Prospects for biological control of Japanese honeysuckle

Lonicera japonica Thunb. (Caprifoliaceae)

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Landcare Research Contract Report: LC0102/104

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DATE: June 2002

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Summary

Project and Client

The feasibility of biological control of Japanese honeysuckle, *Lonicera japonica*, in New Zealand has been investigated for several Regional Councils.

Objectives

- Identify potential conflicts of interest regarding a biological control programme against *L. japonica*, including the members of the Caprifoliaceae and related families that may be affected.
- Summarise the literature and current information available from researchers worldwide on the potential for biological control of *L. japonica*.
- Assess the likelihood of success of a biological control programme for *L. japonica* in New Zealand, and review the steps and costs associated with such a programme.

Methods

- Information for this report was obtained by searching computer databases (CAB abstracts, Current Contents) and Internet sites; cross-referencing; and contact with academics, conservation workers, weed controllers and Regional Council staff.

Results

- Host range testing should include *Alseuosmia* (only genus in the Alseuosmiaceae), a range of native Rubiaceae and Cornaceae, and perhaps native representatives of the Araliaceae, in addition to horticulturally important members of the Caprifoliaceae.
- There may be some objection by horticulturists and apiculturists to the introduction of a biological control agent for *L. japonica*, as the plant plays a minor role in both these industries.
- There are 14 fungal pathogens of *L. japonica* overseas that are potential biological control agents.
- While there are no obvious insect candidates for biological control, a survey of insect pests of *L. japonica* within its native range would be worthwhile. Candidates should have the ability to damage the vegetative mass rather than the reproductive parts, as spread within New Zealand is mainly vegetative. Damage should be significant so as to overcome the weed’s compensatory response to insect herbivory.
- There are no overseas biological control programmes for *L. japonica*. People and agencies in the United States of America and south-eastern Australia may be interested in collaboration with New Zealand.

Conclusions

- *Lonicera japonica* is a suitable candidate for biological control because it is widespread. However, extensive host range testing is required to eliminate the risk of non-target effects.
- While biological control may control *L. japonica*, it will not prevent invasion of other weeds that may occur with a reduction of *L. japonica*.

- The direct benefit of a costly biological control programme is mostly restricted to the conservation of native systems within the lower half of the North Island and Nelson/ Marlborough where its impacts are perceived to be greatest, though its distribution is throughout New Zealand.

Recommendations

- Determine the impact of *L. japonica* and its removal on the communities it invades to allow a better assessment of the benefits of a biological control programme against this weed in New Zealand.
- Survey the invertebrate fauna and pathogens associated with *L. japonica* in New Zealand, and record any damage to the plant resulting from these associations. Hyeon-Dong Shin, Professor of Plant Pathology & Mycology at Korea University, has indicated his availability to complete this task during a proposed visit to New Zealand in January/ February 2003, subject to Korea Science & Engineering Foundation (KOSEF) funding.
- Assess the potential of candidate biological control agents identified within areas of the native range of *L. japonica* that are climatically similar to central and northern New Zealand.

1. Introduction

Lonicera japonica Thunb. (Caprifoliaceae) is an invasive climbing weed of native forest remnants and shrublands throughout most of the North Island and northern South Island of New Zealand. Synonyms include: *L. japonica* var. chinensis (P.W. Wats) Baker, *L. japonica* var. halliana (after Dr. George Hall, 1862), *L. aureoreticulata* T. Moore, *Nintooa japonica* (Thunb.) Sweet. The feasibility of biological control of *L. japonica* in New Zealand was investigated for several Regional Councils.

2. Background

2.1 Global Distribution

Lonicera japonica is native to temperate eastern Asia and has naturalised in New Zealand (Gunning 1964), Australia, North America, Hawaii, southwest Britain, southern Chile and Argentina (Williams et al. 2001), southern Brazil (R. Barreto, Universidade Federal de Vicosa, Brazil, pers. comm.) and parts of Europe (Bay of Plenty Regional Council 1998).

2.2 *Lonicera japonica* in New Zealand

Lonicera japonica was available for purchase in 1872, and is assumed to have become naturalised in Auckland between 1940 and 1970, or earlier (Esler 1988). The plant has spread primarily via stem fragments dumped in garden refuse (Department of Conservation 2001), and to a lesser degree by road and hedge-cutting machinery, deliberate plantings (Auckland Regional Council 1998) and grazing mammals (Williams et al. 2001). Seeds are dispersed by blackbirds, song thrushes, silvereyes and other birds, though seedlings are rare (Williams et al. 2001). Consequently, the rate of spread within New Zealand has been slow relative to that of other invasive weeds with effective means of seedling regeneration, such as old man's beard (Williams & Timmins 1999), but it is nevertheless widespread (cf. *Tradescantia fluminensis* that is also reliant on vegetative reproduction and widespread). Once introduced to a site, *L. japonica* quickly builds up a mass of vegetative material using host plants and its own stems for support (Williams & Timmins 1999).

The distribution of *L. japonica* within New Zealand is restricted principally by its reliance on humans for primary dispersal. Actual distribution is therefore less than potential distribution based on habitat suitability (Williams & Timmins 1999). Distribution is restricted to a lesser extent by its inability to withstand dry conditions, such as those in the inland regions of the South Island, although it can tolerate seasonal drought in inland Hawke's Bay (Williams et al. 2001). Otherwise, it is a hardy plant tolerant of cold winter temperatures (it has been noted as growing until the first frosts), a wide range of soil substrates including poorly draining soils, and those high in salt and heavy metals (Williams et al. 2001). Its failure to establish in the southern South Island is probably because of low summer temperatures (Williams et al. 2001). *Lonicera japonica* spans all 13 Department of Conservation (DOC) conservancies and is regarded as a threat to conservation in all but Canterbury, Otago and Southland conservancies (Fig. 1; survey of DOC staff). Its greatest impact is probably in the lower half of the North Island and Nelson/ Marlborough, with lesser impact in the remainder of the country (Williams et al. 2001). It is spreading in Nelson (D. Newton, NelMac, Nelson, pers. comm.), Golden Bay (D. Foxwell, DOC, Takaka, pers. comm.), Bay of Plenty (Bay of Plenty Regional Council 2002), and within the Tongariro/ Taupo conservancy (N. Singers, DOC, Turangi, pers. comm.).

