
- Where did the pathogens found in the galls come from? Were they introduced accidentally with the mite, or already here?
- Will the mite and the pathogens both weaken the plant so that biocontrol works better than was expected, or, could infestation by mites make the plant less susceptible to disease (as was observed by Jane Barton and Freda Anderson when working with mite-infested Chilean needle grass plants)?

A predatory mite (*Typhlodromus caudiglans*) has also been found living in the galls formed by the broom gall mite. This predatory mite, which is not known to occur in the home range of the broom gall mite in France, may reduce the gall mite's efficacy on broom. And, if that isn't complicated enough, there are other invertebrates present in the galls, which typically feed on fungi, including mites that feed on both fungi and other mites. These fungivorous mites could in turn become food for the predatory mite. This study will examine whether these additional invertebrates are likely to have a positive or negative impact on broom biocontrol. Impact assessment studies of biocontrol agents are usually, by necessity, focused on the direct impacts of the agents on the target weed and other plants. This project is unique in that it will explore the wider interactions of the agent in



Electron micrograph showing spores tucked into creases on the surface of a broom gall mite.

the food web it has now joined. The interactions between such minuscule creatures may not seem very important, but ultimately the ability of the gall mite to control broom may well be determined by them. In addition, we want to examine the effect of the introduced biocontrol agent on local fauna to ensure that it is not having a negative impact on indigenous biodiversity. It is hoped that this study will help us learn more about why some biocontrol agents are more successful than others, and hence help us to get better at picking winners in the future e.g. there is a little known gall mite on old man's beard in Europe we plan to study.

Since this project examines a wide range of organisms, it will involve a wide range of scientists: ecologists, plant pathologists, acarologists (who study mites) and some students. Interesting discoveries are bound to be made when people from different branches of biology work together. It has been noted that the closer one looks at food webs, the more complexity one sees. To quote Augustus De Morgan (who was himself quoting Jonathan Swift): "Great fleas have little fleas upon their backs to bite 'em, and little fleas have lesser fleas, and so ad infinitum." This project will be an important step towards better understanding this complexity.

This project is funded by the Ministry of Science and Innovation through the Beating Weeds Programme and Landcare Research's Capability Fund.

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Gall-formers on Black Wattle: Uninvited but Welcome

Black wattle (*Acacia mearnsii*) was planted widely in the Waikato in the late 19th and early 20th century as its bark was useful for tanning. The tree quickly escaped from plantations and naturalised. While black wattle is still sometimes planted for firewood or as an ornamental tree, it is known to be invasive. A native of Australia, this tree has become problematic in so many other countries that it is included in a list of “100 of the world’s worst invasive alien species”, and until recently it was probably only a matter of time before it lived up to its reputation here too.

On a recent visit to New Zealand, Dr Robin Adair (Department of Primary Industries, Australia) noticed a tiny gall-forming insect on black wattle trees near a motorway in Hamilton. Robin recognised it as the tiny floret galler (*Dasineura rubiformis*) as he helped to formally describe and name it in Australia. The insect develops in the ovaries of wattle flowers causing them to form sterile galls instead of seeds. The galled flowers look a bit like berry fruits, hence the name ‘rubiformis’. “I could tell that the insect had been present for at least 2 years because there were old, mummified galls from previous years as well as fresh new ones,” explained Robin. The fly is likely to have self introduced here and already be quite widespread, as it disperses readily. Adults emerge when wattles are flowering in the spring, and they mate, deposit eggs and die within a few days. Larvae develop slowly and don’t emerge from the galls until the following winter when they pupate in the soil.

Gall-forming flies are common on *Acacia* species and most have a narrow host range. The tiny floret galler only attacks three *Acacia* species: *A. mearnsii*, *A. irrorata*, and *A. paramattensis*. These three species are all very closely related (in the subgenus Phyllodineae, section Botrycephalae) and they all have bipinnate leaves. *A. irrorata* is not present in New Zealand and *A. paramattensis* has naturalised but is not particularly common or useful here, so the tiny floret galler should not cause problems for any valued acacias. In any case, the actual trees are not harmed, with only seed production affected. This gall former has been deliberately released in South Africa where it is considered to be a successful biocontrol agent for black wattle.

Rust fungi in the genus *Uromycladium* also produce galls on black wattle. Seven species have arrived from Australia and attack wattles here. Four of them cause disease symptoms (lesions and pustules/galls) on black wattle: *Uromycladium acacia*, *U. alpinum*, *U. notabile* and *U. robinsonii*. Of these, *U. notabile* causes the most damage. Indeed, 1800 ha of black wattle planted in the hope of starting a tanning industry



Galls caused by the tiny floret galler on *Acacia mearnsii*.

had to be felled in the 1920s because of heavy infection by this pathogen. *U. nobile* causes large blackish/brown galls (typically 2–8 cm in diameter, but they can get as big as 35 cm) on leaf petioles, stems, branches and mature seed pods. Galls continue to grow for several seasons and restrict water movement through the tree. Lack of water results in poor growth beyond the galls, and when infection is severe, whole trees can be killed in a couple of years. Like the tiny floret galler, *U. notabile* is restricted in its host range to a subset of *Acacia* species with bipinnate leaves.

No studies have been done on the impacts of *Uromycladium* gall rusts or the tiny floret galler on black wattle in New Zealand. However, it is probably safe to say that both are useful additions to our fauna given black wattle’s weedy reputation. We would be interested to hear about any additional sightings of the tiny floret galler here. Also keep an eye out for other interesting beasts on acacias here, as other natural enemies are also likely to make their way over the ditch in the future.

For more information about gall flies that attack acacias see: Kolesik P, Adair RJ, Eick G 2005. Nine new species of *Dasineura* (Diptera: Cecidomyiidae) from flowers of Australian *Acacia* (Mimosaceae). *Systematic Entomology* DOI:10.1111/j.1365-3113.2005.00287.x

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Choosing the Best Environmental Weed Targets for Biocontrol

New Zealand environmental weeds are the latest group of plant pests to come under the spotlight for improving prioritisation of targets for biocontrol. Australian and Pacific weeds and New Zealand aquatic weeds have already been ranked in terms of suitability for biocontrol (see *Deciding Which Weeds to Target for Biocontrol*, Issue 48, and *Prospects for Targeting Aquatic Weeds*, Issue 56, respectively) and much the same method was used here, with a few improvements. It is hoped that the updated scoring system can eventually be used to prioritise all weeds in New Zealand.

