Prospects for biological control of Chilean flame creeper

*Tropaeolum speciosum* (Tropaeolaceae)

Helen M. Harman

Landcare Research
PrivateBag 92170, Auckland 1142
New Zealand

Landcare Research Contract Report: LC0607/013

PREPARED FOR:
The National Weed Biocontrol Collective

DATE: August 2006
<table>
<thead>
<tr>
<th>Reviewed by:</th>
<th>Approved for release by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynley Hayes</td>
<td>Matt McGlone</td>
</tr>
<tr>
<td>Programme Leader</td>
<td>Science Leader</td>
</tr>
<tr>
<td>Landcare Research</td>
<td>Biodiversity and Conservation</td>
</tr>
</tbody>
</table>

© Landcare Research New Zealand Ltd 2006

This information may be copied and distributed to others without limitation provided Landcare Research Ltd and the source of the information is acknowledged. Under no circumstances may a change be made to this information without the expressed permission of Landcare Research Ltd.
Contents

Summary ...........................................................................................................................................................................5
1. Introduction ..........................................................................................................................................................................7
2. Objectives ...........................................................................................................................................................................7
3. Methods ...............................................................................................................................................................................7
4. Results ................................................................................................................................................................................8
   4.1 Taxonomy and related species ...........................................................................................................................................8
   4.2 Distribution and weed status of Chilean flame creeper in New Zealand.................................................................8
   4.3 Current control options ..................................................................................................................................................9
   4.4 Potential agents for biological control of Chilean flame creeper...............................................................................10
   4.5 Prospects for achieving biological control of Chilean flame creeper through biological control ..................................................11
5. Conclusions ..........................................................................................................................................................................11
6. Recommendations ...............................................................................................................................................................12
7. Acknowledgements ..............................................................................................................................................................12
8. References .............................................................................................................................................................................12
Appendix 1 Invertebrates recorded on Tropaeolaceae in New Zealand .................................................................14
Appendix 2 Pathogens recorded on Tropaeolaceae in New Zealand..............................................................................14
Appendix 3 Invertebrates recorded on Tropaeolaceae outside New Zealand..............................................................15
Appendix 4 Pathogens recorded on Tropaeolaceae worldwide.........................................................................................19
Appendix 5 Selection of websites containing information on Chilean flame creeper in New Zealand......................22
Summary

Project and Client
The feasibility of biological control of Chilean flame creeper, *Tropaeolum speciosum*, in New Zealand has been investigated for a national collective comprised of regional councils and the Department of Conservation.

Objectives
- Record the distribution and weed status of *Tropaeolum speciosum* in New Zealand.
- Briefly assess the current control options in New Zealand.
- Review the literature, and current information available from researchers worldwide to detect potential agents for biological control of *Tropaeolum speciosum*.
- Assess the prospects of achieving successful biological control of *Tropaeolum speciosum* in New Zealand.
- Propose a realistically costed programme.

Methods
Information for this report was obtained by searching computer databases (CAB Abstracts, Current Contents) and internet sites; cross-referencing; and contact with regional council staff, biological control experts, botanists, plant pathologists, and entomologists in New Zealand and South America.

Main findings
- Chilean flame creeper is an invasive weed of increasing concern to regional authorities, particularly in the southernmost parts of New Zealand.
- The plant is a vigorous climber that smothers shrubs and trees, reducing light levels, and preventing regeneration of desirable species.
- Reproduction is both by seed contained in fleshy fruits dispersed by birds and vegetative, with new populations establishing readily from root fragments where garden waste has been dumped.
- Current control methods include uprooting by hand, cutting and painting stumps with herbicide, and foliar spraying with herbicide. Follow-up sprays with herbicides are recommended.
- The plant is extremely difficult to control because birds can deposit seed in isolated areas and vines can resprout readily from fragments of its large tuberous roots. In addition, there are potential non-target impacts of foliar sprays on native species because the vines are thin and spindly.
- In New Zealand, Chilean flame creeper shares the family Tropaeolaceae with two other naturalised species of *Tropaeolum*, *T. majus* (garden nasturtium) and *T. pentaphyllum*. There are no native species in this family.
- No invertebrates or pathogens have been recorded from Chilean flame creeper in New Zealand or elsewhere, including its native range in Chile.
- Systematic searches for potential biocontrol agents for Chilean flame creeper would be carried out in the Valdivian rain forest of Chile where it is endemic.
Conclusions

- Given the potential environmental impact of Chilean flame creeper, the ineffectiveness of current methods of control, and its taxonomic status in New Zealand, biocontrol is an appropriate strategy for controlling this weed.
- There are no indigenous Tropaeolaceae in New Zealand, so the main consideration for any prospective agents would be any impact on *Tropaeolum* species of value to the nursery industry or home gardeners.
- Systematic searches of Chilean flame creeper in its native range in Chile may reveal invertebrates and pathogens that have potential as classical biocontrol agents.
- If there are no potential classical biocontrol agents sufficiently host specific and damaging, then a bioherbicide approach might be feasible.