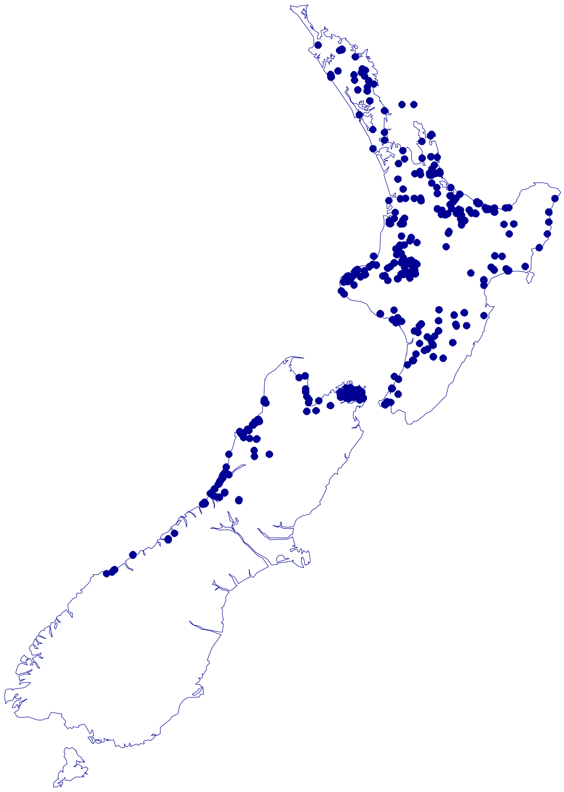

Fig. 1 Distribution of *Lonicera japonica* on conservation lands. Data supplied by the Department of Conservation, 2002.

Estimates of national *L. japonica* impact (Williams et al. 2001) are generally reflected in the plant pest strategies adopted by the various Regional Councils, with the exception of Tasman (includes Nelson) and Marlborough District Councils. In Hawke's Bay *L. japonica* is a 'Total Control Plant Pest' and its eradication from designated areas has been initiated (Hawke's Bay Regional Council 2001). In Bay of Plenty *L. japonica* is a 'High Risk Plant Pest' and information is being gathered for use in control programmes (Bay of Plenty Regional Council 1998). The Wellington Regional Council plans to control *L. japonica* chemically where it occurs in 'Key Native Ecosystems' within the region (K. Worsley, Wellington Regional Council, Wellington, pers. comm.). It is listed as a 'Regional Surveillance Plant Pest', 'Community Initiative Plant Pest' or an equivalent by Regional Councils in Northland, Auckland, Waikato, Manawatu and Wanganui (horizons.mw), Tasman, Marlborough and Canterbury. Plants in these categories are banned from sale, propagation and distribution. Regional Council objectives for surveillance pests are generally to monitor their distribution and impact, and promote their voluntary control.

Nationally, *L. japonica* has a weed ranking of 31 (0 indicates minimal impact and 34 indicates maximal impact), based on its 'effects on natural systems' and 'biological success', compared with scores of 33 for *Clematis vitalba* and 27 for *Passiflora mollissima*, other weedy vines with a distribution overlapping that of *L. japonica* (Owen 1997). *Lonicera japonica* affects hedges, roadsides, wastelands, open scrub, shrublands, woodlands, the margins of forests, including pine plantations (Auckland Regional Council 1998), wetlands, and riparian zones (Williams et al. 2001). It grows on a wide range of soil substrates but most vigorously on friable, moist soils, particularly alluvium and recent colluvium (Williams et al. 2001). It can dominate the understorey and any canopy openings where the forest or scrub is sufficiently open, though it will not climb trees greater than 20 m in height or >15 cm in diameter (Williams et al. 2001). It can continue to thrive once its supporting plant (e.g., hedge) has died (P. Williams, Landcare Research, Nelson, pers. comm.). *Lonicera japonica* is mostly restricted to the outside margins of dense forest or scrub (Williams et al. 2001) despite being relatively shade tolerant (Baars & Kelly 1996). It smothers regenerating forest and scrub at sites on the West Coast (T. Belton, DOC, Hokitika, pers. comm.), and vegetation in the relatively drier areas of wetlands in the Waikato Conservancy (D. Stephens, DOC, Hamilton, pers. comm.). There is an association of *L. japonica* with early secondary vegetation on moist, fertile sites in the central and eastern North Island (Williams et al. 2001) from which it may be lost as succession proceeds (Williams & Timmins 1999). In contrast, the persistence of *L. japonica* in other communities such as wetlands could be longer (Williams & Timmins 1999). However, these two statements are 'best guesses' regarding the persistence and lasting impacts of *L. japonica* invasion, which for any of the communities it invades remain largely unknown (P. Williams, Landcare Research, Nelson, pers. comm.).

2.3 Current control methods

In New Zealand, herbicides are most commonly used to control *L. japonica*, either sprayed onto standing foliage in the case of small-statured infestations or foliage regrowth after vine cutting, or applied directly onto cut stem stumps. A wide range of herbicides is in use or recommended for use (Table 1). There is some preference for Versatil® (Table 1), a rate-selective herbicide (i.e. application rate can determine plant susceptibility, with broadleaf plants becoming susceptible at high rates) that can persist in the top 5 cm of soil for up to a year after broadcast application (Rice et al. 1997) and so affect native seedling regeneration. Koputaroa Scientific Reserve has been almost entirely cleared of a heavy infestation of *L. japonica* using Versatil® herbicide with minimal impact on raupo and other native plants (B. Edwards, DOC, Waikanae, pers. comm.). Roundup® is also a popular choice but can require several follow-up treatments (K. Griffiths, DOC, Napier, pers. comm.; K. Hogan, DOC, Gisborne, pers. comm.). Picloram is the herbicide most likely to have an impact on the recovery of the native plant community as it is rate-selective and leaches and persists in soil (Rice et al. 1997).