As for the previous weed groups studied, the ranking system incorporates measures of the weed's impact (importance), how likely biocontrol is to be successful (feasibility), and the likely effort involved (cost). To determine weed importance, we asked representatives from all Department of Conservation (DOC) conservancies and from regional, district or city councils to list their top ten environmental weeds in terms of perceived impacts and difficulty to control. Some chose to include weeds that also affect the productive sector. For each conservancy or council area the top ten were then scored with the weed ranked at the top of the list allocated 10 points, the second 9 points, and so on. These values were then added together to give a DOC score and a Council score and then combined to give an overall weed impact value (see Table 1).

Several steps were needed to determine the feasibility and cost of biocontrol scores for each weed. First a dataset was compiled from weed biocontrol programmes worldwide. The dataset used for the initial Australian project only used data from weed biocontrol programmes in Australia, South Africa and the USA. "The present project also includes data from programmes in Canada, Hawai'i, New Zealand, Russia, Indonesia and Papua New Guinea," said Quentin Paynter, who led the project. The benefit of a larger dataset is not just that it contains more replicates of data, but also that it covers a greater diversity of weed species. From this much larger dataset, and using improved statistical techniques (relative to the earlier prioritising projects), the factors that have the greatest influence on the cost and impact of biocontrol have been identified.

Examples of factors that will increase the likely cost of a biocontrol programme are: conflicts of interest – whether there is opposition to controlling the weed; and if the weed has valued close relatives. If the weed is the target of a biocontrol programme elsewhere this will decrease costs as research

into natural enemies has already been conducted and damaging biocontrol agents identified. Examples of factors that increase the impact biocontrol is likely to have on a weed are: if it reproduces clonally rather than sexually; and if it is an aquatic or wetland species. If the plant is a major weed in its home range biocontrol is likely to have a lesser impact than if it is uncommon at home. These characteristics are not difficult to determine and, in combination, are strong predictors of the cost and impact of biocontrol. Data on each of these factors were collected for every weed and transformed into an index to give a biocontrol effort and a biocontrol impact score.

Tradescantia (*Tradescantia fluminensis*) tops the list as the best environmental weed target for biocontrol in New Zealand (see Table 1). Some characteristics that contribute to this ranking include the fact that it is not considered weedy in its native Brazil, is a problem in many regions of New Zealand, and spreads vegetatively here. The first characteristic indicates that there must be something keeping it in check in its home range, which may have potential as a biocontrol agent, and the second raises its importance. The third characteristic means it does not have a great range of genetic diversity in New Zealand and therefore is less likely to evolve resistance to biocontrol. Two aquatic weeds take up second and third places – lagarosiphon (*Lagarosiphon major*) and purple loosestrife (*Lythrum salicaria*), respectively – reinforcing how aquatic weeds make good biocontrol targets.



Tradescantia tops the list as the best environmental weed target for biocontrol in New Zealand.

Table 1. Top 20 best environmental weed targets for biocontrol in New Zealand.

Weed	Combined weed impact score	Biocontrol effort score	Biocontrol impact score	Overall score	Notes
Tradescantia (<i>Tradescantia fluminensis</i>)	119	25	77.2	367.47	Current target
Lagarosiphon (<i>Lagarosiphon major</i>)	45	13	99.6	344.77	Feasibility study completed
Purple loosestrife (<i>Lythrum salicaria</i>)	14	4	80	280.00	Successfully targeted in Canada and USA
Japanese honeysuckle (<i>Lonicera japonica</i>)	103	24	50.7	217.59	Current target
African club moss (<i>Selaginella kraussiana</i>)	115	29	50.7	201.05	Feasibility study completed
Barberry (<i>Berberis</i> spp.)	52	15	50.7	175.76	Current target
Wild ginger (<i>Hedychium</i> spp.)	57	19	50.7	152.10	Current target
Chilean flamecreeper (<i>Tropaeolum speciosum</i>)	89	31	50.7	145.56	Feasibility study completed
Climbing asparagus (<i>Asparagus scandens</i>)	102	36	50.7	143.65	Abandoned target due to lack of agents
Willow (<i>Salix</i> spp.)	91	24	37	140.29	Feasibility study completed for <i>S. cinerea</i>
Spartina (<i>Spartina alterniflora</i>)	37	20	73.1	135.24	Preliminary data indicate biocontrol has big impact in USA
Oxygen weed (<i>Egeria densa</i>)	28	15	63.5	118.53	Feasibility study completed
Alligator weed (<i>Alternanthera philoxeroides</i>)	50	34	77.2	113.53	Current target
Moth plant (<i>Araujia hortorum</i>)	48	24	50.7	101.4	Current target
Nodding thistle (<i>Carduus nutans</i>)	28	14	50.7	101.4	Current target
Japanese knotweed (<i>Fallopia japonica</i>)	27	21	77.2	99.26	Biocontrol agent recently released in UK
Golden and coastal wattles (<i>Acacia longifolia</i> and <i>A. sophorae</i>)	15	13	80.0	92.31	Feasibility study completed for <i>A. longifolia</i>
Hawkweed (<i>Hieracium</i> spp.)	22	21	77.2	80.88	Current target
Giant cane (<i>Arundo donax</i>)	17	21	99.6	80.63	Biocontrol agents recently released in USA
Banana passionfruit (<i>Passiflora</i> spp.)	51	34	50.7	76.05	Current target

How does this list compare to the weeds that are presently the focus of biocontrol programmes in New Zealand? Within the top 20, eight species (40%) are currently the target of biocontrol programmes. One more, climbing asparagus (*Asparagus scandens*), was a target but has since been abandoned after failure to find suitably damaging and host-specific natural enemies in its native range (see *Climbing Asparagus Dropped as Biocontrol Target*, Issue 50). A number of others are not widespread weeds, so investment in biocontrol has not been a priority, or aquatics, which were until recently thought to be unsuitable targets. Beyond the top 20 there are 14 weeds for which biocontrol programmes are operating, some for decades: e.g. gorse (*Ulex europaeus*) ranked 22nd, broom (*Cytisus scoparius*) ranked 28th, and Californian thistle (*Cirsium arvense*) ranked 68th. "Having a number of biocontrol targets, into which we have invested a lot of time and effort, rank below the top 20 raises questions about whether limited biocontrol resources are being used in the most effective way," said Quentin.

