Prospects for Biological Control of Barberry *Berberis* spp. (Berberidaceae)

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Contents

Summary

Project and Client

Landcare Research, Palmerston North, investigated the feasibility of biological control of barberry (*Berberis* spp.) in New Zealand for Environment Southland and horizons.mw in November 2001.

Objectives

- Record the distribution and weed status of barberry in New Zealand.
- Summarise the literature and information on the current worldwide status of biological control of barberry.
- Assess the likelihood of success of a biological control programme for barberry in New Zealand and review the steps necessary to implement such a programme.
- Propose a realistically costed programme for implementation of a biological control programme by Environment Southland, horizons.mw and other affected councils.

Main Findings

- Of the five adventive species of *Berberis* in New Zealand, *B. darwinii* (Darwin's barberry) and *B. glaucocarpa* (barberry) are important weeds. *B. darwinii* is spreading faster than *B. glaucocarpa*, which has occupied much of its potential range.
- *Berberis darwinii* and *B. glaucocarpa* invade laxly grazed pasture, open scrub and bush and can establish under a mature forest canopy. They reduce amenity values, can form impenetrable thickets, and can prevent the establishment of other plants.
- Both species produce large crops of palatable fruit, which are dispersed by birds and possums.
- There are no indigenous plant species closely related to *Berberis,* and only one adventive genus in Berberidaceae. In New Zealand there are no species closely related to *Berberis* that are economically or culturally important. Some species of *Berberis* are grown for ornamental purposes, and some of these are potentially invasive weeds.
- Many fungi and invertebrates are recorded from *Berberis* spp.; some of these cause significant damage and may have potential value for biological control, but for most, little or nothing is known about their biology and host specificity.
- Surveys for prospective agents would have to be carried out in southern South America for *B. darwinii* and the western Himalaya for *B. glaucocarpa*.

Conclusions

- Prospects for a biological control programme directed at *B. darwinii* and *B. glaucocarpa* appear good.
- There are no indigenous Berberidaceae in New Zealand and no important exotic members of the family, so that prospective agents need not be restricted to attacking only the adventive species of *Berberis*.

- Several fungi and invertebrate species are known to attack *Berberis* species and some of these cause significant damage to the plant; furthermore, since *Berberis* is a large genus the prospects for locating biological control agents are good.
- Classical biological control and mycoherbicides are both likely prospects.

Recommendations

- Survey populations of *B. darwinii* and *B. glaucocarpa* in different seasons throughout the species' known ranges in New Zealand to determine which invertebrates and diseases are currently associated with these species in New Zealand ($50,000 in total over 2 years);
- Survey *B. darwinii* and other *Berberis* species in Chile and Argentina to identify prospective biological control agents ($50,000 in total over 2 years);
- Survey *B. glaucocarpa* and other *Berberis* species in the western Himalaya to identify prospective biological control agents ($50,000 in total over 2 years);
- On completion of each overseas survey, review the prospects for successful biological control of that species and, if appropriate, prepare a costed programme for consideration by affected regional councils and DOC.

1. Introduction

Two of the five adventive species of barberry (*Berberis* spp.) in New Zealand are important environmental weeds, for which current control options are not adequate. Consequently, Landcare Research, Palmerston North, investigated the feasibility of biological control of barberry (*Berberis* spp.) in New Zealand for Environment Southland and horizons.mw in November 2001.

2. Objectives

- Record the distribution and weed status of barberry in New Zealand.
- Summarise the literature and information on the current worldwide status of biological control of barberry.
- Assess the likelihood of success of a biological control programme for barberry in New Zealand and review the steps necessary to implement such a programme.
- Propose a realistically costed programme for implementation of a biological control programme by Environment Southland, horizons.mw and other affected councils.

3. Sources of Information

Information for this report was obtained by searching computer databases (CAB Abstracts, Current Contents, Agricola, New Zealand Science) and internet sites for information on barberry; by cross-referencing known references; and from:

Chris Buddenhagen, Department of Conservation, Wellington;
Keith Crothers, Environment Southland, Invercargill;
Paul Hatton, horizons.mw, Wanganui;
Murray Nieuwenhuyse, Department of Conservation, Invercargill.

