Proceedings of the X International Symposium on Biological Control of Weeds
4-14 July 1999, Montana State University, Bozeman, Montana, USA
Neal R. Spencer [ed.]. pp. 719-727 (2000)

Technology Transfer Programs for Biological Control of Weeds — the New Zealand Experience

L. M. HAYES

Landcare Research, P.O. Box 69, Lincoln, New Zealand

Abstract

Biological control has become a major focus for managing a variety of agricultural and conservation weeds in New Zealand. For nearly 2 decades Landcare Research (formerly DSIR) has operated successful technology transfer programs with most organizations that manage weeds in New Zealand. Program success is based on strong relationships built up between Landcare Research and participating organizations over this time, and their evolution in response to changing times and the unique needs of each participating organization. As well as providing nucleus populations of biological control agents (insects, mites, and fungi), Landcare Research now offers strategies for managing and enhancing the impact of the agents, more efficient and relevant monitoring and assessment techniques, advice about new projects, and most importantly, comprehensive training in biological control theory and practice. As a result, a network of well-trained people now manage biological control programs for 14 weed species nationwide. Biological control agents have been released faster and more widely than was previously possible. Establishment success is high (95%), and at least 3 weeds: alligator weed (*Alternanthera philoxeroides*), nodding thistle (*Carduus nutans)*, and ragwort (*Senecio jacobaea*) are reported to be under control at many sites. Research trials have also been enhanced and the level of understanding about biological control in the wider community is increasing.

Keywords: Biological control, New Zealand, technology transfer programs, weeds

Weeds threaten many of New Zealand's landscapes and agricultural systems. At present, New Zealand is reliant on agricultural chemicals to maintain economic production and product quality, to meet quarantine requirements for export, and to protect native vegetation (Hill *et al.* 1995). In recent times, efforts have been made to find more sustainable, environmentally friendly methods of control. Landcare Research, a research and consultancy company wholly owned by the New Zealand Government, is responsible for most of the biological control of weeds research in New Zealand.

Before 1981, biological control programs were funded entirely by central government. The scientific staff involved were responsible for the whole process, from selecting, testing, and importing control agents to rearing, releasing, and subsequently monitoring them. Under this system only a few species of control agents could be imported and released at a small number of sites. Redistribution from established sites was not attempted, and the control agents were left to slowly invade new areas.

A new era in biological control of weeds began in New Zealand in the 1980s when technology transfer programs were set up. Under this system central government still paid for the development and assessment of most control agents, while those who benefitted from the research (e.g., regional government, government-owned farming companies, government departments, forestry companies) took responsibility for its widespread implementation. The first co-operative program, with 2 regional governments, focused on a single weed of limited distribution, alligator weed (*Alternanthera philoxeroides*) (Table 1). Co-operative programs with a range of organizations nationwide began in 1986 for weeds of wider distribution. The daily operation of the earlier years of the programs has already been described in detail (Grindell 1995). This paper describes the overall success of the programs and how they have been altered to keep pace with changing times over the past 2 decades.

Achievements of the Technology Transfer Programs

Technology transfer programs for biological control of weeds funded by end-users have worked well in New Zealand (Syrett *et al.* 1993). Before the programs began, participating organizations knew little about biological control, and many were skeptical of its value. Today the same organizations have a high level of commitment to, and competence in, biological control methods. Biological control is now written into many of their weed management strategies and they spend a substantial amount of time working in this area.

The success of our New Zealand programs is due to the strong co-operative relationships that we have developed with participating organizations, and their continued support. These strong relationships have been built up as a result of constant and consistent contact over many years. Our staff frequently spend time with participants on the job, so that they can see and hear their needs. We aim to provide a complete back-up service and we regularly run intensive workshops, field days, and seminars, and provide written and display resource materials.

The technology transfer programs have given us access to a well-trained network of more than 100 field staff nationwide. Without these people none of the activities described below would have been possible.

