Biocontrol of weeds in New Zealand: an overview of nearly 85 years

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Summary This paper reviews weed biocontrol in New Zealand, particularly funding, risk management and future challenges. The areas of research summarised include release studies, host range testing/safety, agent effectiveness and monitoring impacts on weeds.

Keywords Risk assessment, release studies, host range, agent effectiveness, impacts on weeds.

HISTORY AND OVERVIEW

Increasing numbers of weed biocontrol agents have been released in New Zealand (NZ) in the past nine decades (Figure 1). However, from 1940–1979 NZ only acquired agents already released elsewhere.

Thirty-eight (78%) of the 49 species of weed biocontrol agents released in NZ primarily targeted productive sector weeds. Recently the focus has changed: 13 (87%) of the 15 agent species currently researched primarily target environmental weeds. Agent source has also changed for NZ-instigated programs: 25 of 27 agents released in the past were European; now only one is from Europe, with nine species from South America. Agent surveys have also recently been undertaken in Japan, Pakistan and South Africa.

Improved risk assessment and increased public consultation under the *Hazardous Substance and New Organisms Act*, and the quasi-judicial Environmental Risk Management Authority, result in increased costs of biocontrol applications. However, the transparency and lack of overt political involvement has been highly beneficial to weed biocontrol in NZ (Barratt and Moeed 2005).

Weed biocontrol in NZ receives research funding from the Foundation for Research, Science and Technology, with operational funding mostly from local government. We review research highlights from this successful funding partnership, and future challenges to weed biocontrol in NZ.

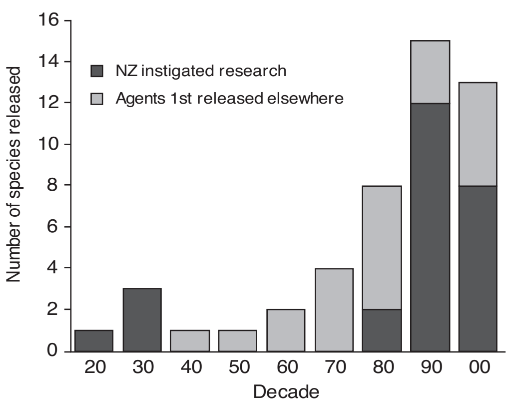

Figure 1. Weed biocontrol releases in NZ (counting only the first release per agent species).

RELEASE STUDIES

Studies show the detrimental effect of rain on releases (Hill *et al.* 1993, Norris *et al.* 2002), an increased extinction risk with small releases (Memmott *et al.* 2005) and that the release size that optimises effort versus number of establishments may be smaller than expected: e.g. <100 individuals per release for gorse thrips compared with a previous release size of 1000 per release (Memmott *et al.* 1998). Information on optimal release size is now often gained early with new agents in NZ, and establishment rates per agent species has increased in NZ from 44% (Cameron *et al.* 1993) to 76% (Fowler *et al.* 2000, Syrett *et al.* 2000).

HOST RANGE TESTING/SAFETY

Analysis of past host-range testing showed mostly reliable procedures (Fowler *et al*. 2004). However, field surveys of non-target plant species revealed three insect species (*Chrysolina* sp., *Phytomyza vitalbae* Kaltenbach and *Tyria jacobaeae* L.) causing minor damage to native plants, and *Bruchidius villosus* (F.) and *Cydia succedana* (Denis and Schiffermüller) attacking close exotic relatives to their target weeds (Paynter *et al*. 2004, Waipara *et al.* 2009). Experimental studies concluded that safety can be improved by (i) increased replication; (ii) including no-choice tests, i.e. without the normal host plant; and (iii) releasing only from the same geographic populations as those tested (Haines *et al*. 2004, Paynter *et al.* 2008).

AGENT EFFECTIVENESS

Over half of weed biocontrol agents established in NZ do not contribute to controlling their target weeds (Paynter *et al.* 2010a). We are investigating several reasons why this might be.

Host plant status Very low organic nitrogen levels (~1% dry weight) in heather, *Calluna vulgaris* L., in parts of NZ appear to contribute to poor establishment of the heather beetle, *Lochmaea suturalis* (Thompson), possibly by an interaction between body size/fat reserves, overwintering survival and fecundity (Fowler *et al.* 2008).

A poor match of agent to plant biotype may explain insignificant weed suppression with accidentally arrived rusts in NZ, e.g. *Phragmidium violaceum* (Schultz) G.Winter and hieracium rust *Puccinia hieracii* var. *piloselloidarum* (Röhl.) H.Mart. Furthermore, co-evolved host plant resident microbes (endophytes) could influence a weed's susceptibility to biocontrol agents (Evans 2008), a hypothesis we are testing with weeds such as *Clematis vitalba* L. and *Cirsium arvense* (L.) Scop.