Table 1 Herbicides in use or recommended for use on *Lonicera japonica* in New Zealand. Personal communications from a survey conducted during January to March 2002.

Registered product	**Active ingredient**	**Reference**
Roundup +/- pulse	Glycophosphate modified polydimethylsiloxane	Department of Conservation 2001; K. Massey, Northland Regional Council, pers. comm.; R. Packe, Hawke's Bay Regional Council, pers. comm.; B. Edwards, DOC, Waikanae, pers. comm.; K. Griffiths, DOC, Napier, pers. comm.; P. Brady, DOC, Picton, pers. comm.; K. Hogan, DOC, Gisborne, pers. comm.; C. Wooldridgeway, DOC, Kerikeri, pers. comm.
Grazon	Triclopyr	D. Newton, Nelmac, Nelson, pers. comm.; Department of Conservation 2001; N. Singers, DOC, Turangi, pers. comm.
Renovate	Triclopyr	K. Massey, Northland Regional Council, pers. comm.
Tordon Brushkiller NF	Picloram, triclopyr & ethyl digol	M. Nieuwenhuyse, DOC, Invercargill, pers. comm.; Auckland Regional Council 1998; T. Birch, DOC, Waipoua, pers. comm.; W. Cooper, DOC, Invercargill, pers. comm.
Vigilant (gel)	Picloram	Department of Conservation 2001; N. Singers, DOC, Turangi, pers. comm.; W. Cooper, DOC, Invercargill, pers. comm.
Versatil	Clopyralid	Bay of Plenty Regional Council 2002; R. van Zoelen, Tasman District Council, pers. comm.; R. Packe, Hawke's Bay Regional Council, pers. comm.; B. Edwards, DOC, Waikanae, pers. comm.; N. Singers, DOC, Turangi, pers. comm.; D. Foxwell, DOC, Takaka, pers. comm.; D. Stephens, DOC, Hamilton, pers. comm.; F. Buchanan, DOC, Thames, pers. comm.; W. Te Are, DOC, Waikaremoana, pers. comm.; H. Jonas, DOC, Wairoa, pers. comm.
Escort	Metsulfuron (60%)	Department of Conservation 2001; Auckland Regional Council 1998; N. Singers, DOC, Turangi, pers. comm.; J. Wotherspoon, DOC, Auckland, pers. comm.
Answer	Metsulfuron (20%)	E. Vanderspek, DOC, Tongariro, pers. comm.
Amitrole 400	Amitrole	Northland Regional Council, K. Massey, pers. comm.

Manual control is suitable for small infestations, and is achieved by removing the stems and digging out the roots (Department of Conservation 2001). Care must be taken in the disposal of the plant as stem fragments and stumps can regenerate (e.g., composting and burial are suitable, whereas mulching is not). Regrowth of *L. japonica* from stem fragments can hamper manual control efforts (Williams et al. 2001). Grazing can be an effective means of control (Auckland Regional Council 1998) but will not eradicate established weed stands. Fire has been used elsewhere to control *L. japonica* (Williams et al. 2001) but has not been trialled in New Zealand and is unsuitable for use in *L. japonica*-affected areas of importance to conservation.

Lonicera japonica is generally regarded as a weed difficult to eradicate (Williams et al. 2001; Department of Conservation 2001; K. Griffiths, DOC, Napier, pers. comm.) requiring follow-up treatment in most cases, though some disagree (D. Newton, Nelmac, pers. comm.;

N. Singers, DOC, Turangi, pers. comm). It is cryptic in most habitats (P. Williams, Landcare Research, Nelson, pers. comm.), particularly in scrub where it is difficult to locate and treat the narrow (and sometimes numerous) stems (M. Newfield, DOC, Nelson, pers. comm.; T. Belton, DOC, Hokitika, pers. comm.).

2.4 Advantages of biological control

Biological control could offer some advantages over current control methods for the management of *L. japonica* (Fowler et al. 2000). First, use of a host-specific biological control agent would reduce impacts on native flora, compared with the detrimental impacts of chemical herbicides. Secondly, biological control offers continuous action and self-dispersal that current control methods do not offer. A widespread biological control agent would be useful for the control of *L. japonica* on roadsides and wastelands, areas that are not likely to be targeted by other control programmes as they pose no immediate threat to conservation; nevertheless material from these sites could disperse to areas of conservation concern.

3. Objectives

- Identify potential conflicts of interest regarding a biological control programme against *L. japonica*, including the members of the Caprifoliaceae and related families that may be affected.
- Summarise the literature and current information available from researchers worldwide on the potential for biological control of *L. japonica*.
- Assess the likelihood of success of a biological control programme for *L. japonica* in New Zealand, and review the steps and costs associated with such a programme.

4. Methods

Information for this report was obtained by searching computer databases (CAB abstracts, Current Contents) and Internet sites; cross-referencing; and contact with:

Dr Robert W. Barreto, Departamento de Fitopatologia, Universidade Federal de Vicosa, Brazil

Phillip Brown, Waikato Regional Council, Hamilton

Prof. Raghavan Charudattan, Plant Pathology Department, University of Florida, USA

DOC staff listed in Table 1

Mark Douglas, Contractor to North Shore City Council, Takapuna

Dr Mark Goodwin, HortResearch, Ruakura Research Centre, Hamilton

Paul Hatton, horizons.mw (contracted by Regional Councils for pest plant control in Manawatu & Wanganui regions), Wanganui

Professor Hyeon-Dong Shin, Division of Environmental Science & Ecological Engineering, Korea University, Seoul, Korea

Dr James Luken, Department of Biological Sciences, North Kentucky University, Highland Heights, KY, USA

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Kevin Worsley, Wellington Regional Council, Wellington

Dr Gregor Yeates, Landcare Research, Palmerston North.

5. Results

5.1 Potential conflicts of interest

Relatives of *Lonicera japonica* in New Zealand

There has been much debate concerning the taxonomy of the Caprifoliaceae, both in circumscribing the family and ascertaining its phylogenetic position (Zomlefer 1994). The most recent treatments place the Caprifoliaceae in the Order Dipsacales (Cronquist 1988; Kubitzki 1990– cited by Mabberley 2000). The Order Dipsacales is not represented in the New Zealand flora, though the endemic genus *Alseuosmia* was formerly considered part of the Caprifoliaceae (Allan 1961). Currently, *Alseuosmia* is the only genus in the Family Alseuosmiaceae (Landcare Research Herbarium 2002).