4. Main Findings

4.1 Distribution, weed status and current control of barberry in New Zealand

Distribution

Of the five species of *Berberis* naturalised in New Zealand, two have very limited distributions. These are *B. soulieana*, with a small population at Trentham in the Hutt Valley, and *B. wilsoniae*, known in the North Island from Te Karaka in Poverty Bay and in the South Island from Culverden in North Canterbury and Macandrew Bay in Dunedin (Webb et al.

1988). The three remaining naturalised species are *B. darwinii* (Darwin's barberry), *B. glaucocarpa* (barberry) and *B. vulgaris* (European barberry).

Berberis darwinii is endemic to south-western South America (Landrum 1999). It is widely distributed in New Zealand, from the East Cape/Te Urewera region south. Its distribution is mostly patchy in Taranaki, the King Country and the Manawatu-Wanganui region, but it is locally common in the Wairarapa and Wellington regions and widespread in and around Wellington City, where it is an important environmental problem (Oates 1998; Wellington Regional Council 2001; C. Buddenhagen, DOC, pers. comm.; P. Hatton, horizons.mw, pers. comm.). In the South Island it occurs patchily in Northwest Nelson/Buller and Canterbury, but is common from central Canterbury south throughout Otago and Southland and is abundant around Halfmoon Bay on Stewart Island; its eradication from Stewart Island is planned (Roy et al. 1998; C. Buddenhagen, DOC, pers. comm.; K. Crothers, Environment Southland, pers. comm.; M. Nieuwenhuyse, DOC, pers. comm.). As its invasive potential becomes better publicised, further large infestations are likely to be identified (K. Crothers, Environment Southland, pers. comm.).

B. glaucocarpa, from the western Himalaya, is common throughout lowland areas of New Zealand, particularly higher rainfall areas, as far south as Canterbury and Westland (Roy et al. 1998; Webb et al. 1988). It probably naturalised earlier than *B. darwinii* (first record 1916 *cf*. 1946), and perhaps for this reason occupies a greater proportion of its potential range than does *B. darwinii*, which is still spreading (Anon. 2001; Webb et al. 1988).

B. vulgaris has a more restricted distribution than either *B. darwinii* or *B. glaucocarpa*, being found predominantly in inland areas of Canterbury and Otago. Although first recorded in the the wild in New Zealand some 40 years before any other species of barberry, it appears far less invasive than *B. darwinii* and *B. glaucocarpa*; its propensity to disperse seems to be more limited than that of those species (Roy et al. 1998; Webb et al. 1988).

Weed status

Only *B. darwinii* and *B. glaucocarpa* are important environmental weeds, and this is reflected in the inclusion of *B. glaucocarpa* as a national surveillance plant pest (Vervoort & Hennessy 1997) and *B. darwinii* in the National Pest Plant Accord list (MAF 2001).

The invasive characteristic of these species arises mainly from their production of large numbers of fruits, which are eaten and subsequently dispersed by birds and possums (*Trichosurus vulpecula*) (Allen & Wilson 1992; Williams & Karl 1996; Williams et al. 2000).

Both species are serious threats primarily to sparsely-vegetated areas of bush and scrub. However, seedlings of both species tolerate shade and can invade native forests, with *B. darwinii* more invasive in these situations than *B. glaucocarpa*. *B. darwinii*'s ability to compete in mature forest is also enhanced by its plasticity of growth form: in open areas it often grows as a dense shrub 3–4 m tall and 3–6 m wide, but under a forest canopy may reach 10 m tall with branches spreading up to 15 m, supported by the branches of other trees (Allen & Wilson 1992). Neither species is an important problem in well-managed pasture, but where grazing intensity is low they can form extensive thickets that reduce pasture production and impede access by stock and vehicles (Anon 2001; K Crothers, Environment Southland, pers. comm.; Wellington Regional Council 2001).

Darwin's barberry prevents the establishment of other plants, and in this respect has been considered worse than gorse (*Ulex europaeus*) (Wellington Regional Council 2001). Other species of *Berberis* may have similar characteristics, as *B. thunbergii* has strong allelopathic activity (Itani et al. 1998).

Other species and cultivars of *Berberis* are commonly grown as ornamentals, including *B. thunbergii*, known overseas as Japanese barberry. This species is recognised as a significant invasive weed in the USA (Anon. 1999; Ehrenfeld 1997) and has the potential to be the same in New Zealand.

