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LANDCARE RESEARCH
MANAAKI WHENUA

Weed Biocontrol

WHAT'S NEW?

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Still Tussling with Tussocks

Many New Zealanders would be very happy if we could successfully biocontrol two closely related weedy grasses: Chilean needle grass (*Nassella neesiana*) and nassella tussock (*Nassella trichotoma*). We have found a suitable agent for Chilean needle grass, a rust fungus (*Uromyces pencanus*), which was approved for release in 2011. Unfortunately, Argentinian authorities have not granted an export permit yet, so we have not been able to import and release the rust. Less progress has been made towards developing biocontrol for nassella tussock, but recently the pros and cons of reactivating a biocontrol project have been reconsidered. Current management, which largely involves the hand-grubbing of tussocks, costs millions annually and is required in perpetuity to keep populations at their current low levels and prevent an economic loss estimated at $417 million (present value) in Canterbury alone.

Freda Anderson (CERZOS-CONICET, Argentina) was employed in the 1990s to look for potential biocontrol agents for Chilean needle grass and nassella tussock for Australia, with New Zealand joining the project later. The project was challenging, with many obstacles to overcome. Freda found three pathogens that initially looked like promising biocontrol agents for nassella tussock: a rust fungus (*Puccinia nassellae*), a smut fungus (*Tranzscheliella* sp.), and an unidentified fungus originally thought to belong in the Corticiaceae family, which we call 'the crown rot fungus'. "We had high hopes with the rust fungus, but it disappointed us," reported Jane Barton, who assisted with the project. "We couldn't get it to complete its life cycle; it needed several hours of free water for infection (a rarity in habitats favoured by nassella tussock); it was attacked by another fungus (a hyperparasite); and preliminary hosts range testing showed it could infect a non-target *Stipa* species native to Australia. We gave up on it, and were frankly happy to see the last of it!"

The smut fungus can replace nassella tussock flower heads and seeds with black fungal spores. "A fungus which reduces the ability of nassella tussock to form seed would be a very useful biocontrol agent," explained Freda. Unfortunately the disease proved to be consistently rare in the field, and at sites where the smut was present it usually infected only a few isolated plants. Laboratory work soon revealed why. "The smut only infects germinating seed, and so there is only a short window of opportunity for infection," said Freda. Given that nassella tussock seeds prolifically, the levels of infection seen in the field in Argentina (about 1%) would be unlikely to have a significant impact on populations in New Zealand, and therefore the smut was ruled out too.

The crown rot fungus was impressive in the field, associated with dead and dying tussocks and at times quite common. The root systems of affected tussocks were far less developed and plants were much easier to pull out of the ground. Other tussock species that occurred in the same area were not affected, giving hope that it might be host specific. However, once again there were difficulties. "We couldn't isolate the fungus causing the crown rot on artificial media," said Freda. At the time this made it impossible to identify it to the species or genus level, or to understand its lifecycle. "We tried to test its host range by planting non-target plants and disease-free nassella tussock plants next to diseased ones in both the field and the laboratory, but after 6 months none of the healthy plants had developed disease symptoms." At this point a decision was made to focus the limited resources for the work on the much more promising Chilean needle grass rust.

Fast forward to 2016, and the ongoing challenge of nassella tussock meant it was worth taking another look at whether biocontrol would be feasible for this target. AgResearch, in collaboration with key stakeholders, obtained a grant from the Sustainable Farming Fund

(SFF) to do this. The project involved reviewing information known about potential agents, modelling the likely impacts of agents on nassella tussock populations, and determining the likely costs and benefits of a biocontrol programme.

"Freda and I prepared a report on the potential for pathogens to be used as classical or inundative biocontrol agents for nassella tussock," explained Jane. While the rust and the smut remain rejected as potential agents, Jane and Freda believe the crown rot fungus deserves further attention. "These days molecular techniques are available that will enable us to quickly identify it at least to the genus level," explained Jane. "Once we have a name, it should be much easier to work out its biology and life cycle, and whether it would make a suitable biocontrol agent."

When Freda and Jane compiled all the information available about this fungus (including unpublished reports from South African researchers who noted dying tussocks in Argentina in the 1970s), it became clear that the crown rot fungus is rarely found alone in the field. "When we tried to isolate the crown rot fungus, *Fusarium* species often grew out of the tissue onto the artificial media," revealed Freda. *Fusarium* species were also found in diseased nassella tussocks in Australia by researchers looking for fungi with potential for inundative biocontrol (i.e. to be developed into bioherbicides). However, when they applied the *Fusarium* species to tussocks alone they weren't damaging. Further research revealed that the *Fusarium* species appeared to only infect plants suffering from feeding damage inflicted by soil nematodes. This is consistent with observations made by South African researchers that both fungi and invertebrates seemed to be involved in nassella tussock death in Argentina. This suggests that a biocontrol programme should focus on developing a combined approach, involving the crown rot fungus and other fungi (such as *Fusarium* species) plus invertebrates, if needed. As a bonus, *Fusarium* species are already commonly present on nassella tussock in New Zealand. Other pathogens of nassella tussock leaves (e.g. *Septoria* and *Pseudoseptoria* species), found occasionally in surveys in Argentina, could also be investigated, and work should be done to explore the largely unknown invertebrate options.