There are at least two other systems of classification that differ in their placement of the Caprifoliaceae. Allan (1961), using Hutchinson (1926) as a guide, placed it in the Order Rubiales along with the Rubiaceae, which include native representatives in the genera *Coprosma*, *Galium* and *Nertera* and the exotic *Coffea arabica* (Landcare Research Herbarium 2002). Hutchinson (1959) placed the Caprifoliaceae within the Order Araliales along with five other families. Two of these families have native representatives: Cornaceae (*Corokia*, *Griselinia*) and Araliaceae (*Kirkophytum*, *Meryta*, *Neopanax*, *Pseudopanax*, *Schefflera*, *Stilbocarpa*) (Allan 1961). There is some recent support for an alliance of Caprifoliaceae with Rubiaceae (Cronquist 1988; Zomlefer 1994) and Cornaceae (Zomlefer 1994), but I can find no support for an alliance with Araliaceae.

There are an additional 11 exotic species belonging to seven genera within the Caprifoliaceae in New Zealand; most are fully naturalised including Himalayan honeysuckle *Leycesteria formosa* (Landcare Research Herbarium 2002), which, like Japanese honeysuckle, is a National Surveillance Plant Pest (Roy et al. 1998). *Sambucus* spp. and *Viburnum* spp. are included on this list, though these genera have been removed from the Caprifoliaceae by Watson & Dallwitz (1992 onwards) and Zomlefer (1994) on the basis of the molecular sequence data of Backlund & Bremer (1997) and Donoghue et al. (1992) respectively. Detailed morphological analyses support this division (Judd et al. 1994 cited by Zomlefer 1994). A broadly defined Caprifoliaceae includes the Dipsacaceae and Valeriancaceae families (Zomlefer 1994; Mabberley 2000), which have eight exotic representatives in New Zealand including spur valerian, *Centranthus ruber*, and wild teasel, *Dipsacus sylvestris* (Landcare Research Herbarium 2002), which are common (Roy et al. 1998).

Excluding *Lonicera*, there are six other genera belonging to the Caprifoliaceae (Watson & Dallwitz 1992 onwards) available for purchase in New Zealand: *Abelia*, *Diervilla*, *Heptacodium*, *Kolkwitzia*, *Symphoricarpos* and *Weigela* (Gaddum 1999). *Sambucus* spp. and *Viburnum* spp. are also available, as well as genera belonging to the Dipsacaceae (*Knautia*, *Scabiosa*, *Dipsacus*) and Valerianaceae (*Centranthus*, *Patrinia*, *Valeriana*, *Valerianella*) (Gaddum 1999).

Three other *Lonicera* spp. are naturalised in New Zealand: *Lonicera* × americana (Mill.) K. Koch, *L. nitida* E.H. Wilson, and *L. periclymenum* L. (Landcare Research Herbarium 2002). In addition, an “aggressive” cultivar, *L. japonica* “Purpurea”, has recently naturalised near Miranda, north-east of Manukau, North Island (D. Stephens, DOC, Hamilton, pers. comm.). There are 32 cultivars of *Lonicera* for sale in nurseries in New Zealand, including *L. caprifolium, L. fragrantissima, L. heckrotti, L. henryi, L. hildebrandtiana, L. involucrata, L. korolkowii, L. maackii*, *L. nitida*, *L. periclymenum*, *L. pileata*, *L. rupicola*, *L. similis*, *L. tatarica*, *L. tragophylla* and their varieties (Gaddum 1999). Of these, *Lonicera nitida* is the plant most commonly available (Gaddum 1999). Ornamental *Lonicera japonica* varieties are available from six retail outlets within New Zealand (Gaddum 1999).

The Caprifoliaceae are an important horticultural family. Plant traders are likely to object to the introduction of a biological control agent that is not host specific. Furthermore, the taxonomic history of the family and the resulting number of close alliances necessitates a cautionary approach to the introduction of a biological control agent. Host range testing should include *Alseuosmia*, a range of native Rubiaceae and Cornaceae, and perhaps native representatives of the Araliaceae, in addition to horticulturally important members of the Caprifoliaceae. Taken together, these results suggest that only biological control agents with a narrow host range should be considered as potential candidates for *L. japonica*, and any potential candidate must be subject to thorough host range testing before release.

Importance of *Lonicera japonica* to apiculture

In addition to possible objection from horticulturists, apiculturists may object to the release of a biological control agent against *L. japonica* (M. Goodwin, HortResearch, Hamilton, pers. comm.). While *L. japonica* is not listed as an important honey source in the beekeeping literature, *Apis mellifera* has been observed to collect pollen from it during November in the North Island (M. Goodwin, HortResearch, Hamilton, pers. comm.).

5.2 Potential agents for biological control of *Lonicera japonica*

Vertebrates

White-tailed deer (*Odocoileus virginianus*) browse *L. japonica* in Arkansas (Rogers et al. 1990) and Alabama (Dyess et al. 1994), USA. Stock grazing of *L. japonica* in New Zealand has been mentioned (Section 2.3). However, grazing is unlikely to eradicate *L. japonica* as it has remained dominant in communities throughout the south-east United States despite heavy cattle and deer grazing (Schierenbeck et al. 1994). This is partly due to its ability to recover from defoliation by increasing biomass allocation to stems and leaves (Schierenbeck et al. 1994).

Parasitic nematodes

Meloidogyne sp. (Tylenchida: Tylenchina) is a root-knot nematode associated with *L. japonica* (Goodey et al. 1965), which could cause damage to the plant if it were stressed (G. Yeates, Landcare Research, pers. comm.). No other records were found.