It is important to get the right balance between targeting the most important weeds and targeting the best biocontrol targets. These are not always the same. There are some weeds that we can predict will be severely impacted by biocontrol but which are not considered a big problem. Purple loosestrife is one of these; it was not rated highly by either DOC or councils but ranks as third most suitable target due to the success of the biocontrol programme against it in Canada and the United States. Over time it might become a more serious weed, so when do we act? Old man's beard (*Clematis vitalba*), by contrast, has a much higher weed importance score than any species in the top 20 (178) yet ranks 26th overall due to the greater effort required to develop the programme and because no high-impact agents have yet been found. It is useful to know up front if a greater effort is likely to be required so a project can be adequately resourced and expectations are appropriate.

The results of this prioritisation work are only as good as the information upon which they are based, and some rankings could change over time, for example if another country begins a project against a novel target and finds good agents. The characteristics of a weed are unlikely to change – i.e. a terrestrial plant is not about to take to the water – and nor are its natural enemies (we just need to find them!). How people value a weed is more likely to change and this could influence its impact score and, consequently, its ranking. It is important to note that because this ranking is based on council and DOC priorities and they were asked to focus on environmental weeds, it is likely to underestimate the importance of weeds that cross over to or largely affect the productive sector. We hope in the future to get even better at understanding the factors that make a weed vulnerable to biocontrol. Many factors have been suggested as possibly important (e.g. susceptibility to secondary disease), for which there is inadequate data and so they are not included in the current prioritisation framework, but may be added as refinements in the future.

We are always striving to improve the way we do things and this ranking project is a good starting point for helping us to focus our biocontrol energies in the most productive way. Some pragmatic decision-making will always be needed when deciding on what biocontrol projects to invest in. Ultimately the projects that go ahead are those which people are prepared to fund. Funding decisions are based on many factors including politics, regional needs, previous investment and timing, as well as science. One thing that is certain is the major funder of operational biocontrol programmes in New Zealand, the National Biocontrol Collective, can look forward to some interesting discussions when it meets later this year!

This project was funded by the Ministry of Science and Innovation's Beating Weeds Programme.

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Biocontrol Agents Released in 2010/11

Species	Releases made
Broom leaf beetle (<i>Gonioctena olivacea</i>)	11
Broom shoot moth (<i>Agonopterix assimilella</i>)	1
Broom gall mite (<i>Aceria genistae</i>)	22
Green thistle beetle (<i>Cassida rubiginosa</i>)	40
Californian thistle stem miner (<i>Apion onopordi</i>)	3
Gorse soft shoot moth (<i>Agonopterix ulicetella</i>)	5
Tradescantia leaf beetle (<i>Neolema oglobini</i>)	8
Woolly nightshade lace bug (<i>Gargaphia decoris</i>)	25
Total	115

Weevils Will Worry Darwin's Barberry

Testing has been completed of two weevils of interest for biocontrol of Darwin's barberry (*Berberis darwinii*), with pleasing results. Darwin's barberry's success as an invasive plant is in part due to its ability to produce large numbers of seeds, so these two weevils were chosen because they are able to target the weed's reproductive capacity. The flower bud weevil (*Anthonomus kuscheli*) is tiny and brown in colour with a striking pale stripe along its thorax and either side of its abdomen. It lays eggs in the flower buds in which the larvae feed. The seed weevil (*Berberidicola exaratus*) is also tiny but a uniform dark brown. Adult weevils lay eggs inside the fruit and the resulting larvae feed on and damage developing seeds. The two weevils appear to complement each other well. In Chile, the flower bud weevil has multiple generations a year, with the first adults emerging in early spring. Adults mate during flowering and larvae feed on flower buds preventing seed formation. The seed feeder has only one generation and emerges later to attack the remaining developing fruit.

Because of the biology of the weevils the host-testing was conducted at field sites in Chile by a colleague Dr Hernán Norambuena. Six sites were chosen for the variety of test plant species growing naturally there and additional species were either transplanted into the area or sourced in pots. The test plants included a range of *Berberis* species and plants from six closely related genera, both native and exotic species. Weevils were given a "no choice" environment by being placed on a sleeved branch or whole plant. No-choice host-testing presents an extreme, and somewhat unnatural, situation for the organism being tested – it must feed, or develop, on what is presented or die. As a result these tests may overestimate the likelihood of non-target attack. To counter this, plants of the test species were also examined at other sites for any sign of attack from either the flower bud or seed weevils when given a choice.

Both weevils look very promising in terms of their specificity. The seed weevil completed development from egg to larva on 5 of the 12 *Berberis* species tested in a no-choice environment, but larval survival was greatest on the target plant, Darwin's barberry. Other weevil species that are "ecological equivalents" to the flower bud and seed weevils are known to occur on other *Berberis* species and were around at the time of the field testing. While steps were taken to remove these similar weevils before testing, some larvae may have gone undetected. The larval stages of these weevils look similar to the flower bud and seed weevils and their different food preferences may account for one or two unexpected testing results. However, no development was observed on plant species outside *Berberis*. "Field surveys confirm that self-sustaining populations are likely to only occur on Darwin's barberry," said Hernán.

When given no choice the flower bud weevil was found to be able to complete development on only Darwin's barberry and Japanese barberry (*Berberis thunbergii* 'atropurpurea'). "However, the no-choice test does appear to overestimate attack on Japanese barberry, which is one of the most common ornamental *Berberis* species in southern Chile, as I have never seen any evidence of developing flower bud weevil larvae on it when they were given a choice," said Hernán. Japanese barberry is sold as an ornamental species in New Zealand and while not currently considered a problem plant here it has become a problem in the USA, so it may have been useful if the weevil could attack it, as the plant may still become a thug here with time.