Once Freda and Jane confirmed that there are biocontrol options worth pursuing, AgResearch worked on the next step. A population model previously developed by Shona Lamoureaux and colleagues was used to simulate the consequences on nassella tussock populations of biocontrol agents that could reduce seed production annually by 10%, plus reduce the plants' growth rate by 5, 10 or 15%. The model predicted that these levels of impact could result in nassella tussock population reductions of 47%, 65% and 76%, respectively.


Bill Pettit

Dying nassella tussock in Argentina affected by crown rot fungus.

The final step was for AgResearch to explore the costs and benefits of a biocontrol programme over a 25-year period for each of the three impact scenarios above. A cost–benefit analysis model showed that benefits should exceed costs for all three scenarios as long as the biocontrol agent(s) achieved 90% of their maximum impact on populations within 30–35 years. "We would usually reject biocontrol agents that reduced seed production and/or plant growth by as little as the 5, 10 or 15% scenarios, and it is certainly realistic to expect they could do much more than this," said Jane. So the results of this SFF project suggest a biocontrol programme for nassella tussock in New Zealand is definitely worthwhile from an economic viewpoint. This finding is being shared with land managers, and their interest in pursuing biocontrol for nassella tussock is being determined.

The study into the feasibility of biocontrol for nassella tussock was funded by the Sustainable Farming Fund (SFF 404930), with co-funding from Environment Canterbury, Marlborough District Council, Hawke's Bay Regional Council and Beef+Lamb. Jane Barton and Freda Anderson are contractors to Landcare Research.

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Alligator Weed: A Financial Snapshot

Alligator weed (*Alternanthera philoxeroides*) is a tough plant to control. Herbicides can be used to some extent, but the structure of this plant, with its many nodes, means translocation can be poor. Manual/physical control can provide short-term relief in some situations, but the plant quickly regrows from any small fragments left behind. Fragments are also easily dispersed, particularly during floods, but also by birds, boats and humans. For these reasons, biocontrol was an obvious choice for alligator weed, particularly in the north, where warm temperatures create near perfect growing conditions.

Snapping at the heels of biocontrol programmes for alligator weed in North America and Australia, the first agent, a beetle (*Agasicles hygrophila*), was released here in 1982. A moth (*Arcola malloi*) was released soon after, and both agents established. Another beetle (*Disonycha argentinensis*) was also released but failed to establish. The alligator weed beetle and moth provide excellent control on static water bodies like lakes. However, they are less effective on flowing water (especially if it floods frequently), in colder areas, or where the weed invades dry land. The project is therefore categorised as a 'partial success', but recently an economic study has shown that a little biocontrol can go a long way.

Fortunately detailed information on alligator weed control costs and the impact of the biocontrol agents was published back in the 1980s. This enabled Simon Fowler to estimate that the biocontrol agents are saving around $505,000 per year in Auckland and Northland. These savings are ongoing and sustainable, with no further input required. Simon also prepared an estimate of the cost (at 2014 rates) of the New Zealand biocontrol programme, which came to $479,000. The figures were adjusted to present-day-value figures (using Treasury's recommended 8% discount rate). The resulting benefit to cost ratio turns out to be an impressive 101:1. "This means for every dollar invested in alligator weed biocontrol there has been $101 worth of benefits," explained Simon.

To test the validity of the economic analysis, Simon ran some scenarios to see how robust the figures were. In this sensitivity analysis discount rates of 6% and 10% were used, as well as scenarios where biocontrol costs were increased by 25% or benefits were reduced by 50%. Under all scenarios the results stood up well, with the overall benefit to cost ratios never dropping below 50:1, suggesting that the conclusion of substantial economic benefits arising from the biocontrol programme was robust.

Alligator weed beginning to show severe moth damage in 1991.

"What was particularly unusual is that valuable information was also published in the 1980s study about the cost of controlling replacement weeds that can move in once alligator weed is controlled," said Simon. Using this data we can calculate that replacement weeds are potentially reducing the effectiveness of alligator weed biocontrol by nearly 70%. However, this suggestion needs further investigation. It is not known exactly which weed species are replacing alligator weed, how easy or expensive they are to control, and if they could be better managed, for example through the development of biocontrol.

Since alligator weed control in the north is still estimated to be costing land managers $6.47 million per year in New Zealand, work to determine if other biocontrol agents could potentially increase the level of control is continuing. A thrips (*Amynothrips andersoni*) and a gall midge (*Clinodiplosis alternantherae*) have been rejected as insufficiently host specific. Testing of a stem/root galling fly (*Ophiomyia marellii*) has shown it has a clear preference for alligator weed but may also attack *A. denticulata*, a recent introduction to New Zealand, albeit to a lesser extent. The likely impact of the fly is being studied to help inform whether a case could be made that damage to *A. denticulata* might be acceptable. However, the economic study suggests it might be worth releasing the fly even if it is only able to increase the existing level of alligator weed control by a modest amount. A foliage-feeding beetle (*Systena nitendula*) is another potential agent that could be considered in the future.

Despite biocontrol agents only having a minimal impact on the overall control costs (a saving of 7.2%), the economic analysis has shown that the overall benefits are substantial. "The financial benefits well outweigh the costs of establishing the programme," said Simon, "and this doesn't include the flow-on effects for the environment, such as improved diversity and ecosystem functioning, that accompany the removal of invasive monocultures." This study also once again emphasises the importance of monitoring the success of agents post-release.