Rapid widespread distribution and successful establishment of control agents

Some species, like the lesser St John's wort beetle (*Chrysolina hyperici*) can rapidly establish widely from a small number of releases (Hancox *et al.* 1986). However, most agents we have released against weeds in New Zealand have slow natural rates of dispersal. For example, the ragwort flea beetle (*Longitarsus jacobaeae*) moved less than 200 m in 3 yr at a site near Hanmer Springs, Canterbury (Harman and Syrett 1989), and gorse thrips (*Sericothrips staphylinus*) are often confined to the original gorse (*Ulex europaeus*) bush they were released on several years after they were liberated (L.M.H., unpublished data). For slow-moving agents, it is vital to make a large number of releases throughout the range of the weed, and to actively facilitate dispersal so that beneficial effects of the agents are achieved early.

Participating organizations have an extensive knowledge of local weed populations so their field staff are able to select the most appropriate release sites, and they often release the control agents themselves. Since 1981 the technology transfer programs have enabled 27 biological control agents (insects, mites, and fungi) to be released at more than 1700 sites for 14 weed species (Table 1). This is a substantial improvement on government-funded programs that resulted in the release of fewer species at far fewer sites in the previous 55 yr (Cameron *et al.* 1989).

When biological control agents are introduced to a new country there is no guarantee

Table 1.
Number of nucleus populations of control agents released under the technology transfer programs between December 1981 and April 1999, and their current status

Target weed and agents released	Populations released	Overall status
Ageratina riparia (Regel) King and Robinson (Asteraceae)		
Entyloma ageratinae Baretto and Evans (Ustilaginales: Tilletiaceae)	9	E
Alternanthera philoxeroides (C. Martius) Grisebach (Amaranthaceae)		
Agasicles hygrophila Selman and Vogt (Coleoptera: Chrysomelidae)	29	E
Disonycha argentinensis Jacoby (Coleoptera: Chrysolmelidae)	17	F
Vogtia malloi Pastrana (Lepidoptera: Pyralidae)	15	E
Carduus nutans L. (Asteraceae)		
Rhinocyllus conicus Froelich (Coleoptera: Curculionidae)	5	E
Trichosirocalus horridus Panzer (Coleoptera: Curculionidae)	138	E
Urophora solstitialis L. (Diptera: Tephritidae)	97	E
Carduus tenuiflorus Curtis (Asteraceae)		
Trichosirocalus horridus Panzer (Coleoptera: Curculionidae)	4	E
Calluna vulgaris (L.) Hull (Ericaceae)		
Lochmaea suturalis[a] Thomson (Coleoptera: Chrysomelidae)	18	?
Cirsium arvense (L.) Scopoli (Asteraceae)		
Altica carduorum Guérin-Méneville (Coleoptera: Chrysomelidae)	26	R
Lema cyanella (L.) (Coleoptera: Chrysomelidae)	44	E
Urophora cardui (L). (Diptera: Tephritidae)	8	E
Cirsium vulgare (Savi) Tenore (Asteraceae)		
Trichosirocalus horridus Panzer (Coleoptera: Curculionidae)	4	E
Urophora stylata (F.) (Diptera: Tephritidae)	2	R
Clematis vitalba L. (Ranunculaceae)		
Phoma clematidina[a] (Thüm) Boerema (Sphaeropsidales: Sphaeropsidaceae)	23	E
Phytomyza vitalbaea[a] Kaltenbach (Diptera: Agromyzidae)	40	E
Conium maculatum L. (Apiaceae)		
Agonopterix alstromeriana (Clerk) (Lepidoptera: Oecophoridae)	2	E
Cytisus scoparius (L.) Link (Fabaceae)		
Arytainilla spartiophila[a] (Förster) (Homoptera: Psyllidae)	49	E
Bruchidius villosus[a] F. (Coleoptera: Bruchidae)	100	E
Leucoptera spartifoliella (Hübner) (Lepidoptera: Lyonetiidae)	3	E
Hieracium pilosella L. (Asteraceae)		
Aulacidea subterminalis[a] Niblett (Hymenoptera: Cynipidae)	2	?
Oxyptilus pilosellae[a] Zeller (Lepidoptera: Pterophoridae)	1	?
Hypericum perforatum L. (Clusiaceae)		
Chrysolina quadrigemina (Suffrian) (Coleoptera: Chrysomelidae)	4	R
Senecio jacobaea L. (Asteraceae)		
Longitarsus jacobaeae (Waterhouse) (Coleoptera: Chrysomelidae)	158	E
Tyria jacobaeae (L.) (Lepidoptera: Arctiidae)	149	E
Ulex europaeus L. (Fabaceae)		
Agonopterix ulicetella[a] (Stainton) (Lepidoptera: Oecophoridae)	60	R
Cydia succedana[a] (Denis and Schiffermüller) (Lepidoptera: Olethreutidae)	92	E
Sericothrips staphylinus[a] Haliday (Thysanoptera: Thripidae)	281	E
Tetranychus lintearius[a] Dufour (Acari: Tetranychidae)	352	E

[a] New Zealand was the first country to import and release these control agents.