Even during no-choice tests neither weevil attacked or utilised any species tested from other families, or from different subfamilies or subtribes within Berberidaceae (barberry family). We are not sure if *Berberis glaucocarpa*, another species that is both a common hedge plant and a problem weed in some parts of New Zealand, will be attacked by either weevil, as this species was not available for testing in Chile. However, if it can attack this species, that will be a bonus. No native New Zealand plants are expected to be at risk as there are none closely related to Darwin's barberry.

An application to release both weevils is being prepared and is expected to be submitted to the Environment Protection Agency (formerly ERMA) by the end of the year. A suite of pathogens that have been found damaging *Berberis* species that may add additional pressure to the plant (see *Can We Take the Barb out of Barberry?*, Issue 47) will be studied further when funds permit.

This project is funded by the National Biocontrol Collective.

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Hernán and landowner Moises Durán set up sleeves containing weevils on a threatened native *Berberis*.

New Agents Approved

The Environmental Risk Management Authority became the Environmental Protection Authority on 1 July 2011, but not before approving the release of three new weed biocontrol agents in June. First up they granted approval to release a rust (*Uromyces pencanus*) against Chilean needle grass (*Nassella neesiana*). Marlborough District Council was the applicant for this one, with their region being the worst affected by this nasty invasive grass. It is hoped that the rust can be released in autumn 2012. The second approval was for a double application to release two additional beetles to attack tradescantia (*Tradescantia fluminensis*). Auckland Council was the applicant for the tradescantia leaf beetle (*Neolema ogloblini*) and did the honours again for the tradescantia tip beetle (*Neolema abbreviata*) and tradescantia stem beetle (*Lema basicostata*). It is hoped that both these beetles will be able to join the leaf beetle in the field later this year, and are expected to complement each other by attacking different parts of the plant. Like the leaf beetle both the new species were also infected with gregarine gut parasites but efforts to clean the colonies up are going well.

Both projects were funded by the National Biocontrol Collective.

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Funding Success

Recently the MAF Sustainable Farming Fund announced that it has approved two projects of importance to land managers in New Zealand. The Tutsan Action Group and National Pampas Biocontrol Initiative requested funds to look for potential biocontrol agents for tutsan (*Hypericum androsaemum*) and pampas (*Cortaderia jubata*, *C. selloana*) respectively. Both are multi-agency groups that formed because they felt something needed to be done about these serious weeds, and now both have funds for 3 years to explore whether biocontrol might be a solution. We will keep you posted on progress, in future issues.

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Newly approved tradescantia tip beetle (*Neolema abbreviata*).

Pamphlet Reprinted

We have recently updated and reprinted the pamphlet that explains about weed biocontrol in New Zealand in a nutshell and illustrates all the biocontrol agents currently available. The pamphlet is again printed in full colour on A2-sized paper, but can be folded up like a map. Copies of the pamphlet are being distributed with hard copies of this newsletter, and each member of the National Biocontrol Collective (regional councils nationwide and DOC) has been supplied with some to give away at their discretion. If you would like more copies of the pamphlet, please contact Lynley Hayes (hayesl@landcareresearch.co.nz or Ph 03 321 9694). An electronic version is also available from: http://www.landcareresearch.co.nz/research/biocons/weeds/documents/biocontrol_agents_reference_2011.pdf

BIOCONTROL AGENTS FOR
WEEDS IN NEW ZEALAND



A QUICK REFERENCE

Update on the Search for Potential Ginger Agents

A major step towards developing biocontrol for wild ginger (*Hedygium* spp.) has been made now that permission for export of potential control agents from India has been given. Colleagues at CABI – Europe UK, who are undertaking the wild ginger project in collaboration with Indian organisations (Indian Council of Agricultural Research/National Bureau Plant Genetic Resources and Department of Forests, Environment and Wildlife Management, Sikkim), have secured a Material Transfer Agreement (MTA) to export key biological material from India. “This step is significant as international expertise is needed to complement the Indian expert identifications of the natural enemies of interest, many of which are likely to be new to science, and the host range testing needs to be carried out in CABI’s quarantine facilities in England,” said Djami Djeddour, the project manager. Initial endorsement of the MTA was given by the Indian Department of Agricultural Research and Education (DARE) in April 2010 but had to be revised after it was realised that not all of the priority species listed had been properly reviewed, and to cover the full duration of the project. During this delay, only those species that had been initially approved were able to be exported to England. Once final approval was received from the facilitation committee and endorsed by DARE in November 2010, pinned specimens of other interesting natural enemies could then be sent to CABI and thereafter exported as live material. The most promising and damaging natural enemies found to date are largely arthropods, although a rarely occurring *Puccinia* rust found on kahili ginger (*H. gardnerianum*) seedlings is worthy of further study.

Of the initial species exported three appear to hold some promise. The large red and black weevil found chewing on kahili, white (*H. coronarium*,) and yellow (*H. flavescens*) ginger plants has been identified as *Tetratopus* sp. (previously tentatively identified as *Prodiocetes* sp., see *Ginger Project Heats Up*, Issue 52). This striking weevil appears to damage all parts of the plant. Large grubs, which are thought to be the larval stage, have now been found in the stems and fruit capsules. The weevil is yet to be properly host tested as the low number initially exported has made it difficult to establish a breeding population, so sourcing more weevils from India will be a priority.

A stem-miner, associated with shoot death, stunting, and flower abortion in the field, has now been identified as a frit fly *Merochlorops dimorphus*. It has only been found on kahili

ginger and affects 60–70% of some populations, despite predation and parasitism. Flies were exported as pupae and late-stage larvae as well as in cut stem material but again there have been problems trying to establish a breeding population. Adult emergence was low due to a combination of parasitism and high larval mortality. “Those that have emerged were released into a cage with kahili ginger plants from New Zealand and Hawai’i but so far there has been no sign of egg-laying,” said Dick Shaw, CABI entomologist. Again sourcing more of these insects from India will be a priority.

A leaf-feeding moth now identified as *Artona flavipuncta* was collected feeding gregariously on kahili ginger. Its identification has created considerable interest among taxonomists as this is a previously unrecorded host for this species. CABI have started host testing the moth, carrying out choice tests with shell ginger (or shell flower, *Alpinia zerumbet*) and kahili ginger from Hawai’i. The moth fed equally well on both plants and at times showed a slight preference for shell ginger. However, it is worthwhile continuing research into this moth as these are only preliminary results, we know there are monophagous species in this genus, and agents with a slightly wider host-range may be acceptable for New Zealand if not for Hawai’i.