Insects: pests and virus vectors

Damage to *L. japonica* would need to be significant for biological control using insect herbivores because the plant shows a compensatory response to herbivory (Schierenbeck et al. 1994). The 'indigenous species' listed in Table 2 do not appear to exert sufficient damage to be considered as potential biological control agents (Schierenbeck et al. 1994). It is difficult to assess the potential of *Phenacoccus perillustris* and *Prociphilus trinus* due to a lack of data on their impacts and respective host ranges. *Phenacoccus perillustris* may be climatically suited to New Zealand if it occurs in the central eastern region of China, though mean summer temperatures in this region are higher (Fullard & Darby 1979). Xinjiang has higher mean summer temperatures and drier winters than New Zealand (Fullard & Darby 1979), so *Prociphilus trinus* may not thrive in New Zealand. The remaining insect pests (Table 2) are not suitable potential biological control agents or virus vectors because of their extended host ranges. Also note that *L. japonica* is not a member of the *L. tatarica* complex (Green 1966) that is host to *Hyadaphis tataricae* (Homoptera: Aphididae) in North America (Voegtlin & Stoetzel 1988).

In addition to the insect pests listed in Table 2, *Tetranychus urticae* (Acarina: Tetranychidae), a pest of corn and peanut in North Carolina, over-winters on *L. japonica* growing on field margins (Margolies and Kennedy 1985). However, it is a common pest in New Zealand orchards (L. Hayes, Landcare Research, Lincoln, pers. comm.), which makes it an unsuitable candidate for biological control of *L. japonica*.

Lonicera japonica contains several chemical compounds (Van Galen 1995), some of which e.g., flavonoids, may deter generalist insect herbivores (Harborne & Williams 2000). A survey of insects associated with *L. japonica* in its native range may yield more potential biological control agents, as some of the records from this region are coincidental (i.e. records of crop pests).

Pathogens

Lonicera japonica is host to a variety of fungi (Table 3). Fourteen of these offer potential as biological control agents of L. japonica in New Zealand, based on their supposed climatic requirements and known host ranges. Most of the 14 affect other Lonicera spp. (Aplosporella punctum, Ascochyta tenerrima, Cercospora lonicerae, C. periclymeni, Kabatia lonicerae, Phaeoramularia antipus, Phoma mariae, Rhabdospora lonicerae, Rhytisma lonicericola), while three have been recorded only on L. japonica (Appendiculella lonicerae, Diatrypella ramularis, Sarcopodium pironii) and two are possibly specific to L. japonica (Microsphaera erlangshanensis, M. penicillata; Table 3). In addition, if Colletotrichum gloeosporioides that affects L. japonica is a host-specific special form (Table 3), then it offers potential as a biological control agent. Special forms (f. sp.) are pathogen populations that often have a different, narrower host range than the full species population (J. Fröhlich, Landcare Research, pers. comm.). For example, Colletotrichum gloeosporioides f. sp. aeschynomene has been developed as a commercially produced bioherbicide against Aeschynomene virginica (Leguminosae) in the USA, and field trials are underway with other special forms of this species for biological control of at least three other weeds (Hasan 1988).

The two Microsphaera species are potential biological control agents because they may possibly be species specific, or in the case of M. penicillata restricted to L. japonica and perhaps other Lonicera species not sold as nursery plants in New Zealand. The distribution of M. penicillata suggests climate suitability to New Zealand (Fullard & Darby 1979), whereas the climatic requirements of M. erlangshanensis cannot be deduced from the host-record. If its distribution includes both northern and southern Korea, then climatic requirements are likely to be met in New Zealand (Skarratt et al. 1995).

Fungi that affect other Lonicera need not be excluded from a list of potential biological control agents if they do not affect Lonicera species traded in New Zealand. Four of the nine fungal species listed in the first paragraph of this section do not affect cultivated Lonicera species. Moreover, given that there are less than five nurseries selling Lonicera species that could be affected by these fungi (Gaddum 1999), a case could be argued for the use of a biological control agent with a host range that included one or more of the cultivated Lonicera spp. More difficult are the host records for Lonicera sp. (Table 3), which would require testing of all 15 Lonicera species (or all 32 varieties?) available as nursery plants to exclude them as hosts if such an exercise was deemed necessary.

Mycoherbicides are highly concentrated inoculums of fungal pathogens used against weeds in a similar manner to chemical herbicides (Hasan 1988). A fungus that does not offer potential as a classical biological control agent, because it spreads slowly or is only effective under a narrow range of environmental conditions, may offer potential as a mycoherbicide. A mycoherbicide can be applied where it is needed and it may be possible to formulate the fungus to persist in the environment until conditions become suitable for infection and disease development. The Deuteromycotina (e.g., Aplosporella punctum, Ascochyta tenerrima, Cercospora lonicerae, C. periclymeni, Colletotrichum gloeosporioides, Kabatia lonicerae, Phaeoramularia antipus, Phoma mariae, Rhabdospora lonicerae, Sarcopodium pironii) are particularly amenable to development as mycoherbicides as they are mostly facultative parasites that can be grown easily on artificial media, for the mass production of the infective stage of the fungus (Hasan 1988).

None of the viruses reported on L. japonica offer potential as biological control agents (Table 3). Tobacco leaf curl virus and tomato spotted wilt virus have an extended host range, while eggplant mottled dwarf virus and honeysuckle latent virus do not cause enough damage to the plant to be useful. In addition, there is no specific vector for transmission of the viruses affecting L. japonica (Table 3).

5.3 Prospects for achieving biological control of *Lonicera japonica*

There are many prospects available that require further research for development as biological control agents against L. japonica in New Zealand. The most promising candidates, 14 in total, are among the fungal pathogens associated with L. japonica overseas. It is difficult to choose one or more ideal candidate/s from this selection without further information regarding aspects of their climate suitability, host range and damage to L. japonica. While there are no obvious candidates for biological control among the insect pests (with the possible exception of Phenacoccus perillustris and Prociphilus trinus), a survey of insect pests of L. japonica within its native range would be worthwhile. Candidates should have the ability to damage the vegetative mass rather than reproductive parts (e.g., seed) as spread within New Zealand is mainly vegetative, and damage should be significant so as to overcome the weed's compensatory response to insect herbivory. Last, there are no biological control programmes for L. japonica overseas, though people and agencies in the United States and south-eastern Australia may be interested in collaboration with New Zealand.