Recommendations

- Survey populations of Chilean flame creeper throughout its range in New Zealand to determine which invertebrates and pests are directly associated with damage to this species. Estimated cost: $50,000–$70,000.
- Survey the plant through its native range in Chile to identify prospective biocontrol agents (possibly in collaboration with SAG, Chile). Estimated cost: $60,000 over 2 years.
- On completion of the overseas survey, review the prospects for successful biocontrol of this species and, if appropriate, prepare a costed programme for consideration by the National Weed Biocontrol Collective.
1. **Introduction**

Chilean flame creeper, *Tropaeolum speciosum* Poepp. & Endl. (Tropaeolaceae), is an invasive climbing weed of disturbed forest and shrubland for which current control options are not adequate. As a result, the National Weed Biocontrol Collective funded Landcare Research, Auckland, to conduct a feasibility study into biological control of this weed.

2. **Objectives**

- Record the distribution and weed status of *Tropaeolum speciosum* in New Zealand.
- Briefly assess the current control options in New Zealand.
- Review the literature, and current information available from researchers worldwide to detect potential agents for biological control of *Tropaeolum speciosum*.
- Assess the prospects of achieving successful biological control of *Tropaeolum speciosum* in New Zealand.
- Propose a realistically costed programme for implementation by the National Weed Biocontrol Collective.

3. **Methods**

Information for this report was obtained by searching computer databases (CAB Abstracts, Current Contents, Worldweb Science, NZ Fungi Database, CABI Fungal database, USDA fungi, Ngā Tipu o Aotearoa – New Zealand Plants Database, USDA weeds database), and internet sites; by cross-referencing known references; and from:

Mr Richard Bowman, Biosecurity Manager, Environment Southland  
Dr Rolf Delhey, Plant Pathologist, Universidad Nacional del Sur, Argentina  
Dr Nicholas Martin, Entomologist, Crop & Food Research  
Dr Sergio Rothmann, Entomologist, Servicio Agricola y Ganadero (SAG), Chile  
Dr Carlos Villamil, Botanist, Universidad Nacional del Sur, Argentina  
Dr Nicholas Waipara, Plant Pathology, Landcare Research
4. Results

4.1 Taxonomy and related species

Chilean flame creeper, *Tropaeolum speciosum* Poeppig & Endl., also known as flame flower and flame nasturtium, is a member of the Tropaeolaceae, a family of prostrate or climbing herbs comprising three genera: *Tropheastrum* (1 species, endemic to Patagonia), *Magallana* (2 species, endemic to Patagonia) and *Tropaeolum* (86 species ranging from southernmost Mexico to Chile and Argentina) (Sparre & Andersson 1991). The genus *Tropaeolum* is subdivided into two sections, *T.* section *Tropaeolum*, the species of which are distributed through the American tropics, and *T.* section *Chilensis*, which contains 22 species and 6 subspecies distributed in temperate South America, primarily in Chile (Andersson & Andersson 2000; Hershkovitz et al. 2006).

There are no indigenous genera or species in the Tropaeolaceae in New Zealand but three members of the genus *Tropaeolum* have naturalised: *T. majus* L. (garden nasturtium), *T. pentaphyllum* Lam. (ladies’ legs), and *T. speciosum* (Chilean flame creeper) (Webb et al. 1988; Ngā Tipu o Aotearoa – New Zealand Plants Database, accessed via http://nzflora.landcareresearch.co.nz/). *T. pentaphyllum* has been placed, along with Chilean flame creeper, in *T.* section *Chilensis*. Both these species originate from the more temperate regions of South America. *T. majus*, on the other hand, is in *T.* section *Tropaeolum*, and is thought to have arisen as spontaneous hybrid in Peru (Sparre & Andersson 1991).