(R=recovered (found since the release), E=established (univoltine agents are considered to have established if they are found in increasing numbers for 2 or more years after release, whereas multivoltine agents are considered to have established if they are found after one winter and have completed several generations), ?= don't know because it is too soon after release or only insufficient or conflicting information is available, F=failed).

that they will establish. In the 55 yr prior to the commencement of these technology transfer programs, 8 of the 12 species released (67%) established in New Zealand (Harman *et al.* 1996). This is comparable to the worldwide success rate (63%) for establishing biological control agents for weeds (Julien 1989). Establishment success worldwide has not really improved in recent decades despite more new agents being released (Syrett *et al.* 1999a). By contrast the establishment success rate in New Zealand is now higher, thanks to the technology transfer programs. Currently we know the fate of 20 of the 27 agents released (Table 1). We have established 16 new species, 1 existing species in areas where it had previously failed (cinnabar moth (*Tyria jacobaeae*)), and 2 self-introduced species in areas where they were not yet present (hemlock moth (*Agonopterix alstromeriana*) and broom twig miner (*Leucoptera spartifoliella*)). Only 1 species, the alligator weed beetle (*Disonycha argentinensis*), has so far failed to establish, giving the programs a 95% success rate (Table 1). New Zealand was the first country to release 8 of these agents, so many of the techniques we used were novel. This makes the establishment success achieved under the technology transfer programs even more notable. We believe that our success rate is high because we release nucleus populations at a large number of sites over several years, which increases the chances of them finding suitable conditions for establishment (Fowler *et al.* 1999).

Once agents are established, participating organizations take responsibility for redistributing them to all areas where they are needed, allowing results to be achieved more quickly. For example, field staff in the Bay of Plenty have spread ragwort flea beetle throughout the region to attack ragwort (*Senecio jacobaea*). They claim that, as a result of active and natural dispersal, beetles are present in all areas where they are needed (P. Ingram, personal communication) less than 15 yr after they were first introduced to the region. Other field staff have, with the support of Landcare Research, built cages and conducted their own rearing programs to ensure that large numbers of ragwort flea beetles and cinnabar moths are available to release in all problem areas.

Rapid monitoring and evaluation of control agents

Many control agents are notoriously slow at reducing weed populations. For example, ragwort flea beetle took 15-19 yr to achieve successful control of ragwort in California (Pemberton and Turner 1990). Because in New Zealand we release small numbers of agents at each site, it can take many years for damaging populations to build up and cause noticeable impacts. We keep participating organizations satisfied that progress is being made by regularly monitoring all release sites and publicizing the smaller milestones of release, recovery, establishment, and spread. We would not be able to do this without the assistance of the network of field staff. Initially our staff at either Auckland, Palmerston North, Nelson, or Lincoln assist with monitoring release sites until they have trained the field staff to take over. We store all the information that is collected on a computer database and provide participants with printed reports annually. This monitoring information can provide an early indication of progress towards effective control. For example, field staff provided numerous reports that ragwort and nodding thistle (*Carduus nutans*) populations were declining at many sites where control agents had been released, well before any experimental evidence was available to substantiate these claims.

Some of the organizations participating in the programs have enabled us to conduct more extensive experiments than would otherwise have been possible. For example, a government-funded collaborative research trial, with British scientists based at Bristol

University and CABI Bioscience, is underway to determine the optimum number of broom psyllids (*Arytainilla spartiophila)* to release for establishment. Fifty-five, well-separated sites were required, and Otago Regional Council field staff made this possible by locating the sites and obtaining the owners' permission to use them.