Species of *Berberis* in New Zealand are also alternative hosts for many pests of economically important crops (see section 4.4).

In New Zealand, barberry species have two main useful characteristics. First, they have been used as hedge plants, and second, they are cultivated for ornamental purposes. Overseas, however, *Berberis* species have been used extensively for medicinal purposes, primarily for treating infections and for diseases and disorders of the liver and heart. For example, barberry extracts have been used for over 3000 years in Ayurvedic (Indian) and Chinese medicine (Birdsall & Kelly 1997). The value of these traditional medicines has been confirmed by numerous recent studies, which have disclosed additional uses in the treatment of such diseases as malaria and some cancers (e.g., McCall et al. 1994; Liu et al. 1995; Karimov 1993; Sheng et al. 1997)

Current control methods

The primary method of control used in New Zealand is to cut the plant down and paint the cut stump with herbicide. Vigilant (5% picloram gel formulation) is a highly effective treatment for applying to cut stumps (HortResearch 2002a; C. Buddenhagen, DOC, pers. comm.), but is more expensive than other cut stump treatments such as glyphosate, Tordon Brushkiller or Grazon (K. Crothers, Environment Southland). However, glyphosate applied as a cut stump treatment does not always effectively control the deep-rooted *B. darwinii* (Ward et al. 1999). All "cut-and-swab" treatments are labour intensive and are therefore unsuitable for large infestations; thus, the method is clearly not sufficient for controlling the Manawatu-Wanganui region's *B. glaucocarpa* infestation, which occurs over an estimated 10,600 ha (Anon. 2001).

Chemical control of *B. glaucocarpa* in forestry has been reviewed by Davenhill et al. (1997). Escort, glyphosate, Tordon Brushkiller and Trounce are suitable for spot treatment by knapsack and for application by brushgun; the first three can also be applied by mistblower. Escort, Tordon Brushkiller and Grazon are recommended for stump swabbing. For aerial application, glyphosate, Tordon Brushkiller and Trounce are recommended herbicides. Herbicide spraying is best carried out in spring and early summer when new growth is abundant, as mature leaves are moderately resistant to herbicides.

Small seedlings can also be uprooted by hand, but this method is labour intensive and quickly becomes impractical as seedlings develop, because the deep root system firmly anchors the plant. Grazing by goats gives effective control in pasture (Holst & Campbell 1987), but because of economic reasons this is now not practical; it is not an option elsewhere because goats are highly destructive, generalist browsers. In general, a well-managed stock grazing regime will prevent barberry seedlings from establishing in pasture, and the few plants that survive can be easily killed by a herbicide treatment.

4.2 Taxonomic status of *Berberis* and its relatives in New Zealand

The ability of natural enemies to attack new hosts is strongly influenced by the evolutionary history of those potential hosts (Briese 1996), so in any biological control programme it is essential to understand the relationships between the target plant and its relatives, particularly those that are economically or culturally significant. *Berberis* is in the family Berberidaceae; in New Zealand there are no indigenous genera in this family, and only one other adventive genus, *Mahonia*. *Berberis* and *Mahonia* are very closely related (Kim & Jansen 1994; Laferriere 1997; Laferriere & Ahrendt 1997); indeed, *Mahonia* is often combined with *Berberis* (Landrum 1999). The main distinguishing feature of *Berberis* and *Mahonia* is that the former has simple leaves whereas the latter has compound leaves.

The species of *Berberis* have been grouped into two subgenera: Septentrionales, with about 300 species, has a Eurasian distribution; and Australes, with about 200 species, originates from South America (Schneider 1905 and Ahrendt 1906, quoted in Landrum 1999). The subgenera have been further divided into sections and subsections, but these appear to be based on geographical distribution and it is not known whether they have any phylogenetic basis (Landrum 1999).

Several other species and hybrids of *Berberis* are cultivated in New Zealand, and common names have sometimes been misapplied (Webb et al. 1988), but these issues have little relevance for the purposes of this report.