*T. pentaphyllum*, not commonly grown in cultivation, is mainly grown in the North Island (Webb et al. 1988). Its vegetative parts can easily be confused with those of Chilean flame creeper but the flowers can be readily distinguished. *T majus*, the garden nasturtium is very commonly cultivated with many cultivars (Webb et al. 1988). A number of varieties of *Tropaeolum* are sold through the nursery industry in New Zealand. There are 27 listings under *Tropaeolum* in Gaddum’s Plantfinder 2000 (Gaddum 1990). These appear to be mostly varieties of *T. majus*, although possibly other species are used (listed as ‘pentaphyllum’, ‘perigrinum’, and ‘tricolorum’ in Gaddum’s Plantfinder 2000).

4.2 Distribution and weed status of Chilean flame creeper in New Zealand

Chilean flame creeper is a climbing perennial vine that can reach at least 10 m into tree canopies. Its thin wiry stems have coiling tendrils that attach to supporting vegetation. The blue-green five- to six-fingered leaves are thin and fleshy and die off over winter. The fleshy stoloniferous, below-ground rhizomes re-sprout each spring. Scarlet tubular flowers, about 15 mm across, are found through spring and summer (November–April). Fruiting occurs from December to March, with the seed contained in fleshy blue-black berries that are about 1 cm wide.

Chilean flame creeper can climb vigorously in full sun, and grows best in fertile, well-drained soil. It can tolerate a wide range of environmental conditions including warm to cold, salt, wind, damp and drought. The seeds are effectively dispersed by birds eating the berries. The vine can also replicate vegetatively through its tuberous root system.
Chilean flame creeper is endemic to Chile, occurring from Concepción and Nuble province to the northern part of Aysén province. It is restricted to the coastal Valdivian rain forest, growing in *Nothofagus* forest and *Chusquea* thickets. Sparre and Anderson (1991) describe it as ‘rather common in both the coastal area and in the Cordillera where it reaches about 1000m altitude’. However, Sergio Rothmann, SAG Chile, says that various entomologists and botanists in Chile ‘agreed it is not a common species in the forest’ when he made enquiries recently (pers. comm.).

Chilean flame creeper was first recorded as naturalised in New Zealand in 1958 (Webb et al.1988). In the North Island, small scattered populations occur as far north as the Waikato Region, where there is a limited number of sites, mostly in the Northern King Country. In the South Island it occurs as far south as Southland and inland from the coast to the Craigieburn intermontaine region of Canterbury (Webb et al. 1988). It is also present on Stewart Island.

Originally an escape from garden cultivation in New Zealand, Chilean flame creeper now occurs typically in disturbed forest and shrublands. It has become more invasive in recent years, especially in Southland where it has been described as ‘flourishing’ and ‘uncontrollable’ (Richard Bowman, pers. comm.) and it has been reported as doing very well in Southland and Stewart Island after the 1996 frosts. The vine suppresses and replaces native vegetation by shading and smothering. This is of particular concern should it invade the habitat of endangered species where it can either displace endangered plant species or reduce food resources for endangered animal species. The ability of birds to spread the seed to remote locations where the plants may not be detected contributes to its invasiveness. Chilean flame creeper has the ability to resprout from fragments of its tuberous roots system and consequently is spread by the dumping of garden waste and by soil movements. It can restrict access in areas of heavy infestation adversely affecting amenity values. Environment Waikato, which is currently undertaking direct control with the Department of Conservation, has estimated that the “do nothing” option for control would result in identifiable damage to Regional conservation values in over 5265 hectares.

Chilean flame creeper is listed as an Unwanted Organism on the National Pest Plant Accord (NPPA) list which makes it illegal to sell, propagate or distribute the plant under the Biosecurity Act. It also appears in the Regional Pest Management Strategies (RPMS) from the following Regional Councils (see Appendix for websites):

- Environment Southland – a total control plant on Stewart Island, a surveillance plant in the rest of the region;
- Greater Wellington Regional Council – identified for Key Ecosystem Management, i.e. controlled in some special places;
- Horizons Regional Council – Regional Surveillance Plant;
- Environment Waikato – Eradication (Service Delivery) Plant.

### 4.3 Current control options

*T. speciosum* is extremely difficult to eradicate because new vines re-sprout from the root, requiring ongoing follow-up work. The optimum control time is from spring through summer (September–February).