This project was funded by the Ministry of Business, Innovation and Employment as part of Landcare Research's Beating Weeds programme.

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Turning up the Heat on Ginger

Wild ginger (*Hedychium spp.*) is highly invasive in New Zealand and has already made an especially bad name for itself in Northland. Molecular studies suggest that the most invasive form of wild ginger here is a hybrid between kahili ginger (*Hedychium gardnerianum*) and most likely white ginger (*H. coronarium*), both of which originate from India. Hybrid vigour may be giving this ginger a competitive advantage.

Quentin Paynter recently reviewed the impacts of wild ginger. In New Zealand this plant is able to invade forests that have experienced little or no human disturbance. "Apparently pure *Hedychium gardnerianum* rarely grows under low-light conditions in India, but it commonly does here, allowing it to suppress native forest regeneration and alter the food webs on the forest floor," said Quent. "This is also happening in Hawai'i and Reunion Island," he went on to say, adding that "the lack of natural enemies is also likely to be allowing the plant to colonise habitats where it would not be able to thrive in India." Studies in the Azores have found that where wild ginger is invading, there are fewer insects overall and this has negative implications for native birds and other insectivorous animals. Studies in New Zealand found that numbers of mites, amphipods, spiders, flies and bugs were lower where wild ginger was present, although overall invertebrate diversity was not affected.

Ginger infestations in Northland are now so bad that Ashlee Lawrence, from the Northland Regional Council, has started a public campaign aimed at raising public awareness about this plant and support for biocontrol. A group of concerned stakeholders, led by Ashlee, has formed the Stop Wild Ginger Group and developed a website (www.stopwildginger.co.nz/), which shows the damage the plant can do to native ecosystems and the extent of infestations in Northland and Auckland. The public are encouraged to add other known unmarked infestations to the maps. "We have noticed that in areas where the wild ginger has invaded, there are few opportunities for native plant recruitment," Ashlee said. "This is very disheartening. In a few decades we will start to see major forest collapse along our coastlines due to the wild ginger. However, many residents are unaware of the scale of infestation as it is hidden beneath tall canopy species, or in the middle of dense state and production forests. The Stop Wild Ginger website highlights the problem and brings the issue into the public eye."

Sadly, wild ginger is well beyond the point where eradication is feasible, and the cost of widespread herbicide use would be astronomical (tens of millions of dollars), let alone environmentally harmful. This leaves biocontrol as one of the only realistic options for this invader. Researchers from CABI in the UK have been looking for potential agents in Sikkim, India, for a number of years. This has required the potentially tricky balancing act of finding agents that are sufficiently specific but also able to attack a hybrid species that may not even exist naturally in the wild. Fortunately such candidates seem to exist, and the prospect of a successful biocontrol programme being developed for New Zealand is promising.


Northland Regional Council.

Ginger infesting plantation forestry in Northland.

The two best-studied agents both appear to have good potential. One is a large weevil (*Metaprodioctes cf. trilineatus*) that feeds on all parts of the plant, including the rhizomes. The weevil also developed on white ginger and an ornamental (*Cautleya spicata*) in host range studies. This wouldn't necessarily be a show stopper for New Zealand (unlike Hawai'i, where white ginger is highly valued), because all *Hedychium* species are considered to be weeds and there are no native members of the *Zingiberaceae* family. Further testing is needed to determine the level of risk to other closely related ornamental *Zingiberaceae* and to edible ginger (*Zingiber* spp.).

Host-range testing of the shoot-mining fly (*Merochlorops cf. dimorphus*), whose larva mines the stem, is tantalisingly close to completion, and this fly is highly likely to be sufficiently host-specific for in New Zealand. "Work on the fly and weevil had been on hold since October 2016, when permits and agreements with Indian authorities were unexpectedly revoked. But these issues appear to have been resolved and the project is set to resume in September 2017," said Quent. With a bit of luck the weevil and fly testing can be wrapped up fairly quickly. Other agents, such as a range of hispine beetles and several defoliating moths, will also be studied as funds permit.

This report on the impacts of wild ginger was funded by an Envirolink grant (1726-NLRC196) to Northland Regional Council. The biocontrol work is funded by the National Biocontrol Collective.

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Biocontrol for Mexican Daisy?

Mexican daisy (*Erigeron karvinskianis*), an emerging environmental weed in New Zealand, was introduced as an ornamental plant in the 1940s. Since then it has escaped from gardens to spread around both the North Island and South Island. Mexican daisy has even found its way to the Chatham Islands, so it isn't fussy about where it grows and its range is still expanding. The plant has 'unwanted' status, making it illegal to propagate, sell or knowingly spread the plant around.

In its native range (Mexico and South America) Mexican daisy is found from sea level to as high as 3200 m, so it doesn't mind cold temperatures. An invader also in Hawai'i, this plant forms dense mats there that displace native vegetation, and it seems likely that, given the chance, Mexican daisy could do the same in warmer parts of New Zealand. In suburban areas of Auckland Mexican daisy is now considered a major roadside weed. It may look innocent enough, but this weed has the potential to invade important ecological areas such as the Waitakere ranges and other areas of conservation value.