Increased public awareness

Participating organizations have raised the level of understanding about biological control in the community. The general public is concerned about the safety and efficacy of biological control agents. Education about how biological control works, especially safety aspects and expectations, is vital if the community is to lend its support. Field staff often involve journalists from local media at the release of control agents and again when results are apparent. We provide public relations and display materials, live exhibits, and other support so that participating organizations can promote biological control to the general public by holding field days, and developing links with local schools.

Improving a Successful Formula

We are continually modifying the technology transfer programs so that they continue to meet the needs of the organizations responsible for weed control in New Zealand. As a consequence the technology transfer programs have become larger, more complex, and more diverse. Projects are now undertaken on weeds of both widespread and more restricted distribution. As well as providing nucleus populations of biological control agents and monitoring services, Landcare Research now offers strategies for managing and enhancing the impact of the agents, more efficient monitoring and assessment techniques, advice about new projects, and comprehensive training in biological control methods. In this section these changes are described in more detail.

Increased complexity of programs to meet the needs of end-users

In the past, participating organizations signed up for a uniform program, but we now formulate a unique program of work with each one. Both the importance of weeds and research priorities vary tremendously between regions and the programs now reflect this. These tailor-made programs are more challenging for us to operate, but are more sustainable, useful, and satisfying. To ensure that we continue to offer the best possible programs, we regularly keep in touch with and visit participating organizations. They often ask us about the prospects of biological control for many new problem weeds, so we now offer feasibility studies as part of the programs.

The role of the community in the implementation of biological control is an important and often under-utilized resource (Darby and McLaren 1993). In Australia, community groups play a key role in releasing and monitoring biological control agents and increasing their distribution once established (Briese and McLaren 1997). Recently we have begun to work more closely with community groups to tackle weed problems that are of particular concern to them. Some of these projects, like Californian thistle (*Cirsium arvense*) and Scotch thistle (*C. vulgare*), are not funded and not likely to be funded elsewhere, so we have assisted the community groups to successfully secure money from appropriate sources. One community group, the Hieracium Control Trust, has raised its own funding from a variety of sources to enable a new project for hieracium (*Hieracium pilosella*) to begin from scratch. Other community groups augment existing funded projects, like broom (*Cytisus scoparius*), to speed up progress.

Increasingly central government has moved away from funding the routine research required to develop new agents and put biological control programs in place, in favour of supporting research into some of the wider underpinning issues. To enable biological control introductions to continue, we have fostered a collaborative approach between several organizations troubled by the same weed. For example, mist flower (*Ageratina riparia*) threatens conservation and production values on land administered by four organizations, and they are collaborating to fund a complete program to test, import, rear, release, and monitor two agents.

Increased efficiency in rearing and release activities

Efficient rearing programs and release strategies are crucial to a successful technology transfer program, and we have improved ours in four ways. Firstly, we now schedule more time following introduction to study the agent's life history, to build up small-scale rearing methods, and experiment with new rearing techniques before committing ourselves to widespread releases. If necessary, we ask participating organizations to help fund this vital step. We also limit the number of species offered each year.

Secondly, we give a high priority to establishing field sites. If we can harvest agents from the field, intensive artificial rearing can be kept to a minimum. For example, it takes 27 h to rear one release of 100 gorse pod moths *(Cydia succedana*) and the same number can be field-collected in about 1–2 h. If agents are difficult to rear indoors we may not offer them until they can be harvested from field sites.

Thirdly, we continually revise our release strategies. The factors that determine whether or not a control agent can establish (e.g., number of agents released) are not well understood. Although a number of factors have been explored theoretically, until recently they have not been tested in the field (Memmott *et al.* 1996). We are collaborating with British scientists (based at Bristol University) in a study partially funded by the New Zealand Government to test how numbers of agents per release, numbers of releases per site, and site-based factors affect establishment success. We hope that the results of this work will enable control agents to be distributed more efficiently in future.

Finally, we stress the need to take care when selecting release sites so that as few as possible control agents are wasted. The agents are released widely so they are less likely to all be lost in some freak event, but even then, many individual sites are accidentally destroyed. We encourage all field staff to avoid release sites that are prone to natural disasters like flooding, and to erect signs (giving a contact name and telephone number) warning that the site has special significance. We also recommend that field staff involve land owners at all times so they know where the site is, know how to recognize the agents and their damage, and have realistic expectations about the time frame and level of control expected.