Plants can be controlled physically by tracing stems to the ground and digging up the roots. Care must be taken as the plant can re-grow from relatively small root fragments, and stems in contact with the ground may also form new roots. Root fragments remaining in the ground
may need to be treated with herbicide where possible. Plant material can be disposed of by burning or drying out in the sun. Aerial parts may be composted following removal of seeds or fruit, but root material should not be composted. The safest method of disposal is deep burial in a landfill. This method is more suited to smaller plants. An alternative method is to cut the vines and treat the stems or stumps with herbicide.

There are no completely effective chemical control methods known, however, the following treatments have been suggested by regional councils. Tordon Brushkiller (3 ml/L) and Glyphosate (20 ml/L) with a penetrant may be used for foliar spraying. This should be done during spring–summer because the plant loses its leaves during winter. A 6-monthly follow-up is recommended to deal with any re-sprouting that occurs from the root stock. Because the vines are thin and spindly and scramble over other vegetation, non-target spraying is an issue with this treatment method. Cut stems or stumps can be swabbed with either glyphosate (50%), Escort (5 g/L), or Tordon Brushkiller (25–35%). This treatment may be used all year round.

The above information was supplied from Environment Southland, Christchurch City Council, Horizons Regional Council, and Auckland Regional Council websites (see Appendix).

4.4 Potential agents for biological control of Chilean flame creeper

No invertebrates have been recorded from Chilean flame creeper in New Zealand (Spiller & Wise 1982). A systematic survey would probably reveal herbivorous insects feeding on the plant in New Zealand; however, they may not be causing significant damage to the plant. There are no records of plant diseases on Chilean flame creeper (NZ Fungi Database, http://nzfungi.landcareresearch.co.nz ), but again surveys are likely to find some.

There are no records of invertebrates from Chilean flame creeper in the literature (CAB Abstracts 1910–2006, Current Contents, Web of Science). Sergio Rothmann (an entomologist with SAG, Chile) is unaware of any studies of arthropods associated with this species, and after consulting other Chilean entomologists and botanists reports there are no records of invertebrates on this plant. Moreover, no-one could recall any particular damage by invertebrates to the plant, which they agreed was not a common species in its native range. Similarly, there are no records of pathogens on Chilean flame creeper outside New Zealand including the native range (Viégas, 1961; Sergio Rothmann, pers. comm.; Rolf Delhey, pers. comm.; SBML Fungal database; CABI Bioscience Database; CAB Abstracts).

There are records of invertebrates and pathogens on other species of Tropaeolaceae in New Zealand and elsewhere (see Appendix) (Spiller & Wise 1982; Plant-SyNZ database; NZ Fungal database, SBML Fungal database; CABI Bioscience Database; CAB Abstracts). In New Zealand, the cabbage white butterfly, a moth and three leafmining flies have been recorded feeding on T. major (nasturtium). All are known to utilise other plant species, with several feeding on brassicas. Most invertebrate records in the international literature are for polyphagous species that feed on T. major (nasturtium), in particular the large white butterfly, Pieris brassicae, leaf-mining flies Liriomyza spp. (Agromyzidae), and several aphid species.

Some species of damaging disease pathogens have been recorded on related members of the family (see Appendix). While many of these may be specific to the reported associated host(s), some could be scoped for either inundative or classical biocontrol agents if no
appropriate diseases are found on the target in its native range. For example, *Glomerella
cingulata* (recorded from *T. majus*, Brunei and Borneo) and *Sclerotinia* sp. (recorded from *T.
majus* in Uganda and Korea) have potential as inundative biocontrol agents (bioherbicides),
and *Uredo tropealoi* (recorded from *T. aduncum* in the UK) has potential as a classical
biocontrol agent (Nick Waipara, pers. comm.) However, as most are recorded on *T. majus*,
there could be unacceptable non-target impacts on the cultivated relative.

4.5 Prospects for achieving biological control of Chilean flame creeper through
biological control

No potential biocontrol agents for Chilean flame creeper have been identified, including in its
native range in Chile. It is interesting that researchers in Chile have reported that the plant is
not a common species (Sergio Rothmann, pers. comm.), when it is invasive in parts of New
Zealand, especially in the south where there is much concern about its potential to smother
native bush. Even though little invertebrate damage has been observed, invertebrates and
pathogens may contribute to Chilean flame creeper not being common in its native range. A
systematic search could reveal potential agents with sufficient host specificity and would be
worth pursuing given the inadequacy of current control methods in New Zealand.