Species that were exported from India once full approval was received are still in the process of being identified. Once identified, CABI can get an indication of their biology and



Artona flavipuncta gregarious larvae.

decide whether it is worth host testing them. They include a species of fungus gnat (*Prosciara* sp.) that was seen laying eggs on kahili ginger in the field and was the most common fly emerging from exported “dead hearted” ginger stems. “The biology of the fungus gnat family is not well known but the larvae tend to feed on dead plant material so the question is whether the gnat is causing the dead heart or whether it is feeding there once the stem has started dying,” said Dick. So far no egg laying or damage has been seen on kahili ginger plants in quarantine.

A small weevil has been tentatively identified as *Acythopus dehradunensis*. Two weevils in this genus have been released as biocontrol agents for ivy gourd (*Coccinia grandis*) in Hawai’i, Guam and the Northern Mariana Islands. CABI are hoping to be able to further investigate this weevil’s potential soon.

Mowing in the Rain

For years farmers have known anecdotally that mowing Californian thistle (*Cirsium arvense*) in the rain seems to provide better control than mowing it when it is dry. A recent AgResearch-led field trial investigated this observation quantitatively and the results agree. The project took place on 12 farms and involved three treatments: patches of Californian thistle mown in the dry, in the rain, or not mown at all. The following year, the thistle ground cover (stem density) in spring was 30% less in the wet-mown patches than in the patches mown in dry conditions. “It is great to have proven what has been suspected for a long time; now farmers can significantly increase the impact mowing is having on Californian thistle by using this simple, low cost technique,” said Graeme Bourdôt, project leader at AgResearch.

But why should this be the case? It is suspected that a pathogen may be responsible. The vascular wilt fungus *Verticillium dahliae* is commonly found on Californian thistle in New Zealand and researchers thought it was a likely candidate due to its biology. The wilt fungus produces spores inside the plant and they are released when it is damaged – such as being mown – and then dispersed by rain splash or on wet mower blades. The fungus then infects new plants through the wounds caused by mowing.

The researchers sampled for the wilt fungus during the trial but found no correlation between the wet mowing effect and the fungus’ abundance. It could be that a completely

In addition to natural enemies, plant material could finally also be exported through the MTA. Specimens of *Hedygium* species from a range of locations in India have been sent here to New Zealand, along with material from Hawai’i and commercially sourced plants from the UK. Our plant population geneticist, Gary Houliston, is undertaking molecular studies of ginger with the aim of providing diagnostic tools for the various species, which can be hard to tell apart from morphological features alone, and also in an attempt to determine the geographic origins of weedy populations.

This project is funded by the National Weed Biocontrol Collective and the Nature Conservancy of Hawai’i.

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Mowing thistles.

different pathogen or combination of pathogens causes the increased impact on Californian thistle. Many other damaging fungi and some bacteria have been collected from Californian thistle so there are many possibilities. To clarify this question, researchers are planning a field trial incorporating the presence and absence of the wilt fungus as well as the wet and dry mowing treatments and will also look for other pathogens that may be causing the effect. “If we can identify the specific fungus behind the effect then we could potentially turn it into a bioherbicide so all farmers can use it to maximise the benefits of mowing thistles in the rain,” said Graeme.

For more information including a video about this project see <http://www.agresearch.co.nz/our-science/biocontrol-biosecurity/weed-control/Pages/californian-thistle.aspx>.

This work was funded by Beef + Lamb NZ (formerly Meat and Wool NZ).

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New Weed Identification Key Online

A new interactive key has been developed that will be a big help for people who need to identify weeds in New Zealand. The computer-based online key draws on the National Pest Plant Accord (NPPA) Key, which was completed in July 2009 (see *Plant Identification Keys Now Online*, Issue 49), and the Department of Conservation's consolidated list of environmental weeds in New Zealand. "The new key covers more than 500 plant taxa (species, subspecies, varieties, hybrids and cultivars), including about 150 NPPA species, 330 environmental weeds, and many similar species and close relatives," said Murray Dawson, the lead developer. The key is available for use, free of charge, on the Landcare Research website (see www.landcareresearch.co.nz/research/biosystematics/plants/weedskey/index.asp or use the shortcut <http://tinyurl.com/weedkey>).

As with the original NPPA Key, which it replaces, the New Zealand Weeds Key was very much a team effort. Murray and Peter Heenan (of Landcare Research) worked with Trevor James (AgResearch), who provided the majority of images, Sheldon Navie (University of Queensland), who provided data from similar keys he has developed in Australia, and Paul Champion (NIWA), who provided expertise on aquatic species. All five authors provided images for the key and further illustrations were contributed by the Department of Conservation, Weedbusters, regional authorities, and overseas contributors. The key is well illustrated with about 9,000 images showing a range of features for each plant – e.g. plant form, leaf, floral, fruit and seed characteristics. Only 11 taxa lack images and these will be added when they become available.

The key works by selecting any of 48 characters and the 216 character states scored for each taxon. "For old man's beard (*Clematis vitalba*), for example, the character state for Plant Form is Vine and the character state for Leaf Arrangement is Opposite," said Murray, "It's really easy to use." The plant names follow the Landcare Research Ngā Tipu o Aotearoa – New Zealand Plants databases. There are several cases where the taxonomic names used in the new key are more recent than those listed in the NPPA manual and the Department of Conservation list of environmental weeds – both published in 2008. These name changes are recorded within the key (as synonyms in brackets) and in comparison tables (at www.landcareresearch.co.nz/research/biosystematics/plants/weedskey/species.asp).