6. Conclusions and Recommendations

The next step in assessing the potential for biocontrol of *L. japonica* would be to systematically survey the invertebrate fauna and pathogens associated with the weed in New Zealand, and to record any damage to the plant resulting from these associations. Professor Hyeon-Dong Shin, Plant Pathology & Mycology at Korea University, has indicated his availability to conduct a 2-week survey of the fungal pathogens of *L. japonica* during a proposed visit to New Zealand in January/ February 2003, subject to Korea Science & Engineering Foundation (KOSEF) funding. Professor Shin's research interests include the morphological taxonomy of phytopathogenic fungi with special interest in powdery mildews (e.g., *Microsphaera*), downy mildews, *Septoria*, *Cercospora* and allied genera. His expertise would greatly assist a biological control programme for *L. japonica* in New Zealand.

Following a survey of invertebrates associated with *L. japonica* in New Zealand, the next step would be to survey *L. japonica* within its native range, and to record any damage to the species resulting from insects and pathogens. Generally, South Korea, central eastern China, Northern Taiwan and the southern three islands of Japan are the regions within the native range of *L. japonica* most similar in climate to New Zealand (Fullard & Darby 1979). More specifically, the climate (i.e. total rainfall, rain pattern; maximum, minimum and mean temperature) of Osaka and Niigata, Japan and Guiyang, (south) China most closely resembles that of Auckland (Skarratt et al. 1995). Similarly, the band of China that extends diagonally from its border with Myanmar eastwards to the Yellow Sea is most similar in climate to Christchurch (Skarratt et al. 1995). These regions generally experience wetter spring/summers and drier autumn/winters and more extreme annual minimum and maximum temperatures than New Zealand.

One option would be to conduct a survey of insect pests and pathogens of *L. japonica* in southern Korea. Professor Shin may agree to hosting such a survey from his laboratory in Seoul, Korea, or perhaps supervising one by a Korean-based student or students. One aim of the survey would be to determine whether *Microsphaera erlangshanensis* occurs on *L. japonica* in South Korea and to describe its symptoms. Another aim would be to assess the potential of *Rhytisma lonicericola* as a biological control agent, recorded on *L. japonica* at Kangnung, South Korea (Table 3; Shin 1994). The cost of this option, requiring an entomologist and a plant pathologist, would be approximately $75,000–100,000, or less if a student project was funded on site.

Alternatively, or in addition, the survey of *L. japonica* within its native range could focus on China. There are several host records for China (Table 2, 3). One aim of such a survey would be to determine if the homopterans recorded on *L. japonica* in China (Table 2) are likely to be climatically suited to New Zealand and to assess their damage to *L. japonica*. Another aim would be to describe the symptoms of the fungi recorded on *L. japonica* in China, including *Appendiculella lonicerae*, *Ascochyta tenerrima*, *Cercospora periclymeni*, *Rhytisma lonicericola*, and particularly *Colletotrichum gloeosporioides* (Table 3). This option would cost approximately $75,000–100,000, or less if combined with the Korean-based survey.

A third, more costly option would be to conduct a survey of the pathogens and insect pests of *L. japonica* in the United States, where several of the fungal host records originate including eight of the 14 highlighted in section 5.3 (Table 3). The survey could focus on eastern USA, from New York State south to North Carolina, as this region is more similar in climate to Auckland and Christchurch than the other regions of the country (Skarratt et al. 1995). Fungal pathogens with known distributions restricted to states further south (e.g., *Cercospora lonicerae*, *Diatrypella ramularis*, *Sarcopodium pironii*; Table 3) are likely to survive in parts of northern New Zealand that are similar in climate to Auckland but may not survive in southern New Zealand (Skarratt et al. 1995). The cost of this option ($100,000–125,000) could be reduced if an American-based student was to complete the task.

For the overseas biological control candidates, an assessment of their efficacy as potential biocontrol agents *in situ* should allow fairly accurate predictions to be made regarding their likely success in New Zealand (Hasan 1988). Such assessments would eliminate all but the most likely candidate/s and so reduce the number of potential imports to New Zealand. This process of elimination is necessary because of the large number of potential agents and the extensive host testing recommended for each import. The development and use of a commercial standard mycoherbicide is likely to cost more than development and use of a classical biological control agent. Perhaps with so many candidates to choose from, an effective classical biological control agent will become apparent and mycoherbicides can be avoided.

There are three matters to consider regarding the prospects for successful biological control of *L. japonica*. First, like chemical and manual control methods, biological control targets the invasive species rather than the attributes of systems that make them invasible, which contradicts current theory regarding management of weed invasion (Hobbs & Humphries 1995; Luken 1997; Mack et al. 2000). Therefore, while biological control may effectively manage *L. japonica*, it will not prevent invasion of other weeds that may occur with a reduction of *L. japonica* (e.g., exotic grasses, *Cirsium vulgare, Solanum nigrum*; Williams & Timmins 1998). Second, a better understanding of the long-term impact of *L. japonica* on native systems in New Zealand would enable a more effective assessment of the likely benefits of a biological control programme targeting this weed, particularly whether or not *L. japonica* persists, or at least persists long enough to alter the successional trajectory of the communities it invades. Last, for each of these communities, it is essential to know the effect of removing *L. japonica*, and it would be useful to know the level of control required for protection of selected native species. The only study of the response of a community to *L. japonica* removal (by herbicide spray) in New Zealand is for a small (0.25 ha) species-poor roadside scrub community, where native regeneration 1 year later was minimal (Williams & Timmins 1998).

In conclusion, there are many prospects available that require further research for development as biological control agents against *L. japonica* in New Zealand. It is a suitable candidate for biological control because it is widespread, though extensive host range testing is required to eliminate the risk of non-target effects. The direct benefit of a costly biological control programme is mostly restricted to the conservation of native systems within the lower half of the North Island and Nelson/ Marlborough, where its impacts are perceived to be greatest. An assessment of the benefits of a biological control programme in New Zealand would be enhanced with better understanding of the impact of *L. japonica*, and its removal, on the communities it invades.