Climate match/seasonal phenology Ragwort flea beetle *Longitarsus jacobaeae* (Waterhouse) and gorse spider mite *Tetranychus lintearius* Dufour perform poorly in higher rainfall regions (Hill *et al.* 1991, Gourlay *et al.* 2008), and poor seasonal synchrony reduces the impact of *C. succedana* (Paynter *et al.* 2008) and *Botanophila jacobaeae* Hardy (Dymock 1987). Recent modelling indicates that *Cleopus japonicus* Wingelmüller should be most effective against *Buddleja davidii* Franch., in warmer parts of NZ (Kriticos *et al.* 2009).

Competition or natural enemies *Rhinocyllus conicus* (Froehlich) and *Urophora solstitialis* L., predate seeds in nodding thistle heads, and it appears *U. solstitialis* alone would achieve greater seed destruction (Groenteman *et al.* 2007). Predation reduces the effectiveness of gorse spider mite in NZ (Peterson *et al.* 2000). The effect of predators on weed biocontrol agents in NZ is an area of continuing research. Agent success is negatively associated with parasitism, which affects about 36% of insect weed biocontrol agents in NZ (Paynter *et al.* 2010a). In many instances parasitism could be predicted by the presence of ecologically analogous native insects also feeding on the target weed (Paynter *et al.* 2010a). We are also researching the impacts of pathogens on the performance of insect biocontrol agents after problems with a microsporidian in heather beetle and gregarine parasites in chrysomelid beetles.

Additive agent interactions Where agents are abundant, but still cause insufficient impact on weed populations, we are interested in further agent species with additive or synergistic interactions. We showed additive interactions between biocontrol agents in laboratory studies using gorse (Fowler and Griffin 1995) and mist flower. Synergistic interactions could be achieved via mutualisms with insects vectoring plant pathogens. Our research showed this did not occur with *P. vitalbae* and *Phoma clematidina* (Thüm.) Boerema (Hill *et al*. 2004), and recent data question the significance of *Ceratapion onorpordi* Kirby as a vector of *Puccinia punctiformis* (Str.) Röhl. (Cripps *et al.* 2009).

Mutualisms may affect weed biocontrol in other ways. For example, although it has been assumed that seed-feeders rarely destroy adequate seed to affect weed populations, Paynter *et al.* (2010b) predicted that reducing pollinator abundance by controlling placement of beehives, could enhance the impact of the broom seed beetle *B. villosus*.

MONITORING IMPACTS ON WEEDS

Successful programs have often only been assessed to a limited extent. These include quantitative studies of St John's wort *Hypericum perforatum* L. and alligator weed *Alternanthera philoxeroides* (Mart.) Griseb., largely observational reports on Mexican devil weed *Ageratina adenophora* (Sprengel) R.King & H.Robinson (all reviewed in Cameron *et al.* 1989), surveys and experimental studies of ragwort *Senecio jacobaea* L. (Gourlay *et al.* 2008), and modelling for nodding thistle (Shea and Kelly 2004). An exception is the mist flower biocontrol program, where detailed studies showed that the white smut fungus *Entyloma ageratinae* Barreto and Evans reduced the mean percentage cover of mist flower from 81% to 1.5% over 5 years. This decline was accompanied by increased species richness and percentage cover of native plants, with only a weak 'replacement weed' effect (Barton *et al.* 2007). In contrast, a 10 year experiment removing *Hieracium pilosella* L. showed very little vegetation change (Syrett *et al.* 2004). A 'wait and see' approach has been taken for targets such as broom *Cytisus scoparius* (L.) Link and *C. arvense*. However, long term plots in place for broom and substantial population dynamics and economic impact studies have been carried out with these weeds (Kaye-Blake and Dhakal 2008, Paynter *et al.* 2010b). We are developing simple, cost-effective methods so end-users can generate data to complement selective flagship monitoring studies.

FUTURE ISSUES/CHALLENGES

New Zealand has many existing and 'sleeper' weeds, and given limited resources, we need improved prioritisation. A recent decision framework allows us to identify both likely 'winners' and difficult weed biocontrol targets with a surprising degree of confidence (Paynter *et al.* 2009). In cases where a taxonomic group of target weeds is unrelated to either the NZ indigenous flora or valued exotic plants, such as crops or ornamentals, then we are moving to 'multi-targeting', where biocontrol agents are introduced to target more than 1 exotic weed species (Groenteman *et al.* 2008). Biocontrol remains the only cost-effective, sustainable way to suppress widespread weeds, and we expect increasing pressure to reduce herbicide use to reinforce this. Nearly 85 years of weed biocontrol activity in NZ has already delivered many benefits. Research efforts are now largely focused on improving success rates, better cost effectiveness and demonstrating value to NZ.

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