Host-range testing is important to minimize the risk of damage to valued non-target plants. If
there are no native plants or plants of economic significance in the same family, then the
chances of finding agents with a suitable degree of host specificity are enhanced. The
prospects of finding agents that will not impact on native New Zealand plants therefore look
good as there are none in the Tropaeolaceae. The only members of Tropaeolaceae naturalized
in New Zealand other than Chilean flame creeper are *T. pentaphyllum* (ladies legs) and *T.
majus*, the garden nasturtium. *T. pentaphyllum* is the most closely related to Chilean flame
creeper, with both species occurring in the same section of *Tropaeolum* (*Chilensis*). *T.
majus*, although in the same genus, is less related, occurring in a different section. A number of
ornamental ‘species’ of *Tropaeolum* are cultivated by nurseries and home gardeners
(Gaddum 1999) and any impact of potential biocontrol agents on these plants would need to
be considered. A host test list would also need to consider members of other closely related
families in New Zealand including some ornamentals and brassicas. If there are no suitable
candidates for classical biocontrol and if suitable pathogens are present in New Zealand, then
a bio-myoherbicide could be considered, although this would have a high development cost.

5. Conclusions

Chilean flame creeper has the potential to be a serious invasive weed in New Zealand and is
of particular concern currently in the southernmost parts of the country. It invades disturbed
forest and shrubland, and can tolerate a wide variety of environmental conditions. Its
climbing vines smother native vegetation and alter light levels, thus preventing recruitment of
desirable species, as does its thick tuberous roots. Its fruit is readily dispersed to new areas by
birds and it is difficult to eradicate by physical or chemical means because new vines resprout
from root fragments. Chilean flame creeper belongs to the family Tropaeolaceae, (which is
from Central and South America), and is endemic to the Valdivian rain forest in Chile. Two
other species from the Tropaeolaceae, *T. majus* (the garden nasturtium) and *T.
pentaphyllum*, are naturalized in New Zealand. *T. majus* is in a separate section of the genus.
Given the potential impact of Chilean flame creeper, the ineffectiveness of current methods of control, and its taxonomic status in New Zealand, biological control is an appropriate strategy for controlling this weed. The main consideration would be any impact of potential agents on *Tropaeolum* species of value to the nursery industry or home gardeners as these are the most likely to be affected. There are no recorded invertebrates or diseases on Chilean flame creeper in New Zealand or elsewhere, including its native range. However, systematic surveys in the native range may reveal potential biocontrol agents that are sufficiently host specific for biological control of Chilean flame creeper in New Zealand.

6. Recommendations

- Survey populations of Chilean flame creeper throughout its range in New Zealand to determine which invertebrates and pests are directly associated with damage to this species. Estimated cost: $50,000–$70,000.
- Survey the plant through its native range in Chile to identify prospective biocontrol agents (possibly in collaboration with SAG, Chile). Estimated cost: $60,000 over 2 years.
- On completion of the overseas survey, review the prospects for successful biocontrol of this species and, if appropriate, prepare a costed programme for consideration by the National Weed Biocontrol Collective.

7. Acknowledgements

Thanks to all those who responded to my requests for information. Lynley Hayes, Merrilyn Merritt, Quentin Paynter and Nick Waipara provided helpful comments on the draft report. Thanks also to Anne Austin for editorial assistance and to Wendy Weller for final word processing.

8. References


Appendix 1  Invertebrates recorded on Tropaeolaceae in New Zealand

<table>
<thead>
<tr>
<th>Invertebrate species</th>
<th>Associated host plant</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Epyaxa rosearia</em></td>
<td><em>Tropaeolum majus</em></td>
<td>Plant-SyNZ (N.A. Martin) (also in Spiller &amp; Wise 1982)</td>
</tr>
<tr>
<td>Geometrid moth - endemic</td>
<td>(and native species)</td>
<td></td>
</tr>
<tr>
<td>Larvae feed on foliage</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Liriomyza brassicae</em></td>
<td><em>T. majus</em></td>
<td>Plant-SyNZ (N.A. Martin)</td>
</tr>
<tr>
<td>Agromyzid fly – adventive</td>
<td>(also Brassicaceae)</td>
<td></td>
</tr>
<tr>
<td>Larvae mine leaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Liriomyza watti</em></td>
<td><em>T. majus</em></td>
<td>Plant-SyNZ (N.A. Martin)</td>
</tr>
<tr>
<td>Agromyzid fly – endemic</td>
<td>(also Brassicaceae)</td>
<td></td>
</tr>
<tr>
<td>Larvae mine leaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pieris rapae</em></td>
<td><em>Tropaeolum majus</em></td>
<td>Spiller &amp; Wise 1982</td>
</tr>
<tr>
<td>Cabbage white butterfly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyphagous species</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Scaptomyza flavia</em></td>
<td><em>Tropaeolum majus</em></td>
<td>Plant-SyNZ (N.A. Martin)</td>
</tr>
<tr>
<td>Drosophilid fly – adventive</td>
<td>(also Brassicaceae and other species)</td>
<td></td>
</tr>
<tr>
<td>Larvae mine leaves</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix 2  Pathogens recorded on Tropaeolaceae in New Zealand