4.3 Steps necessary for a biological control programme for barberry

The steps necessary for a classical biological control programme have been well discussed by Harley and Forno (1992) and Forno (1997). Some of these steps have already been undertaken; others have been partially addressed and some, because they occur later in the programme, cannot yet be actioned.

The first step is to initiate the programme. This covers processes such as reviewing the problem and identifying—and if possible resolving—conflicts of interest relating to whether the plant's weedy characteristics outweigh its useful characteristics. In New Zealand, the only issue concerns that of the ornamental species of *Berberis* and *Mahonia* that are still sold and grown. This step also encompasses reviews of current knowledge on the biology and ecology of the weed and its natural enemies, and identification of any attempts at biological control. Much of this has been achieved with this report.

The second step is to gain approval and funding for work on the weed. This would be a matter for Regional Councils to negotiate among themselves, as approval from the Emvironmental Risk Management Authority (ERMA) would not be needed until later in the process.

Step three encompasses the procedures necessary to identify candidate agents in the target plant's native range. This would require surveys of *B. darwinii* in Chile and southern Argentina, and of *B. glaucocarpa* in the western Himalaya[1] to identify the plant's natural

[1] Given the current political situation in this region in late 2001–early 2002, the programme for *B. glaucocarpa* might have to be delayed.

enemies, then prioritisation of those considered worthy of further investigation. Because seed dispersal is the major reason for the weeds' invasiveness, particular, but not exclusive, effort should be given to identifying agents that attack flowers and fruits. Landcare Research could undertake this work either directly or in collaboration with overseas researchers. A likely time frame for this would be 2 years.

The fourth step, to survey the fauna of barberry in New Zealand, could proceed concurrently with step three, and would best be conducted by Landcare Research, which has extensive experience and expertise in these surveys.

Step five, while not essential, is highly recommended. It comprises ecological studies of the weed and its natural enemies, and it has two parts. The first is to compare the ecology of the weed in its native range with its ecology in New Zealand, to gain insight into why it is a weed here; what factors are likely to limit its distribution here; and to improve further the understanding of whether biological control is a good option. These studies could begin at any stage before the release of any agent in New Zealand; top priority would be *B. darwinii* because its range is expanding more rapidly than that of *B. glaucocarpa*.

The second part of step five is to study the ecology of potential biological control agents to help predict whether they would successfully establish in New Zealand and their possible impacts on the weed. For *B. darwinii* this would have to take place in Chile or Argentina and for *B. glaucocarpa* in the western Himalaya. These studies could be coordinated by Landcare Research and the resulting information would contribute to any eventual application to ERMA to import agents.

Step six is to determine the host range of potential biological control agents. This is an essential step and must progress outside New Zealand until sufficient information is available to justify an application to ERMA to import the potential agent into quarantine for further host-range testing. Landcare Research could coordinate this overseas testing through its links with international researchers, as it has done previously for other biological control agents.

The next step is to gain approval to import agents into quarantine for further host range testing. An application to ERMA would be prepared and submitted by one or more affected regional councils, possibly supported by other interested agencies such as DOC and forestry companies. Landcare Research would not be an applicant, and its role in this process would be to provide expert technical advice. However, if approval for importation into quarantine was granted, Landcare Research could complete the New Zealand host range testing. For these two steps, the balance of overseas host-range testing *cf.* New Zealand testing in quarantine depends on several factors, particularly the characteristics of the plants and putative agents. In total, these steps are likely to take 3–5 years.

On completion of host-range testing, a further application to ERMA would be required; this would seek approval for the release in New Zealand of any suitable agents. Again, Landcare Research would not apply for this permission; instead, regional councils and/or DOC would drive this process.

If ERMA was to grant approval for the release of one or more agents for control of barberry, these agents would normally have to be cage-reared in quarantine through at least one generation, first, to ensure that the founding individuals carried no diseases or parasitoids, and second, to rear sufficient individuals for field releases. The number of generations required to achieve these goals, and hence the time needed, is difficult to determine because we know nothing of the biology of some potential agents. A minimum period would be 1 year, but a more likely estimate is 2–3 years.

Although straightforward programmes may take as little as 5 years, a realistic estimate of the overall time frame from a decision to proceed with a biological control programme for barberry to the widespread release of the first agent in New Zealand would be 6–10 years.