Although Mexican daisy responds well to herbicide, it is now so widespread and expensive to control that Auckland Council are looking at biological control as a possible solution. Mexican daisy has established in some regional parks and is competing for habitat with threatened native plants. "It produces vast amounts of small windborne seed and can spread vegetatively," said Paul Peterson, who has recently looked into the feasibility of biocontrol for this potential target on behalf of Auckland Council. The Department of Conservation (DOC) also consider the weed a high priority and have reported it to be difficult to control, especially in coastal areas.

"Biocontrol of Mexican daisy has not been attempted anywhere before, but it could provide a cost effective solution to the problem," said Paul. "Unfortunately, being a novel project does escalate the likely overall cost," he added. Host-range testing could be extensive given that in New Zealand we have eight native genera also in the Astereae tribe, although in different sub-tribes to Mexican daisy, with 68 species considered of conservation value here in New Zealand. However, we may only need to test a much smaller list of species if a candidate agent were found that did not attack the more closely related exotic species also present here.

Auckland Council.

Mexican daisy.

In terms of natural enemies, Mexican daisy is known to host at least two pathogens. One is a leaf spot (*Didymella glomerata*), which is relatively common in New Zealand but has only been recorded once from Mexican daisy. Searching for a more virulent strain to attack Mexican daisy would be precluded by its wide host range. The other, a powdery mildew (*Podosphaera fusca*), is also unsuitable because it is too damaging to valued plants in the gourd family. However, very little research been done on the natural enemies of this plant, so other potentially useful pathogens may be out there. As far as insects go, there are several associated with Mexican daisy in its native range, but none are considered to be specific to the plant. "Proper surveys would be expected to have a reasonably good chance of finding potential agents worthy of further study," said Paul.

In 2012 Quentin Paynter developed a framework to help make decisions about the likelihood of success of biocontrol programmes given the traits of a weed. "Information about the life history and breeding strategy of the weed are compared to other weeds that have been targeted with biocontrol agents," said Paul. This results in an overall score reflecting the mean proportional reduction of the weed expected due to biocontrol, and for Mexican daisy we can anticipate a moderate to good outcome. "But this does depend a little on what we can learn about the way Mexican daisy reproduces here, which is currently unknown. If it reproduces sexually rather than producing clonal seed (apomictic), then there is less chance of successful biocontrol," Paul cautioned.

As well as surveys in the native range, a key first step in a biocontrol programme would be to survey Mexican daisy growing in New Zealand to see what is living on it here that might be detrimental to any potential biocontrol agents. "We also need to study the DNA profile of Mexican daisy plants growing here and compare them with plants from overseas, to try and pinpoint exactly where they originated from. This would give a better picture of where we might find the most suitable agents and the climate match with New Zealand," explained Paul.

This study was funded by Auckland Council.

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Beating Weeds with Science

More than 50 species of woody weeds occur in large, dense patches throughout New Zealand. Most of these weeds can displace native vegetation and disrupt ecosystem processes, so predicting which species are likely to persist and which are likely to be replaced by native vegetation is critical for informing management tactics. The idea that leaving woody weeds in the environment until they are outcompeted by native species has the advantage of reduced control and management costs.

Kate McAlpine from DOC is leading research into this question. "Our theory is that weed species that regenerate strongly under their own canopy are most likely to persist, because the next generation is already present in the understory, 'lying in wait' to take over when the current adult cohort dies," explained Kate. On the other hand, woody weed species that don't regenerate under their own canopy (presumably because of shade intolerance) are less likely to persist in the long term. Instead, they are likely to be replaced by more shade-tolerant species that do establish in the understory. If those species are native, then the weeds may be replaced by native plant succession, provided no further disturbance occurs. Some species, such as gorse (*Ulex europaeus*), are known to act as 'nurse' plants, and facilitate native succession. However, the likely persistence and long-term impact of most woody weed species in New Zealand is poorly documented.

Kate and her colleagues (Susan Timmins from DOC, and Shona Lamoureaux and Sarah Jackman from AgResearch) have surveyed the understory vegetation in 132 populations of 41 woody weed species around New Zealand. "We found that 27 weed species had little or no regeneration under their own canopy, and thus appear to have potential to be replaced by native succession – particularly at sites where there is a dense native understory. This is good news and many more species than was previously thought. However, 14 woody weed species did regenerate strongly under their own canopy, and thus appear more likely to be able to persist in the long term," said Kate. Of those 14 species, Chinese privet (*Ligustrum sinense*) appeared to be the 'worst', having consistently high weed regeneration in the understory and very little native vegetation. Some species, such as sycamore (*Acer pseudoplatanus*) and tree privet (*Ligustrum lucidum*) were highly variable in terms of regeneration, with very high numbers of seedlings and saplings in the understory at some sites but none at all at others.

Kate also found that many woody weed stands had a dense native understory (50–90% cover), and suggests that this should give the natives a head start over re-invading weed species when the canopy plants die. "In fact, natives far outnumbered non-native species in the understories of these

Alder with dense native understory.

weed stands, both in terms of percent cover and the number of species," Kate said. In total, more than 170 native species were recorded, including canopy-forming species such as tawa (*Beilschmiedia tawa*), tītoki (*Alectryon excelsus*) and kahikatea (*Dacrycarpus dacrydioides*). Māhoe (*Melicytus ramiflorus*) was the most commonly recorded species, present at 67% of sites. Sites close to a native forest remnant were more likely to have a dense native understory, which shows that distance to a native seed source is important.