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Associated host plant</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acroconidiella tropaeoli</em></td>
<td><em>Tropaeolum majus</em></td>
<td>*NZ Fungi database</td>
</tr>
<tr>
<td>Broad bean wilt virus 1</td>
<td><em>T. majus</em></td>
<td>NZ Fungi database</td>
</tr>
<tr>
<td><em>Colesporium tropaeoli</em></td>
<td><em>Tropaeolum peregrinum</em></td>
<td>NZ Fungi database</td>
</tr>
<tr>
<td>(rust from Germany, not New Zealand – stored in ICMP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pseudomonas syringae</em></td>
<td><em>T. majus</em></td>
<td>NZ Fungi database</td>
</tr>
<tr>
<td>Tomato spotted wilt virus</td>
<td><em>T. majus</em></td>
<td>NZ Fungi database</td>
</tr>
<tr>
<td>Turnip mosaic virus – TuMV</td>
<td><em>T. majus</em></td>
<td>Tang et al. 2006</td>
</tr>
<tr>
<td>(economically important virus)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbena latent carlavirus – VeLV</td>
<td><em>T. majus</em></td>
<td>Tang et al. 2006</td>
</tr>
<tr>
<td>Unidentified <em>Carmovirus</em></td>
<td>tentative</td>
<td>Tang et al. 2006</td>
</tr>
</tbody>
</table>

*Landcare Research’s NZ Fungi Database (http://nzfungi.landcareresearch.co.nz):