The final steps in a biological control programme overlap considerably, and comprise a substantial effort to mass-rear and release the agent, and research to determine how well it is establishing and what impact it is having on the weed problem. For most weeds, these steps generally take many years, with the major effort occurring over an initial 3–5 year period.

4.4 Potential agents for biological control of barberry

Pathogens

In New Zealand, *Rigidoporus vinctus,* the causal agent of Junghuhnia root disease, has been recorded on *B. glaucocarpa*. It is saprophytic in indigenous forests, but parasitic on *B. glaucocarpa* and some commercially important trees, including *Pinus radiata* (Dick 1987; Hood & Dick 1988; McKenzie 1999).

Overseas, three species of *Microsphaera* have been recorded from *Berberis* spp. These are *M. euonymi*, which also infects roses (Chauvel et al. 1999); *M. berberidis* var. *berberidis*, which was recorded also from a species of *Mahonia* (Czerniawska & Madej 1998); and *Microsphaera thaxteri*, which was described from *Berberis buxifolia* (Havrylenko & Braun 1998). *Aecidium berberidis* (barberry rust) has caused serious damage to *B. vulgaris* in Iran (Karimi et al. 1997). Several species of the rust genus *Puccinia* also infect *Berberis* spp. overseas but some are heteroecious[2], with life histories that include economically important grasses and cereals as alternate hosts. For example, *B. vulgaris* is an alternate host for wheat rust, *Puccinia graminis* (Lekomtseva et al. 1996), and significant control of this disease in the U.S.A. and Canada has been attributed partly to an extensive programme of barberry eradication using herbicides and physical removal (Schafer et al. 1993). However, *P. berberidis, P. berberidis-darwinii* and *P. mayeri-alberti* are all autoecious[3] on *B. darwinii*, and a new species, *P. minshanensis*, has recently been recorded from *Berberis* sp.. The biology of these species and their effects on the host plant have not been studied (Johnston 1990; Zhuang & Wei 1999).

In India, *B. vulgaris* is also infected by the leaf spot fungus *Pseudocercospora berberis-vulgarae* Gautam et al. 1983) and by *Lanzia parasitica*, which causes severe leaf drop (Dumont 1978), but the potential of these for biological control of barberry is not known (Johnston 1990).

Invertebrates

The fruit fly *Rhagoletis meigenii* (Diptera: Tephritidae) has been recorded from *B. vulgaris* in Belgium (Leclercq 1998). In Poland, the eriophyid mites *Eriophyes caliberberis* and *Aceria* sp. attacked *B. thunbergii* (Soika & Labonowski 1998); *Lasioptera* sp. (Diptera:

[2] Heteroecious: passing different stages of the life history in different hosts.
[3] Autoecious: passing all stages of the life history in the same host.

Cecidomyiidae) attacks, deforms and reduces the size of fruits of *B. chitryia* in India (Grover & Jaiswal 1993).

In the Netherlands, a sawfly, *Arge berberidis* (Hymenoptera: Argidae) infests *B. thunbergii*, causing sufficient damage to be regarded as a pest. Larvae were seen to migrate to nearby *Mahonia aquifolium* and complete their development on that species, so there is some question about its host specificity (van Frankenhuyzen & Blommers 2000). *A. berberidis* appears to be expanding its distribution (Magis 1999). A eulophid parasitoid, *Cirrospilus vittatus* (Hymenoptera: Eulophidae), has been recorded from eggs of *A. berberidis*.
Heavy infestations of the aphid *Liosomaphis berberidis* (Homoptera: Aphididae) on *B. vulgaris* in Poland resulted in discoloration, curling and premature fall of leaves, as well as harmful and disfiguring fungal attack due to honeydew emissions (Jaskiewicz 1995, 1996); *L. berberidis* also attacks *B. thunbergii* (Labanowski 1990). *L. berberidis* is present in New Zealand, where it has been recorded only from *B. glaucocarpa* (Dale & Maddison 1982). Overseas, *L. berberidis* is attacked by the parasitic mite *Allothrombium pulvinum* (Acari: Trombidiidae) (Zhang, 1996, 1997); this mite has not been recorded from New Zealand (Ramsay 1980). Alates (winged forms) of *Aphis fabae* and *Anoecia corni* ((Homoptera: Aphididae) have also been recorded from *B. vulgaris* but these were considered accidental occurrences (Jaskiewicz 1995).