7. Acknowledgements

I would like to thank all the people who responded to my requests for information, particularly Professor H.D. Shin for translating Chinese text. Thanks also to Richard Harris for providing the CLIMEX data; and to Eric McKenzie and Peter Williams for commenting on draft versions of this report.

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Table 2 Insect pests of *Lonicera japonica*

Order: Family	**Species**	**Location**	**Source**	**Damage**	**Host range**	**Present in NZ?**
Coleoptera: Scarabaeidae	*Costelytra zealandica*	New Zealand (laboratory)	Burgess et al. 1988	Leaf feeding	Pasture	Yes — major pasture pest (Jackson et al. 1999)
Hemiptera: Aphididae	?	Sichuan, China	Li & Wen 1988	?	Pest of corn & peanut crops in same region	?
Homoptera: Aleyrodidae	*Bemisia tabaci* non-B biotype	Shikoku, Japan	Lee et al. 2000	?	Includes *Glycine max*, *Ipomoea batatas* & *Perilla frutescens*	Non-B biotype considered indigenous to Far Eastern Asia
	Bemisia tabaci biotype B?	Europe	MacIntosh et al. 1992	Transmits tobacco leaf curl virus —refer to Table 3	B biotype a virus vector for at least 15 geminiviruses (Bedford et al. 1992)	Pest of greenhouse tomato (Martin 1989) & ornamental plants (DSIR 1991) in NZ, probably biotype B (De Barro 1995)
Homoptera: Cicadellidae	*Empoasca biguttula*	Hunan, China	Chen et al. 1987	?	Pest of cotton in same region	?
Homoptera: Coccoidea: Pseudococcidae	*Phenacoccus perillustris*	China	Wu 2000	?	No data (CAB Abstracts, Current Contents)	?
Homoptera: Pemphigidae	*Prociphilus trinus*	Xinjiang, China	Zhang & Qiao 1997	?	No data (CAB Abstracts, Current Contents)	?
Lepidoptera: Gelechiidae	'Indigenous species'	South Carolina	Schierenbeck et al. 1994	Leaf feeding	Includes *L. sempervirens*	
Lepidoptera: Noctuidae	*Heliothis virescens*	Georgia & Florida	Pair 1994	Larvae feed on flowers, leaves & berries in laboratory	Wide host range & a pest on cotton, soyabeans & tobacco (Sheck & Gould 1996)	No (J. Dugdale, Landcare Research, pers. comm.)
	Helicoverpa zea	Georgia & Florida	Pair 1994	Larvae feed on flowers	A pest on cotton (Johnson et al. 2000), maize Buntin et al. 2001) & tomato (Jordao & Nakano 2000)	No (J. Dugdale, Landcare Research, pers. comm.)
Lepidoptera: Sphingidae	'Indigenous species'	South Carolina	Schierenbeck et al. 1994	Leaf feeding	Includes *L. sempervirens*	

Table 3 Pathogens of *Lonicera japonica*

Plant pathogen	Classification	Species	Location	Symptoms	Distribution, host range — notes	Source
Fungi	Mastigomycotina - Oomycetes	*Pythium* sp.	Florida	Root rot		Farr et al. 1989
	Ascomycotina	*Appendiculella lonicerae* (syn. *Irenina lonicerae*)	China, Taiwan	?	No other records (Farr et al. 2002)	Tai 1979; Anon. 1979
		Botryosphaeria obtusa (syn. *Physalospora obtusa*)	Louisiana	Stem cankers	Temperate regions; wide host range. Associated with dieback of grapevines (Castillo-Pando et al. 2001); causes apple stem cankers (Brown-Rytlewski & McManus 2000). Recorded in NZ (Pennycook 1989)	Farr et al. 1989
		Diatrypella ramularis	Louisiana	?	No other records (Farr et al. 2002)	Cash 1952
		D. puccinioides (syn. *D. collecta*)	Georgia	Affects stems	United States, Asia, Europe; wide host range	Farr et al. 1989
		Eutypella fraxinicola	Georgia	?	Records for eastern USA, Bermuda, Brazil; wide host range (Farr et al. 2002)	Hanlin 1963
		E. juglandicola	Georgia	?	Eastern United States; wide host range	Farr et al. 1989
		Microsphaera penicillata (syn. *M. caprifoliacearum*, *M. alni*)	Most of USA	Powdery mildew, reduces plant growth & may cause leaves to turn yellow & defoliate (O'Mara & Hudgins 2001)	Temperate regions; host range restricted to *L.* spp.? (O'Mara & Hudgins 2001), prob. diff. variety on rhododendrons (Cochran & Ellett, 1990) & *Alnus* (Braun 1995). Present in NZ on oak (Landcare Research 1999). This genus: obligate parasites (i.e. will not usually kill host), sexual stage infects host	Farr et al. 1989; O'Mara & Hudgins 2001
		M. erlangshanensis	Korea	Powdery mildew	"Severe infection". Tend to be host-specific (Braun 1995; Benson 2001)	H. Shin, Korea University, Seoul, pers. comm.
		Mycosphaerella clymenia	Virginia	Leaf spot	Central and eastern United States, Europe; host records for *L. caprifolium*, *L. flava*, *L. implexa*, *L. periclymeni*, *L. periclymenum*, *L.* sp.	Farr et al. 1989; 2002