The rate at which a woody weed will be replaced through the process of succession is likely to be at least as long as the life span of the weed, but can also be influenced by site-specific factors such as the presence of browsing animals, and temporal factors such as the rate at which the weed naturally thins out, allowing more light to enter the understory. "But we are talking in terms of decades or even centuries for native species to become dominant," agreed Kate. "And, if a major disturbance such as a fire or flood occurs, the successional clock may be set right back to zero".

Kate is now planning to investigate what happens next when the adult weed plants die: do the natives in the understory take over, or does the weed re-invade? "My aim is to provide regional councils, DOC, restoration groups, and anyone else dealing with plant invasions on a large geographic scale with better information about which species are likely to persist, and which might die out naturally. This will help weed managers to prioritise species and sites for control," Kate said.

This project is funded by the Ministry of Business, Innovation and Employment as part of Landcare Research's Beating Weeds programme, with additional support provided by the Department of Conservation.

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Spring Activities

Broom leaf beetles (*Gonioctena olivacea*)

- Look for beetles by beating plants over a tray. The adults are 2–5 mm long and goldish-brown (females) through to orangey-red (males), with stripes on their backs. Look also for greyish-brown larvae, which may also be seen feeding on leaves and shoot tips.
- The beetles can be harvested if you find them in good numbers. Aim to shift at least 300 beetles to sites that are not yet infested with gall mites.

Broom shoot moth (*Agonopterix assimilella*)

- Late spring is the best time to check release sites, so look for the caterpillars' feeding shelters made by webbing twigs together. Small caterpillars are dark reddish-brown and turn dark green as they get older. We are unsure if this moth has managed to successfully establish in New Zealand, so we will be interested to hear if you find any sign of the caterpillars.
- We would not expect you to be able to begin harvesting and redistribution just yet.

Darwin's barberry weevil (*Berberidicola exaratus*)

- Although it is early days for checking release sites, later in the spring it might be worth beating some plants to see if any of the small (3–4 mm long), blackish adults can be found. Also examine the fruits for signs of puncturing.
- Since establishment is not yet confirmed, it will be too soon to consider harvesting and redistribution if you do find the weevils.

Green thistle beetles (*Cassida rubiginosa*)

- Look for adult beetles, which emerge on warm days towards the end of winter and feed on new thistle leaves, making round window holes. They are 6–7.5 mm long and green, so they camouflage quite well. Both the adults and the larvae make windows in the leaves. Larvae have a protective covering of old moulted skins and excrement. You may also see brownish clusters of eggs on the undersides of leaves.
- It should be possible to harvest beetles at many of the older sites. Use a garden leaf vacuum machine and aim to shift at least 100 adults from spring throughout summer and into autumn. Be careful to separate the beetles from other material collected, which may include pasture pests. Please let us know if you discover an outbreak of these beetles.

Lantana blister rust (*Puccinia lantanae*)

- Check sites where lantana plants infected with blister rust have been planted out, especially after a period of warm, wet weather. Signs of infection include leaf and stem chlorosis (yellowing), accompanied by large, dark pustules on the undersides of leaves and on the stems. Stunting, defoliation and die-back may also be apparent.
- Once established, this rust is likely to be readily dispersed by the wind. If redistribution efforts are needed, the best method is likely to involve placing small, potted lantana plants beneath infected ones and then planting these out at new sites once they have become infected. However, to propagate and distribute lantana in this manner an exemption from the Ministry for Primary Industries (MPI) will be required.

Lantana leaf rust (*Prospodium tuberculatum*)

- Check sites where the leaf rust has been released, especially after a period of warm, wet weather. Look for yellowing on the leaves, with corresponding brown pustules and spores, rather like small coffee granules. A hand lens may be needed to see the symptoms during early stages of infection. If the rust is well established then extensive defoliation may be obvious.
- Once established, this rust is likely to be readily dispersed by the wind. If redistribution efforts are needed, the best method will likely involve harvesting infected leaves, washing them in water to make a spore solution and then applying this to plants.

Privet lace bug (*Leptoypha hospita*)

- Although it is early days for privet lace bug, signs of their presence seem to be obvious quite soon following releases so it would definitely be worth checking the older release sites to confirm establishment. Examine the undersides of leaves for the adults and nymphs, especially leaves showing signs of bleaching.
- If large numbers are found, cut infested leaf material and put it in chilly bin or large paper rubbish bag, and tie or wedge this material into Chinese privet at new sites. Aim to shift at least 1,000 individuals to each new site.

Ragwort plume moth (*Platyptilia isodactyla*)

- October is the best time to check release sites for caterpillars, so 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 confused by larvae of the blue stem borer (*Patagoniodes farinaria*), which look similar to plume moth larvae until they develop their distinctive bluish colouration.
- If the moth is present in good numbers, the best time to shift it around is in late spring. Dig up damaged plants, roots and all. Pupae may be in the surrounding soil so retain as much as possible. Shift at least 50–100 plants, but the more the better. Place one or two infested plants beside a healthy ragwort plant so that any caterpillars can crawl across.