The key includes links at the species level to related websites such as MAF Biosecurity New Zealand, the New Zealand

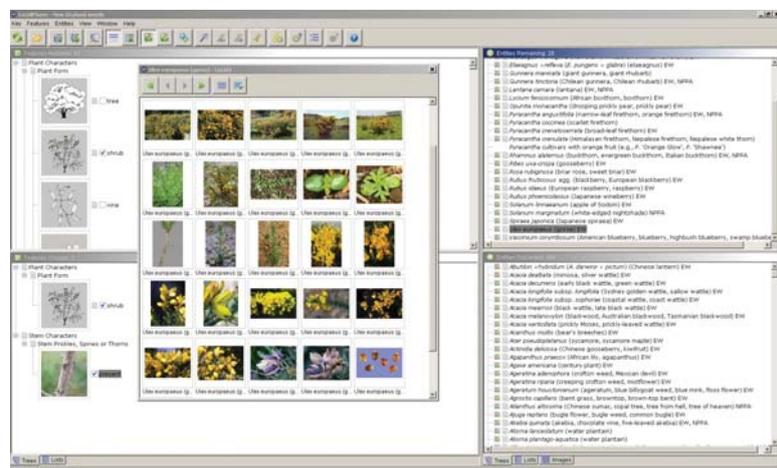
Plants databases, and Weedbusters New Zealand, all of which provide further information on the plants. A new feature also allows the user to retrieve lists of NPPA species and environmental weeds, the suffixes "NPPA" and "EW", respectively, having been added to the names of these plants within the key.

The new interactive key to the weed species of New Zealand is a unique and extensive resource. It is a powerful tool that makes it easy to identify weedy plants without having to learn complex botanical terminology.

Further online interactive keys are being developed at Landcare Research – these will also be free to use and are two-year projects. Murray Dawson, Jeremy Rolfe, and the New Zealand Native Orchid Group have started work on a key to the New Zealand native orchids – a group of difficult-to-identify plants with high conservation values. Also, a team led by David Glenny has started working on a key to flowering plant genera in New Zealand, covering both native and naturalised plants; sounds like a big job!

The development of this key was funded by the Terrestrial & Freshwater Biodiversity Information System (TFBIS) Programme and is based on Lucid™ software (developed by the CBIT in Australia). The TFBIS Programme is funded by the Government to help achieve the goals of the New Zealand Biodiversity Strategy, and is administered by the Department of Conservation.

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Keying out gorse using the new Weeds Key.

Spring Activities

Most biocontrol agents become active during spring, making it a busy time of year. Some activities that you might want to fit in over this time include:

Boneseed leafroller (*Tortrix* s.l. sp. "*chrysanthemoides*")

- Check release sites from mid-spring for feeding shelters made by caterpillars webbing together leaves at the tips of stems. Small caterpillars are olive-green in colour and become darker with two parallel rows of white spots as they mature. We would be very interested to hear if you find any severe damage to boneseed foliage.
- Caterpillars can be harvested if you find them in good numbers. Cut off infested boneseed tips and wedge them into plants at new sites. Aim to shift at least 500 caterpillars.

Bridal creeper rust (*Puccinia myrsiphylli*)

- Check bridal creeper infestations for bridal creeper rust, especially sites where it has not been seen before. Infected plants will have yellow and black pustules on the undersides of leaves and on the stems and berries. They may look sickly and defoliated.
- If need be you can spread bridal creeper rust around – for detailed instruction on how to do this see www.csiro.au/resources/BridalCreeperRustFungus.

Broom gall mite (*Aceria genistae*)

- Spring and summer are the best times to check plants at release sites for galls, which look like deformed lumps and range in size from 5 to 30 mm across. They will probably be fairly close to the release point. Occasionally galls can be found on broom that are not made by the gall mite, but these are much less dense. We are happy to help confirm the identity of any galls you find.



Broom shoot moth larva.

- If present in good numbers you may be able to begin harvesting and redistributing galls in late summer when they are mature. Aim to shift at least 50 galls, and tie them onto plants at the new site so the tiny mites can shift across.

Broom leaf beetles (*Gonioctena olivacea*)

- It might still be early days at some sites, but check release sites for adult beetles. They are 2–5 mm long and females tend to be goldish-brown while males have an orangey-red tinge – although colouration can be quite variable. Look for larvae in late spring – they are a crocodile shape and feed on leaves and shoot tips. Use a beating tray to help find this agent.
- We would not expect you to find enough beetles to be able to begin harvesting and redistribution just yet.

Broom seed beetles (*Bruchidius villosus*)

- Look for adult beetles gathering together on broom flowers or for eggs on the pods.
- If need be the beetles can be moved around fairly easily. Use a beating tray and a pooter to collect adults or put a large bag over a branch of flowers and give them a good shake.

Broom shoot moth (*Agonopterix assimilella*)

- Check broom shoot moth release sites, although it might still be early days for finding them at most sites. Late spring is the best time to look. Look for the caterpillars' feeding shelters made by tying twigs together with webbing and for the caterpillars inside. Small caterpillars are dark brown and turn dark green as they mature.
- We would not expect you to find enough caterpillars to be able to begin harvesting just yet.

Gorse soft shoot moth (*Agonopterix ulicetella*)

- Late November to early December is the best time to check release sites as the caterpillars are about half-grown. Look for webbed or deformed growing tips with a dark brown or greyish-green caterpillar inside. Please let us know if you find an outbreak of this agent anywhere that you didn't expect. We would especially like to hear how they are doing in the North Island and lower South Island.
- If they are not yet widespread, caterpillars can be moved around by harvesting infested branches or even whole bushes and wedging them in plants at the new site.

Gorse colonial hard shoot moth (*Pempelia genistella*)

- Late spring, before plants put on new growth, is the best time to check release sites as the green-and-brown striped caterpillars and their webs are at their largest. Please let us know if you find any, anywhere, as we still have only confirmed establishment at a few sites in Canterbury.
- If you can find the webs in good numbers, harvest infested branches and move these to new sites as help is needed to increase the moth's distribution. Late spring is the best time, when large caterpillars or pupae are present.

Green thistle beetles (*Cassida rubiginosa*)

- Check release sites for adult beetles, which emerge on warm days towards the end of winter and feed on new thistle leaves making round window holes. The adults are 6–7.5 mm long and green, but are quite well camouflaged against the leaf. The larvae also make windows in the leaves. They have prominent lateral and tail spines and a protective covering of old moulted skins and excrement.
- Beetles may have built up to harvestable numbers at some of the oldest sites so it may be possible to begin redistribution. Use a garden-leaf vacuum machine and aim to shift at least 50 adults in the spring. Be careful to separate the beetles from other material collected during the vacuuming process, which may include pasture pests.