Plant pathogen	Classification	Species	Location	Symptoms	Distribution, host range — notes	Source
		Oidium sp.	NZ	Powdery mildew. Likely similar to *Microsphaera* (Benson 2001)	Tend to be host-specific (Benson 2001). Obligate parasite (i.e., will not usually kill host), asexual stage infects host	Amano 1986
		Ophiobolus nigro-clypeata	Georgia		Georgia; wide host range	Farr et al. 1989
		Rhytisma lonicericola	Korea; south eastern Russia, northern China, Japan	Tar spot & dwarfing	Known distribution includes locations listed; host records for *L. chrysantha*, *L. maackii*, *L. modesta*, *L. trichosantha* (Farr et al. 2002)	Shin 1994 (incl. photo symptoms); Mueller 1981
		Valsa ceratosperma (syn. *V. decorticans*)	Georgia	Canker	Cosmopolitan; wide host range, e.g., apple (Kong et al. 1991)	Farr et al. 1989
	Basidiomycotina	*Aleurodiscus botryosus* (syn. *Aleurobotrys botryosus*)	South Carolina	Affects stems	Widespread; hosts incl. conifers & hardwoods. Questionable record	Farr et al. 1989
		Herpobasidium deformans (syn. *Insolibasidium deformans;* asex. stage *Glomopsis lonicerae*)	NZ; Central, eastern & nw USA, Canada	Leaf browning, defoliation & reduction in plant growth	Reported on *L. tatarica* in NZ; *L.* spp. except *L. dioica*, *L. gracilipes* & *L. sempervirens* elsewhere	Pennycook 1989; O'Mara & Hudgins 2001
		Merismodes ochraceus	Louisiana	On bark	Northern hemisphere; other hosts: *Alnus*, *Betula*, *Carya*, *Salix*	Farr et al. 1989
		Pellicularia koleroga	Louisiana	Thread blight	Southern United States; wide host range. Affects coffee (Pereira et al. 2000) and apple (Jimenez-Fonseca & Mendoza-Zamora, 1990)	Farr et al. 1989
		Puccinia festucae	China	Rust	Alaska & Eurasia; affects 279 *Lonicera* spp. & 157 *Festuca* spp. (Farr et al. 2002). Host record for *F. rubra* in NZ (McKenzie 1998)	Tai 1979
	Deuteromycotina - Hyphomycetes	*Alternaria* sp.	Florida	Leaf spot		Farr et al. 1989
		Cercospora lonicerae	Florida	Leaf spot	Southeastern United States, Bermuda; host records for *L. sempervirens*, *L.* sp.	Farr et al. 1989
		C. periclymeni	China	Leaf spot	Also records for Washington State & Canada; *L. periclymenum* & *L.* sp. other	Tai 1979

Plant pathogen	Classification	Species	Location	Symptoms	Distribution, host range — notes	Source
					known hosts (Farr et al. 2002)	
		C. varia	Texas	Leaf spot	Northcentral & northeastern North America; hosts are *Lonicera* spp. & *Viburnum*. Recorded on *Viburnum* spp. in NZ (Pennycook 1989)	Farr et al. 1989
		Corynespora cassiicola	Florida	Leaf spot	Cosmopolitan; more than 70 host plant species (Silva et al. 1998), including 3 crop species in NZ (Pennycook 1989)	Farr et al. 1989
		Phaeoramularia antipus	Florida	Leaf spot	Central North America; *L. sempervirens* & *L.* sp. other known hosts	Farr et al. 1989
		Pseudocercospora lonicericola (syn. *Cercospora lonicericola*)	NZ, Korea, China	Brown leaf spot & defoliation	Recorded in NZ on *Leycesteria formosa* (Pennycook 1989)	McKenzie 1990; Shin & Braun 1993; Shin 1998; Zhang 1992
		Sarcopodium pironii (syn. *Kutilakesa pironii*)	Florida		No data (Farr et al. 2002)	Miller 1991
		Verticillium albo-atrum	Greece		Cosmopolitan, most common in temperate regions incl. NZ; wide host range (Farr et al 2002)	Pantidou 1973
	Deuteromycotina - Coelomycetes	*Aplosporella punctum* (syn. *Sphaeropsis punctum*)	Mississippi	Secondary stem spot	One other record for *L.* sp. in District of Columbia	Farr et al. 1989
		Ascochyta tenerrima	China	Leaf spot	North America & Europe; *L. bella*, *L. tatarica*, *L. xylosteum* (Farr et al. 2002)	Zhang 1992
		Colletotrichum gloeosporioides (syn. *Glomerella cingulata* used in NZ)	China	Leaf spot	A species-specific form? Recorded on *Cassia obtusifolia* and *Phytolacca americana* in Georgia (Farr et al. 2002). Infects grapes, kiwifruit etc. in NZ (Landcare Research 1999)	Zhang 1992
		Diplodia sp.	Virginia	Affects stems		Farr et al. 1989
		Kabatia lonicerae	China	Leaf spot	Also Canada, northern USA; known hosts include *L. canadensis*, *L. ciliosa*, *L. conjugialis*, *L. involucrata*, *L. oblongifolia*, *L.* sp. (Farr et al. 2002)	Zhang 1992

Plant pathogen	Classification	Species	Location	Symptoms	Distribution, host range — notes	Source
		Phoma mariae	New York	Affects stems	Temperate North America, Europe; *L. dioica*, *L. morrowii*, *L.* sp., *L. tatarica* only known hosts	Farr et al. 1989
		Phyllosticta sp.	Florida	Leaf spot		Farr et al. 1989
		Rhabdospora lonicerae	New Jersey, Louisiana	Can cause vine death	New Jersey, Louisiana; *L.* sp. only other known host	Farr et al. 1989; 2002
	Deuteromycotina	*Rhizoctonia solani* (syn. *Thanatephorus cucumeris* used in NZ)	Florida	Leaf spot	Cosmopolitan; wide host range. Infects potato, carnation etc. in NZ (Landcare Research 1999)	Farr et al. 1989
Viruses	Geminivirus	Tobacco leaf curl bigeminivirus/ tobacco leaf curl virus	Europe; Japan (naturally)	Yellow vein mosaic of leaves "decorative"	Broad host range including tobacco and tomato crops (Sharma et al. 1997). Persistent transmission by whitefly (Brown & Bliss 2001)	MacIntosh et al. 1992; Sharma et al. 1997
	Tospovirus	Tomato spotted wilt virus	Czech Republic (mechanical innoculation)	Chlorotic & necrotic spots, & deformation of leaves	Host range includes 64 plant species (e.g., tomato). At least 32 host plant species in NZ (Pennycook 1989)	Mertelik et al. 1996
		Eggplant mottled dwarf virus	Mediterranean (mechanical innoculation)	Yellow veinbanding of leaves	*L.* spp.	Brown & Bliss 2001
		Honeysuckle latent virus	Europe	None	*L.* spp. Non-persistent transmission by aphids	Brown & Bliss 2001