Tradescantia leaf beetle (*Neolema ogloblini*)

- Look for the shiny metallic bronze adults or the larvae, which have a distinctive protective covering over their backs. Also look for notches in the edges of leaves caused by adult feeding, or leaves that have been skeletonised by larvae grazing off the green tissue.
- The beetles can be harvested if you find them in good numbers. Aim to collect and shift 100 beetles using a suction device or a small net.

Tradescantia stem beetle (*Lema basicostata*)

- The black knobbly adults can be difficult to see, so look for their feeding damage, which consists of elongated windows in the upper surfaces of leaves, or sometimes whole leaves consumed. Also look for stems showing signs of larval attack: brown, shrivelled or dead-looking.
- If you can find widespread damage you can begin harvesting. If it proves too difficult to collect 100 adults with a suction device, remove a quantity of the damaged material and put it in a wool pack or on a tarpaulin and wedge this into tradescantia at new sites (but make sure you have an exemption from Ministry for Primary Industries that allows you to do this).

Tradescantia tip beetle (*Neolema abbreviata*)

- Look for the adults, which are mostly black with yellow wing cases, and their feeding damage, which, like stem beetle damage, consists of elongated windows in the leaves. Larvae will be difficult to see inside the tips, but brown frass may be visible. When tips are in short supply, the slug-like larvae feed externally on the leaves.
- The beetles can be harvested if you find them in good numbers. Aim to collect and shift 100 beetles using a suction device or a small net.

Tutsan moth (*Lathronympha strigana*)

- Although the moths were only released last autumn, if you can't wait, look for the small orange adults flying about flowering tutsan plants. They have a similar look and corkscrew flight pattern to the gorse pod moth (*Cydia succedana*). Look also for shoot tips that have been tied together and damaged by the larvae.
- It is too soon to consider harvesting and redistribution if you do find the moths.

Other agents

You might also need to check or distribute the following this spring:

- boneseed leafroller (*Tortrix* s.l. sp. "chrysanthemoides")
- broom gall mites (*Aceria genistae*)

Fruits infested with Darwin's barberry weevil.

- gorse soft shoot moth (*Agonopterix ulicetella*)
- gorse thrips (*Sericothrips staphylinus*)
- gorse colonial hard shoot moth (*Pempelia genistella*).

National Assessment Protocol

For those taking part in the National Assessment Protocol, spring is the appropriate time to check for establishment and/or assess population damage levels for the species listed in the table below. You can find out more information about the protocol and instructions for each agent at: www.landcareresearch.co.nz/publications/books/biocontrol-of-weeds-book

Target	When	Agents
Broom	Oct–Nov Oct–Nov Sept–Oct Aug–Sept	Leaf beetle *(Gonioctena olivacea)* Psyllid *(Arytainilla spartiophila)* Shoot moth *(Agonopterix assimilella)* Twig miner *(Leucoptera spartifoliella)*
Lantana	Oct–Nov (or March–May)	Blister rust *(Puccinia lantanae)* Leaf rust *(Prospodium tuberculatum)*
Tradescantia	Nov–April	Leaf beetle *(Neolema ogloblini)* Stem beetle *(Lema basicostata)* Tip beetle *(Neolema abbreviata)*

Send any reports of interesting, new or unusual sightings to Lynley Hayes (hayesl@landcareresearch.co.nz, Ph 03 321 9694).

Who's Who in Biological Control of Weeds?