Ragwort crown-boring moth (*Cochylis atricapitana*)

- No signs of establishment of this moth have been seen yet so it would be good to check release sites one last time. Look for rosettes with damaged centres and black frass or thickened stems and bunched leaves. If present the caterpillars should be most easily found by pulling apart damaged plants during August–September. They are creamy-white, with black heads that become brown when they are older, and are quite short and fat.

Ragwort plume moth (*Platyptilia isodactyla*)

- October is the best time to check release sites for caterpillars. Look for plants with wilted or blackened or blemished shoots with holes and an accumulation of debris, frass or silken webbing. Pull back the leaves at the crown of damaged plants to look for large hairy, green larvae and pupae. Also check where the leaves join bolting stems for holes and frass. Don't get mixed up with blue stem borer larvae



Woolly nightshade lace bug adults and juvenile.

(*Patagoniodes farinaria*), which look similar to plume moth larvae until they develop their distinctive bluish colouration.

- If present in good numbers the best time to harvest this moth is in late spring. Dig up damaged plants, roots and all. Pupae may be in the surrounding soil so retain as much as possible. We recommend shifting at least 50–100 plants but the more the greater the chance the moth will establish. Place one or two infested plants beside a healthy ragwort plant at the release site so any caterpillars can crawl across.

Tradescantia leaf beetle (*Neolema ogloblini*)

- Given that the first releases only went out last autumn it may well be far too early to find the beetle at release sites this spring, but no doubt some of you will be dying for a look anyway! The adults may be hard to spot as they tend to drop when disturbed. Look instead for the slug-like larvae in areas where there is damage to the leaves.

Woolly nightshade lace bug (*Gargaphia decoris*)

- Lacebug releases only began last summer, but given the gregarious nature of these insects, and how well they did early on, it would be worth checking release sites as soon as the weather warms up. Look on the undersides of leaves for the adults and nymphs, especially on leaves showing signs of bleaching or black spotting around the margins.

Send any reports of interesting, new or unusual sightings to Lynley Hayes (hayesl@landcareresearch.co.nz, Ph 03 321 9694). Monitoring forms for most species can be downloaded from www.landcareresearch.co.nz/research/biocons/weeds/book/ under Release and Monitoring Forms.

Who's Who in Biological Control of Weeds?

Alligator weed beetle (<i>Agasicles hygrophila</i>)	Foliage feeder, common, often provides excellent control on static water bodies.
Alligator weed beetle (<i>Disonycha argentinensis</i>)	Foliage feeder, released widely in the early 1980s, failed to establish.
Alligator weed moth (<i>Arcola malloi</i>)	Foliage feeder, common in some areas, can provide excellent control on static water bodies.
Blackberry rust (<i>Phragmidium violaceum</i>)	Leaf rust fungus, self-introduced, common in areas where susceptible plants occur, can be damaging but many plants are resistant.
Boneseed leaf roller (<i>Tortrix</i> s.l. sp. "chrysanthemoides")	Foliage feeder, first released in 2007, establishment confirmed at some North Island sites but no significant damage seen yet. Appears to be limited by predation and parasitism.
Bridal creeper rust (<i>Puccinia myrsiphylli</i>)	Rust fungus, self-introduced, first noticed in 2005, widespread, appears to be causing severe damage at many sites.
Broom gall mite (<i>Aceria genistae</i>)	Gall former, first released at limited sites in late 2007, establishing well and severe damage to plants already seen at some sites, widespread releases are continuing.
Broom leaf beetle (<i>Gonioctena olivacea</i>)	Foliage feeder, first released in 2006/07 and establishment appears likely at a few sites so far. Widespread releases are continuing.
Broom psyllid (<i>Arytainilla spartiophila</i>)	Sap sucker, becoming common, some damaging outbreaks seen so far but may be limited by predation, impact unknown.
Broom seed beetle (<i>Bruchidius villosus</i>)	Seed feeder, becoming common, spreading well, showing potential to destroy many seeds.
Broom shoot moth (<i>Agonopterix assimilella</i>)	Foliage feeder, first released early in 2008, limited releases made so far and establishment success not yet known.
Broom twig miner (<i>Leucoptera spartifoliella</i>)	Stem miner, self-introduced, common, often causes obvious damage.
Californian thistle flea beetle (<i>Altica carduorum</i>)	Foliage feeder, released widely during the early 1990s, not thought to have established.
Californian thistle gall fly (<i>Urophora cardui</i>)	Gall former, rare, galls tend to be eaten by sheep, impact unknown.
Californian thistle leaf beetle (<i>Lema cyanella</i>)	Foliage feeder, only established at one site near Auckland where it is causing obvious damage. Further releases may be made from this site.
Californian thistle rust (<i>Puccinia punctiformis</i>)	Systemic rust fungus, self-introduced, common, damage not usually widespread.
Californian thistle stem miner (<i>Ceratopion onopordi</i>)	Stem miner, attacks a range of thistles, first released early in 2009, limited releases made so far and establishment success not yet known. Difficult to rear, releases will continue as available.
Green thistle beetle (<i>Cassida rubiginosa</i>)	Foliage feeder, attacks a range of thistles, widespread releases began in 2007/08 and are continuing, establishment is looking promising at most sites.
Chilean needle grass rust (<i>Uromyces pencanus</i>)	Rust fungus, permission to release granted in 2011 and it is hoped releases can begin in autumn 2012. South Island populations only likely to be susceptible.
Echium leaf miner (<i>Dialectica scalariella</i>)	Leaf miner, self-introduced, becoming common on several <i>Echium</i> species, impact unknown.
Gorse colonial hard shoot moth (<i>Pempelia genistella</i>)	Foliage feeder, limited releases to date, established only in Canterbury, impact unknown but obvious damage seen at several sites.
Gorse hard shoot moth (<i>Scythris grandipennis</i>)	Foliage feeder, failed to establish from small number released at one site, no further releases planned due to rearing difficulties.
Gorse pod moth (<i>Cydia succedana</i>)	Seed feeder, becoming common, spreading well, can destroy many seeds in spring but is not so effective in autumn and not well synchronised with gorse-flowering in some areas.
Gorse seed weevil (<i>Exapion ulicis</i>)	Seed feeder, common, destroys many seeds in spring.
Gorse soft shoot moth (<i>Agonopterix umbellana</i>)	Foliage feeder, becoming common in Marlborough and Canterbury with some impressive outbreaks, establishment success in the North Island poor to date, impact unknown.
Gorse spider mite (<i>Tetranychus lintearius</i>)	Sap sucker, common, often causes obvious damage, but persistent damage limited by predation.
Gorse stem miner (<i>Anisoplaca pyoptera</i>)	Stem miner, native insect, common in the South Island, often causes obvious damage, lemon tree borer has similar impact in the North Island.
Gorse thrips (<i>Sericothrips staphylinus</i>)	Sap sucker, gradually becoming more common and widespread, impact unknown.
Hemlock moth (<i>Agonopterix alstromeriana</i>)	Foliage feeder, self-introduced, common, often causes severe damage.