In New Zealand other insects recorded from *Berberis* spp. include the aphid *Aulacorthum solani* (Homoptera: Aphididae), the mussel scale *Lepidosaphes ulmi*, the grass grub beetle *Costelytra zealandica* (Coleoptera: Scarabaeidae) and caterpillars of *Ctenopseustis herana, C. obliquana*, *Epiphyas postvittana*, *Planotortrix excessana*, *P. notophaea*, *P. octo* (Lepidoptera: Tortricidae) and *Pseudocoremia suavis* (Lepidoptera: Geometridae) (Allen & Wilson 1992; Dale & Maddison 1982; HortResearch 2002b). All these species are polyphagous and have no potential as biological control agents for barberry; moreover, many are horticultural pests and barberry is therefore a potential reservoir for infestation of crops (HortResearch 2002b).

4.5 Prospects for achieving successful biological control of barberry

There are no current or past biological control programmes against any species of *Berberis.*

While none of the species of *Berberis* in New Zealand have been systematically surveyed for pests or pathogens, it seems that natural enemies have little effect on the plant and in particular place few or no constraints on flower or fruit production (Allen & Wilson 1992). Overseas, however, the fungi *Aecidium berberidis* and *Lanzia parasitica* have caused significant damage to *B. vulgaris*, while the cecidomyiid midge *Lasioptera* sp. and the sawfly *Arge berberidis* damage some *Berberis* spp. This suggests that the potential for introducing agents that would reduce the vigour and production of viable seeds of barberry species in New Zealand is good. Other fungi and invertebrates also attack the plant, but the extent of damage they cause is not clear; nevertheless, the pool of potential agents is likely to be large, particularly in light of the genus’ wide distribution.

Prospects are further improved by the lack of closely related genera in New Zealand, so there is less requirement for prospective agents to be restricted to just one, or very few, species within *Berberis*. Whether damage to the ornamental species of *Berberis* and *Mahonia* should exclude prospective agents is arguable, but it is worth noting the potential for those ornamental species to become serious weeds – a clear example is *B. thunbergii* which is an invasive weed in the North America but is still sold as an ornamental in New Zealand.

For *B. darwinii*, particular emphasis should be given to searching for agents that reduce the production of viable seeds, because its range is expanding rapidly. However, the precise role of seed production in determining local abundance of *Berberis* spp. in New Zealand has not been determined, and agents that affect other stages of the plant's life history may also prove to be important for effective control.

Given the likelihood that highly host-specific, pathogenic fungi may be identified, development of a mycoherbicide for *B.* darwinii and *B. glaucocarpa* is an option. This would have two major benefits. First, if the mycoherbicide persisted in a viable form for several years, so that it killed emerging seedlings throughout that period, it would have a distinct advantage over conventional herbicides. Second, it would pose no risk to other vegetation, so would have the potential to be applied aerially over native forest and scrub.

5. Conclusions

Prospects appear good for a biological control programme directed at *B. darwinii* and *B. glaucocarpa*. There are no indigenous Berberidaceae in New Zealand and no important exotic members of the family, so that prospective agents need not be restricted to attacking only the adventive species of *Berberis*. Several fungi and invertebrate species are known to attack *Berberis* species and some of these cause significant damage to the plant; furthermore, since *Berberis* is a large genus the prospects for locating biological control agents are good. Classical biological control and mycoherbicides are both likely prospects.

6. Recommendations

- Survey populations of *B. darwinii* and *B. glaucocarpa* in different seasons throughout the species' known ranges in New Zealand to determine which invertebrates and diseases are currently associated with these species in New Zealand (likely cost $50,000 in total over 2 years);
- Survey *B. darwinii* and other *Berberis* species in Chile and Argentina to identify prospective biological control agents (likely cost $50,000 in total over 2 years);
- Survey *B. glaucocarpa* and other *Berberis* species in the western Himalaya to identify prospective biological control agents (likely cost $50,000 in total over 2 years);
- On completion of each overseas survey, review the prospects for successful biological control of that species and, if appropriate, prepare a costed programme for consideration by affected regional councils and DOC.

7. Acknowledgements

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