Improved monitoring and evaluation of control agents

Because data are collected by many people of varying abilities, we have found it useful to limit the scope of monitoring information to presence or absence of the control agent, and rate of spread. We have made recovery forms simpler to complete and less ambiguous by offering multiple choices to circle rather than blank spaces to fill in. Volunteers trial recovery forms so problems can be identified and remedied early. If more complex information is required, we have found it more useful to train a few people to intensively sample a smaller number of sites.

We are constantly searching for better ways of locating control agents in the field. Pheromone traps can provide information about the survival and spread of control agents much more quickly and reliably than conventional searching techniques. HortResearch in New Zealand helped us to find a pheromone that attracts gorse pod moth (Suckling *et al.* 1999), and within weeks we had a good understanding of the moth's establishment success nationwide. The technology transfer programs are currently funding a study to increase our monitoring efficiency by searching for a suitable pheromone mixture to attract gorse soft shoot moth (*Agonopterix ulicetella*).

Organizations participating in the programs need to be able to justify their continued involvement, and this means assessing the impact of control agents on problem weeds in their areas. Assessment has often been the weak link in biological control programs worldwide because it usually requires complex long-term studies, which are expensive to carry out. We are working to develop faster and simpler assessment techniques that participating organizations can use themselves. For example, this year a workshop was held to teach field staff to use an insecticide exclusion method for assessing the effectiveness of ragwort flea beetle over 1-2 yr.

Improved efficacy of biological control

Most field staff are reluctant to harvest and redistribute control agents if they have to collect them one at a time on their hands and knees. The technology transfer programs now fund projects that develop practical and efficient methods for harvesting control agents. For example, we have shown that it is more efficient to distribute the broom seed beetle (*Bruchidius villosus*) by cutting and shifting whole broom bushes or branches with mature infested pods during the summer, than collecting the adults by beating or vacuuming them off plants and shifting them to new sites in the spring (Syrett *et al.* 1999b).

At present the interactions between biological control agents, chemicals, and land management techniques are not well understood, and worldwide there have been few studies attempting to link the various management tools together. The lack of information about the integration of biological control with other approaches to weed control can be a major stumbling block when establishing biological control agents (Jupp 1996), let alone allowing them to achieve maximum potential. The technology transfer programs are now funding small projects to improve our knowledge in this area. For example, the programs are currently funding a study to investigate how herbicides may be used in conjunction with ragwort flea beetles. Many landowners are unwilling to stop spraying ragwort while the flea beetles are establishing, and field staff have told us that the beetles have survived at sites that have been sprayed with herbicide. We hope to be able to identify a spray regime that has the least possible impact on ragwort flea beetle. We anticipate that the programs will increasingly fund more of these types of projects in the future.

Improved public awareness

We now allocate more resources to training participants in the technology transfer programs and encouraging them to undertake activities that promote biological control. Intensive in-house workshops have been highly successful at increasing the enthusiasm and skills of field staff, who then pass this information on to others. We have had excellent feedback about our promotional material, which includes quarterly newsletters and a reference manual. We target this material at a wider audience who do not have scientific training. The reference manual (The Biological Control of Weeds Book — A New Zealand

Guide) is a loose-leaf publication that covers all aspects of biological control of weeds and its application in New Zealand. The programs fund the production of additional pages for the manual each year. Recently, a video Natural Born Weed Killers was made, which is aimed at the general public and will be distributed widely.

Conclusion

Co-operative technology transfer programs have successfully established a large number of biological control agents for weeds throughout New Zealand in a relatively short time. A large network of people trained in biological control procedures manage these agents and spread both their knowledge and the agents further. As a result the level of understanding about biological control in the community and the distribution of the agents continue to increase.

The success of these programs is largely due to strong relationships that have been built up over a long period of time. The programs have evolved as the needs of the participating organizations have changed. The programs are now complex and diverse and aim to provide a total back-up service. As well as supplying nucleus populations of control agents, the programs now have an increased emphasis on the management of agents, integration of biological control with other weed management techniques, and evaluation of biological control strategies.