Hieracium crown hover fly <i>(Cheilosia psilophthalma)</i> Hieracium gall midge <i>(Macrolabis pilosellae)</i> Hieracium gall wasp <i>(Aulacidea subterminalis)</i> Hieracium plume moth <i>(Oxyptilus pilosellae)</i> Hieracium root hover fly <i>(Cheilosia urbana)</i> Hieracium rust <i>(Puccinia hieracii var. piloselloidarum)</i>	Crown feeder, limited releases made so far, establishment success unknown, rearing difficulties need to be overcome to allow widespread releases to begin. Gall former, widely released and has established but is not yet common at sites in both islands, impact unknown but very damaging in laboratory trials. Gall former, widely released and has established but is not yet common in the South Island, impact unknown but reduces stolon length in laboratory trials. Foliage feeder, only released at one site so far and did not establish, further releases will be made if rearing difficulties can be overcome. Root feeder, limited releases made so far, establishment success unknown, rearing difficulties need to be overcome to allow widespread releases to begin. Leaf rust fungus, self-introduced?, common, may damage mouse-ear hawkweed but plants vary in susceptibility.
Heather beetle <i>(Lochmaea suturalis)</i>	Foliage feeder, released widely in Tongariro National Park, some damaging outbreaks now starting to occur, also established near Rotorua and severely damaging heather there.
Lantana plume moth <i>(Lantanophaga pusillidactyla)</i>	Flower feeder, self-introduced, distribution and impact unknown.
Mexican devil weed gall fly <i>(Procecidochares utilis)</i>	Gall former, common, initially high impact but now reduced considerably by Australian parasitic wasp.
Mist flower fungus <i>(Entyloma ageratinae)</i> Mist flower gall fly <i>(Procecidochares alani)</i>	Leaf smut, common and often causes severe damage. Gall former, now well established and common at many sites, in conjunction with the leaf smut provides excellent control of mist flower.
Nodding thistle crown weevil <i>(Trichosirocalus horridus)</i> Nodding thistle gall fly <i>(Urophora solstitialis)</i> Nodding thistle receptacle weevil <i>(Rhinocyllus conicus)</i>	Root and crown feeder, becoming common on several thistles, often provides excellent control in conjunction with other nodding thistle agents. Seed feeder, becoming common, can help to provide control in conjunction with other nodding thistle agents. Seed feeder, common on several thistles, can help to provide control of nodding thistle in conjunction with the other nodding thistle agents.
Old man's beard leaf fungus <i>(Phoma clematidina)</i> Old man's beard leaf miner <i>(Phytomyza vitalbae)</i> Old man's beard sawfly <i>(Monophadnus spinolae)</i>	Leaf fungus, initially caused noticeable damage but has since either become rare or died out. Leaf miner, common, only one severely damaging outbreak seen, appears to be limited by parasites. Foliage feeder, limited widespread releases have been made, has probably failed to establish.
Phoma leaf blight <i>(Phoma exigua var. exigua)</i>	Leaf spot fungus, self-introduced, becoming common, can cause minor-severe damage to a range of thistles.
Scotch thistle gall fly <i>(Urophora stylata)</i>	Seed feeder, limited releases to date, establishing readily, impact unknown.
Tradescantia leaf beetle <i>(Neolema ogloblini)</i> Tradescantia stem beetle <i>(Neolema abbreviata)</i> Tradescantia tip beetle <i>(Lema basicostata)</i>	Foliage feeder, permission to release granted in 2008, releases finally got underway in autumn 2011 after beetle successfully cleared of a gut parasite, widespread releases now planned. Tip feeder, permission to release granted in 2011 and it is hoped releases can begin later this year. Stem borer, permission to release granted in 2011 and it is hoped releases can begin later this year.
Cinnabar moth <i>(Tyria jacobaeae)</i> Ragwort crown-boring moth <i>(Cochyliis atricapitana)</i> Ragwort flea beetle <i>(Longitarsus jacobaeae)</i> Ragwort plume moth <i>(Platyptilia isodactyla)</i> Ragwort seed fly <i>(Botanophila jacobaeae)</i>	Foliage feeder, common in some areas, often causes obvious damage. Stem miner and crown borer, limited number of widespread releases made in 2006/07, establishment looking unlikely. Root and crown feeder, common in most areas, often provides excellent control in many areas. Stem, crown and root borer, widespread releases made in past 5 years, appears to be establishing readily and reducing ragwort already at some sites. Seed feeder, established in the central North Island, no significant impact.
Greater St John's wort beetle <i>(Chrysolina quadrigemina)</i> Lesser St John's wort beetle <i>(Chrysolina hyperici)</i> St John's wort gall midge <i>(Zeuxidiplosis giardi)</i>	Foliage feeder, common in some areas, not believed to be as significant as the lesser St John's wort beetle. Foliage feeder, common, often provides excellent control. Gall former, established in the northern South Island, often causes severe stunting.
Woolly nightshade lace bug <i>(Gargaphia decoris)</i>	Sap sucker, permission to release granted by ERMA in 2009, releases began in late 2010 and widespread releases are continuing.

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Thanks to: Christine Bezar
Design: Anouk Wanrooy



www.weedbusters.org.nz

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ISSN 1173-762X (Print) ISSN 1173-8784 (Online)