Alligator weed beetle (*Agasicles hygrophila*) Alligator weed beetle (*Disonycha argentinensis*) Alligator weed moth (*Arcola malloi*)	Foliage feeder, common, often provides excellent control on static water bodies. Foliage feeder, released widely in the early 1980s, failed to establish. Stem borer, common in some areas, can provide excellent control on static water bodies.
Blackberry rust (*Phragmidium violaceum*)	Leaf rust fungus, self-introduced, common in areas where susceptible plants occur, can be damaging but many plants are resistant.
Boneseed leaf roller (*Tortrix* s.l. sp. "chrysanthemoides")	Foliage feeder, established and quite common at some North Island (NI) sites but no significant damage yet, limited by predation and parasitism.
Bridal creeper rust (*Puccinia myrsiphylli*)	Rust fungus, self-introduced, first noticed in 2005, widespread and providing good control.
Broom gall mite (*Aceria genistae*) Broom leaf beetle (*Gonioctena olivacea*) Broom psyllid (*Arytainilla spartiophila*) Broom seed beetle (*Bruchidius villosus*) Broom shoot moth (*Agonopterix assimilella*) Broom twig miner (*Leucoptera spartifoliella*)	Gall former, establishing well and becoming widespread in some regions, and showing considerable promise by beginning to cause extensive damage to broom at many sites. Foliage feeder, recently released widely, establishment confirmed at sites in both islands and numbers appear to be building, impact unknown. Sap sucker, becoming common, some damaging outbreaks seen, but may be limited by predation, impact unknown. Seed feeder, common in many areas, now destroying up to 84% of seeds at older release sites. Foliage feeder, recently released at limited sites as difficult to rear, appears to be established in low numbers at perhaps 3 sites. Stem miner, self-introduced, common, often causes obvious damage.
Californian thistle flea beetle (*Altica carduorum*) Californian thistle gall fly (*Urophora cardui*) Californian thistle leaf beetle (*Lema cyanella*) Californian thistle rust (*Puccinia punctiformis*) Californian thistle stem miner (*Ceratapion onopordi*) Green thistle beetle (*Cassida rubiginosa*)	Foliage feeder, released widely during the early 1990s, failed to establish. Gall former, extremely rare as galls tend to be eaten by sheep, impact unknown. Foliage feeder, only established at one site near Auckland where it causes obvious damage and from which it is dispersing. Systemic rust fungus, self-introduced, common, damage usually not widespread. Stem miner, attacks a range of thistles, recently released at limited sites as difficult to rear, establishment success unknown. Foliage feeder, attacks a range of thistles, released widely and establishing well with some damaging outbreaks beginning to occur.
Chilean needle grass rust (*Uromyces pencanus*)	Rust fungus, approved for release in 2011 but no releases made yet as waiting for export permit to be granted, only South Island (SI) populations likely to be susceptible.
Darwin's barberry flower bud weevil (*Anthonomus kuscheli*) Darwin's barberry seed weevil (*Berberidicola exaratus*)	Flower bud feeder, approved for release in 2012, releases will be made after the seed weevil is established if still needed. Seed feeder, approved for release in 2012, first release made in early 2015, and releases are continuing.
Field horsetail weevil (*Grypus equiseti*)	Foliage and rhizome feeder, approved for release in 2016, first field release planned for spring 2017.
Giant reed gall wasp (*Tetramesa romana*) Giant reed scale (*Rhizaspidiotus donacis*)	Stem galler, approved for release in 2017, first field release planned for spring 2017. Sap sucker, approved for release in 2017, first field release planned for 2018.
Gorse colonial hard shoot moth (*Pempelia genistella*) Gorse hard shoot moth (*Scythris grandipennis*) Gorse pod moth (*Cydia succedana*) Gorse seed weevil (*Exapion ulicis*) Gorse soft shoot moth (*Agonopterix umbellana*) Gorse spider mite (*Tetranychus lintearius*) Gorse stem miner (*Anisoplaca pytoptera*) Gorse thrips (*Sericothrips staphylinus*)	Foliage feeder, from limited releases established only in Canterbury, impact unknown, but obvious damage seen at several sites. Foliage feeder, failed to establish from a small number released at one site, no further releases planned due to rearing difficulties. Seed feeder, common in many areas, can destroy many seeds in spring but not as effective in autumn, not well synchronised with gorse flowering in some areas. Seed feeder, common, destroys many seeds in spring. Foliage feeder, common in parts of the SI with some impressive outbreaks seen, and well established and spreading at a site in Northland, impact unknown. Sap sucker, common, often causes obvious damage, but ability to persist is limited by predation. Stem miner, native, common in the SI, often causes obvious damage, lemon tree borer has similar impact in the NI. Sap sucker, common in many areas, impact unknown.
Heather beetle (*Lochmaea suturalis*)	Foliage feeder, established in and around Tongariro National Park (TNP), also Rotorua, 1,500 ha heather damaged/killed at TNP since 1996, new strains more suited to high altitude released recently.
Hemlock moth (*Agonopterix alstromeriana*)	Foliage feeder, self-introduced, common, often causes severe damage.
Hieracium crown hover fly (*Cheilosia psilophthalma*) Hieracium gall midge (*Macrolabis pilosellae*) Hieracium gall wasp (*Aulacidea subterminalis*)	Crown feeder, released at limited sites as difficult to rear, establishment success unknown. Gall former, established in both islands, common near Waiouru, where it has reduced host by 18% over 6 years, also very damaging in laboratory trials. Gall former, established but not yet common in the SI and not established yet in the NI, impact unknown but reduces stolon length in laboratory trials.