Acknowledgements

Thank you to all the individuals and organizations who have helped make the technology transfer programs such a success. Thanks to Christine Bezar, Richard Hill, Trevor Partridge, and Pauline Syrett for their comments on this manuscript.

References

Cameron, P.J., R.L. Hill, J. Bain, and W P. Thomas. 1989. A review of biological control of invertebrate pests and weeds in New Zealand 1874 to 1987. CAB International, Wallingford, UK.

Briese, D.T., and D.A. McLaren. 1997. Community involvement in the distribution and evaluation of biological control agents: Landcare and similar groups in Australia. Biocontrol News Info. 18 (2): 39-49.

Darby, S., and D.A. McLaren. 1993. The role of the community in the implementation of biological control. Plant Prot. Q. 8 (4): 155-158.

Grindell, J.M. 1995. Biological control of weeds extension programs in New Zealand. *In* E. Delfosse and R. R. Scott [eds.], Biological control of weeds. CSIRO Publishing, Melbourne, Australia.

Fowler, S.V., P. Syrett, and R.L Hill. 1999. Success and safety in the biological control of environmental weeds in New Zealand. Aust. J. Zool. (in press).

Hancox, N.G., P. Syrett, and R.R. Scott. 1986. Biological control of St John's wort (*Hypericum perforatum*) in New Zealand: a review. Plant Prot. Q. 1: 152–155.

Harman, H.M., and P. Syrett. 1989. Establishment and seasonality of two ragwort feeding insects at Hanmer, New Zealand. Proc. 42nd NZ Weed Pest Cont. Conf.: 48–51.

Harman, H.M., P. Syrett, R.L. Hill, and C.T. Jessep. 1996. Arthropod introductions for biological control of weeds (1929-1995). NZ Entomol. 19:71–80.

Hill, R.L., P.E. Cowan, and J.M. Williams. 1995. The role of biological control in sustainable land management, pp. 238–242. *In* M. Ralston [ed.], Proceedings, New Zealand Conference on Sustainable Land Management, 12–14 April 1994, Lincoln University, Canterbury, New Zealand.

Julien, M.H. 1989. Biological control of weeds worldwide: trends, rates of success and the future. Biocontrol News Info. 10 (4): 299–306.

Jupp, P.W. 1996. The establishment of a distribution network for the mite *Aculus hyperici* to control St John's wort (*Hypericum perforatum*) in Australia, pp. 451–453. *In* V. C. Moran and J. H. Hoffman [eds.], Proceedings, IX International Symposium on Biological Control of Weeds, 19–26 January 1996, University of Cape Town, Stellenbosch, South Africa.

Memmott, J., S.V. Fowler, H.M. Harman, and L.M. Hayes. 1996. How best to release a biological control agent, 291–196. *In* V. C. Moran and J. H. Hoffman [eds.], Proceedings, IX International Symposium on Biological Control of Weeds, 19–26 January 1996, University of Cape Town, Stellenbosch, South Africa.

Pemberton, R.W., and C.E. Turner. 1990. Biological control of *Senecio jacobaea* in northern California, an enduring success. Entomoph. 35: 71–77.

Suckling, D.M., R.L. Hill, A.H. Gourlay, and P. Witzgall. 1999. Pheromone-based monitoring of biological control agents of gorse. Biocontrol Sci. Tech. (in press).

Syrett, P., L.M. Hayes, and J.J. Sheat. 1993. Benefits of a nationwide extension program to biological control of weeds research in New Zealand. Proc. 10th Aust. Weeds Conf: 445–449.

Syrett, P., D.T. Briese, and J.H. Hoffman. 1999a. Biocontrol of terrestrial weeds. *In* G. Curr and S. D. Wratten [eds.], Measures of success in biological control, Kluwer, Dordrecht, The Netherlands (in press).

Syrett, P., J.J. Sheat, H.M. Harman, R.J. Harris, L.M. Hayes, and E.A.F. Rose. 1999b. Strategies for optimizing widespread establishment of broom seed beetle, *Bruchidius villosus*, a biological control agent for broom, *Cytisus scoparius*, in New Zealand. *In* Proceedings, X International Symposium on Biological Control of Weeds (this volume).