Hieracium plume moth (*Oxyptilus pilosellae*) Hieracium root hover fly (*Cheilosia urbana*) Hieracium rust (*Puccinia hieracii* var. *piloselloidarum*)	Foliage feeder, only released at one site due to rearing difficulties, did not establish. Root feeder, released at limited sites as difficult to rear, establishment success unknown. Leaf rust fungus, self-introduced?, common, causes slight damage to some mouse-ear hawkweed, plants vary in susceptibility.
Japanese honeysuckle white admiral (*Limenitis glorifica*) Japanese honeysuckle stem beetle (*Oberea shirahati*)	Foliage feeder, approved for release in 2013, releases began in 2014, well established and dispersing from site in the Waikato, further widespread releases planned. Stem miner, approved for release in 2015, difficult to rear in captivity, removed from containment and first proper field releases planned before end of 2017.
Lantana blister rust (*Puccinia lantanae*) Lantana leaf rust (*Prospodium tuberculatum*) Lantana plume moth (*Lantanophaga pusillidactyla*)	Leaf and stem rust fungus, approved for release in 2012, releases began autumn 2015, establishment success unknown. Leaf rust fungus, approved for release in 2012, releases began autumn 2015, established well and causing severe defoliation already at several sites in Northland. Flower feeder, self-introduced, host range, distribution and impact unknown.
Mexican devil weed gall fly (*Procecidochares utilis*) Mexican devil weed leaf fungus (*Passalora ageratinae*)	Gall former, common, initially high impact but now reduced considerably by Australian parasitic wasp. Leaf fungus, probably introduced with gall fly in 1958, common and almost certainly having an impact.
Mist flower fungus (*Entyloma ageratinae*) Mist flower gall fly (*Procecidochares alani*)	Leaf smut, common and often causes severe damage, providing excellent control. Gall former, common now at many sites, probably contributing to control by the smut fungus.
Moth plant beetle (*Freudita cupripennis*) Moth plant rust (*Puccinia araujiae*)	Root feeder, approved for release in 2011 but no releases made yet as waiting for export permit to be granted by Argentinian authorities. Rust fungus, approved for release in 2015 but no releases made yet as waiting for export permit to be granted by Argentinian authorities.
Nodding thistle crown weevil (*Trichosirocalus horridus)* Nodding thistle gall fly (*Urophora solstitialis*) Nodding thistle receptacle weevil (*Rhinocyllus conicus*)	Root and crown feeder, becoming common on several thistles, often provides excellent control in conjunction with other thistle agents. Seed feeder, becoming common, can help to provide control in conjunction with other thistle agents. Seed feeder, common on several thistles, can help to provide control of nodding thistle in conjunction with other thistle agents.
Old man's beard leaf fungus (*Phoma clematidina*) Old man's beard leaf miner (*Phytomyza vitalbae*) Old man's beard sawfly (*Monophadnus spinolae*)	Leaf fungus, initially caused noticeable damage but has become rare or died out. Leaf miner, common, damaging outbreaks occasionally seen, but appears to be limited by parasitism. Foliage feeder, limited releases as difficult to rear and only established in low numbers at one site in Nelson, more material will be imported in 2017 in an attempt to establish this insect more widely.
Privet lacebug (*Leptoypha hospita*)	Sap sucker, releases began spring 2015, establishment confirmed in Auckland and Waikato, some promising early damage seen already, widespread releases continuing.
Cinnabar moth (*Tyria jacobaeae*) Ragwort crown-boring moth (*Cochylis atricapitana*) Ragwort flea beetle (*Longitarsus jacobaeae*) Ragwort plume moth (*Platyptilia isodactyla*) Ragwort seed fly (*Botanophila jacobaeae*)	Foliage feeder, common in some areas, often causes obvious damage. Stem miner and crown borer, released widely, but probably failed to establish. Root and crown feeder, common, provides excellent control in many areas, provided they are not too wet. Stem, crown and root borer, recently released widely, well established and quickly reducing ragwort noticeably at many wetter sites. Seed feeder, established in the central NI, no significant impact.
Greater St John's wort beetle (*Chrysolina quadrigemina*) Lesser St John's wort beetle (*Chrysolina hyperici*) St John's wort gall midge (*Zeuxidiplosis giardi*)	Foliage feeder, common in some areas, not believed to be as significant as the lesser St John's wort beetle. Foliage feeder, common, nearly always provides excellent control. Gall former, established in the northern SI, often causes severe stunting.
Scotch thistle gall fly (*Urophora stylata*)	Seed feeder, released at limited sites, establishing and spreading readily, fewer thistles observed at some sites, impact unknown.
Tradescantia leaf beetle (*Neolema ogloblini*) Tradescantia stem beetle (*Lema basicostata*) Tradescantia tip beetle (*Neolema abbreviata*) Tradescantia yellow leaf spot *Kordyana brasiliense*	Foliage feeder, released widely since 2011, establishing well and already causing noticeable damage at many sites. Stem borer, releases began in 2012, establishing well with major damage already at several sites. Tip feeder, releases began in 2013, appears to be establishing readily. Leaf fungus, approved for released in 2013, first field releases planned for spring 2017.
Tutsan beetle (*Chrysolina abchasica*) Tutsan moth (*Lathronympha strigana*)	Foliage feeder, approved for release in 2016, only one small field release made in autumn 2017 due to rearing challenges but further releases planned. Foliage and seed pod feeder, approved for release in 2016, first field releases made in autumn 2017 with further widespread releases planned.
Woolly nightshade lace bug (*Gargaphia decoris*)	Sap sucker, recently released widely, establishing readily at many sites, and beginning to cause significant damage at many sites.

Further Reading

Barton J, Anderson F 2016. **Prospects for the biological control of nassella tussock (*Nassella trichotoma*, Poaceae: Stipeae) with pathogens.** Landcare Research Contract Report LC2692 prepared for AgResearch. 45 p.

Bellgard S, Probst C, Johnson V 2016. **Synergism between herbicides and *Nigrospora oryzae* (Berk. and Broome) Petch for the inundative control of pampas in New Zealand.** In: Randall R, Lloyd S, Borger C eds. Proceedings of the 20th Australasian Weeds Conference. Weeds Society of Western Australia. Pp. 274–278.

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Paynter Q, Konuma A, Dodd SL, Hill RL, Field L, Gourlay AH, Winks CJ 2017. **Prospects for biological control of *Lonicera japonica* (Caprifoliaceae) in New Zealand.** Biological Control 105: 56–65.

Peterson P, Hayman E, Barton J 2017. **Feasibility for biological control of Mexican Daisy, *Erigeron karvinskianus* DC.** Landcare Research Contract Report LC2807 prepared for Auckland Council. 35 p.

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Changes to Pages

If you are keeping your copy of *The Biological Control of Weeds Book* up to date you might like to download the following new or amended pages from www.landcareresearch.co.nz/publications/books/biocontrol-of-weeds-book:

Information Sheets

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- Tutsan Moth
- Tutsan Rust

Monitoring Forms

- Tutsan Beetle
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