### Appendix 3  Invertebrates recorded on Tropaeolaceae outside New Zealand

<table>
<thead>
<tr>
<th>Invertebrate</th>
<th>Associated host plant</th>
<th>Location (Reference)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aphis abbreviate</em> (buckthorn aphid)</td>
<td>Many cultivated and wild plants worldwide including nasturtium</td>
<td>US (Patch 1924)</td>
</tr>
<tr>
<td><em>Aphis barberae</em> (aphid)</td>
<td><em>T. majus</em> and burdock (<em>Arctium minus</em>)</td>
<td>Canada (Robinson 1980)</td>
</tr>
<tr>
<td><em>Aphis fabae</em> (black bean aphid) subspecies <em>mordwilkoi</em></td>
<td><em>T. majus</em> (and <em>Rumex obtusifolius</em>)</td>
<td>UK (Tosh et al. 2004)</td>
</tr>
<tr>
<td></td>
<td>And other clones</td>
<td>UK (Douglas 1997)</td>
</tr>
<tr>
<td><em>Athalia proxima</em> (mustard sawfly)</td>
<td>Crucifers and a number of noncrucifers (<em>Cruciferae</em> and <em>Tropaeolaceae</em>) <em>Tropaeolum sp.</em></td>
<td>India (Sehgal et al. 1975)</td>
</tr>
<tr>
<td><em>Brevicoryne brassicae</em> (cabbage aphid)</td>
<td><em>T. majus, Brassica oleracea</em> (cabbage)</td>
<td>Netherlands (Tjallingii 1976)</td>
</tr>
<tr>
<td><em>Chromatomyia horticola</em> (agromyzid leaf-mining fly) <em>Polyphagous</em></td>
<td><em>T. majus</em></td>
<td>India (Singh &amp; Bhati 1996)</td>
</tr>
<tr>
<td><em>Globodera spp.</em> (nematode pest of potatoes)</td>
<td><em>T. tubersosum</em> – 1 of 27 lines tested acted as a trap crop for <em>Globodera spp.</em></td>
<td>Bolivia (Main et al. 1999)</td>
</tr>
<tr>
<td><em>Hyposchila galactodice</em> (Patagonian-Fuegian white butterfly)</td>
<td><em>Tropaeolum incisum</em> = natural food plant but could be reared on cruciferous weeds</td>
<td>Western Patagonia, Argentina (Shapiro 1990)</td>
</tr>
<tr>
<td><em>Leptophobia aripa</em> (pierid butterfly)</td>
<td><em>T. majus</em> Defoliates host plant</td>
<td>Argentina (Neder de Roman et al. 1983)</td>
</tr>
<tr>
<td><em>Liriomyza brassicae</em> (agromyzid fly)</td>
<td><em>T. majus, T. minus</em> Also on <em>Brassica</em> spp. Infests various cruciferous plants and nasturtium (US, Canada and Hawaii)</td>
<td>India (Udayagiri 1987, Gokulpure 1975) Argentina (Valladares 1984) Frick 1957</td>
</tr>
<tr>
<td><em>Liriomyza huidobrensis</em> (agromyzid leaf-mining fly) <em>Important pest species</em></td>
<td>Wild plants and <em>Tropaeolum</em></td>
<td>Costa Rica (Spencer 1983)</td>
</tr>
<tr>
<td><em>Myzus persicae</em> (green peach aphid)</td>
<td><em>T. majus</em> And other hosts?</td>
<td>US (Barker et al. 1951)</td>
</tr>
<tr>
<td>Nematode pests</td>
<td><em>Tropolaeum tuberosum</em> (mashua)</td>
<td>Tropical and subtropical agriculture (Bridge et al. 2005, Jatala &amp; Bridge 1990)</td>
</tr>
<tr>
<td><em>Pieris brassicae</em> (large white butterfly) <em>Polyphagous</em></td>
<td><em>T. majus</em></td>
<td>Estonia (Jogar et al. 2005, Metspalu et al. 2003), Chile (Angulo et al. 1982)</td>
</tr>
<tr>
<td>Invertebrate</td>
<td>Associated host plant</td>
<td>Location (Reference)</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td><em>Pieris rapae</em> (white butterfly)</td>
<td><em>T. majus</em></td>
<td>USA (Renwick et al. 1999, 1995)</td>
</tr>
<tr>
<td>Polyphagous</td>
<td></td>
<td>India (Sood &amp; Kakar 1990)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New Zealand (Ferguson 1975)</td>
</tr>
<tr>
<td><em>Plutella xylostella</em> (diamondback moth)</td>
<td><em>T. majus</em></td>
<td>Japan (Habu et al. 1995)</td>
</tr>
<tr>
<td>polyphagous</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Trialeurodes vaporariorum</em> (greenhouse</td>
<td><em>Tropoleaeum majus</em></td>
<td>China (Ma et al. 2005)</td>
</tr>
<tr>
<td>whitefly) polyphagous</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

References

Most of the following references taken from CAB Abstracts have not been directly sighted.


Appendix 4  Pathogens recorded on Tropaeolaceae worldwide

*SBML Fungus-Host Database 13 July 2006:

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Associated host plant</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acroconidiella tropaeoli</td>
<td><em>Tropaeolum majus</em></td>
<td>Australia, Azores, California, India, New Zealand, Papua New Guinea, South Africa</td>
</tr>
<tr>
<td>Alternaria sp.</td>
<td><em>Tropaeolum majus</em></td>
<td>California, Hawaii</td>
</tr>
<tr>
<td>Alternaria tropaeoli</td>
<td><em>Tropaeolum majus</em></td>
<td>India</td>
</tr>
<tr>
<td>Alternaria tropaeolicola</td>
<td><em>Tropaeolum majus</em></td>
<td>China</td>
</tr>
<tr>
<td>Ascochyta sp.</td>
<td><em>Tropaeolum majus</em></td>
<td>India</td>
</tr>
<tr>
<td>Botrytis cinerea</td>
<td><em>Tropaeolum majus</em></td>
<td>Alaska</td>
</tr>
<tr>
<td>Cercospora tropaeoli</td>
<td><em>Tropaeolum majus</em></td>
<td>Alabama, Texas, Uganda</td>
</tr>
<tr>
<td>Cladosporium macrocarpum</td>
<td><em>Tropaeolum majus</em></td>
<td>China</td>
</tr>
<tr>
<td>Cladosporium sp.</td>
<td><em>Tropaeolum majus</em></td>
<td>California</td>
</tr>
<tr>
<td>Coelosporium sp</td>
<td><em>Tropaeolum minus</em></td>
<td>Sweden</td>
</tr>
<tr>
<td>Coleosporium tussilaginus</td>
<td><em>Tropaeolum peregrinum</em></td>
<td>Sweden</td>
</tr>
<tr>
<td>Cronartium flaccidum</td>
<td><em>Tropaeolum minus</em></td>
<td>Sweden</td>
</tr>
<tr>
<td>Didymosphaeria sarmenti</td>
<td><em>Tropaeolum peregrinum</em></td>
<td>California</td>
</tr>
<tr>
<td>Glomerella cingulata</td>
<td><em>Tropaeolum majus</em></td>
<td>Brunei</td>
</tr>
<tr>
<td>Heterosporium tropaeoli</td>
<td><em>Tropaeolum majus</em></td>
<td>California, Hawaii, Kenya, New York</td>
</tr>
<tr>
<td>Leveillula taurica</td>
<td><em>Tropaeolum majus</em></td>
<td>Australia, Barbados, Canary Islands, China, Egypt, Ethiopia, France, India, Indonesia, Iran, Iraq, Israel, Italy, Kenya, Madagascar, Malawi, Mauritius, Morocco, Mozambique, Myanmar, New Caledonia, Pakistan, Portugal, Saudi Arabia, Senegal, South Africa, Southern Africa, Sudan, Tanzania, Turkey, Zambia, Zimbabwe</td>
</tr>
<tr>
<td>Leveillula tropaeoli</td>
<td><em>Tropaeolum majus</em></td>
<td>China</td>
</tr>
<tr>
<td>Myrothecium roridum</td>
<td><em>Tropaeolum majus</em></td>
<td>California, Denmark</td>
</tr>
<tr>
<td><strong>Oidiopsis sicula</strong></td>
<td><em>Tropaeolum majus</em></td>
<td>California</td>
</tr>
<tr>
<td><strong>Oidiopsis sicula</strong></td>
<td><em>Tropaeolum majus</em></td>
<td>Ethiopia</td>
</tr>
<tr>
<td>Pathogen</td>
<td>Associated host plant</td>
<td>Location</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td><em>Oidiopsis sp.</em></td>
<td><em>T. majus</em></td>
<td>Barbados, China, New Caledonia</td>
</tr>
<tr>
<td><em>Oidiopsis taurica</em></td>
<td><em>T. majus</em></td>
<td>Australia, New Caledonia, South Africa</td>
</tr>
<tr>
<td><em>Oidium sp.</em></td>
<td><em>T. majus</em></td>
<td>Australia, India, Kenya, Madeira Islands, New Caledonia, Sri Lanka, Uganda</td>
</tr>
<tr>
<td></td>
<td><em>T. pentaphyllum</em></td>
<td>Argentina, India</td>
</tr>
<tr>
<td><em>Ovulariopsis sp.</em></td>
<td><em>T. majus</em></td>
<td>Venezuela</td>
</tr>
<tr>
<td><em>Phyllosticta sp.</em></td>
<td><em>T. majus</em></td>
<td>Wisconsin</td>
</tr>
<tr>
<td><em>Pleospora sp.</em></td>
<td><em>T. majus</em></td>
<td>Mississippi, New Jersey, Ohio</td>
</tr>
<tr>
<td><em>Pleospora tropaeoli</em></td>
<td><em>T. majus</em></td>
<td>Oklahoma, Southern Africa, Zimbabwe</td>
</tr>
<tr>
<td><em>Pseudomonas solanacearum</em></td>
<td><em>T. majus</em></td>
<td>South Africa</td>
</tr>
<tr>
<td><em>Puccinia aristide</em></td>
<td><em>T. majus</em></td>
<td>Utah</td>
</tr>
<tr>
<td><em>Pythium sp.</em></td>
<td><em>T. majus</em> (root rot)</td>
<td>Hawaii, Scotland</td>
</tr>
<tr>
<td><em>Pythium ultimum</em></td>
<td><em>T. majus</em></td>
<td>South Africa</td>
</tr>
<tr>
<td><em>Rhizoctonia solani</em></td>
<td><em>T. majus</em> (root rot)</td>
<td>Florida</td>
</tr>
<tr>
<td><em>Septoria sp.</em></td>
<td><em>T. majus</em></td>
<td>Korea</td>
</tr>
<tr>
<td><em>Sphaeria sarmenti</em></td>
<td><em>T. minus</em></td>
<td>California</td>
</tr>
<tr>
<td><em>Stemphylium sp.</em></td>
<td><em>T. majus</em></td>
<td>Venezuela</td>
</tr>
<tr>
<td><em>Uredos tropaeoli</em></td>
<td><em>Tropaeolum aduncum</em></td>
<td>UK</td>
</tr>
<tr>
<td></td>
<td><em>T. majus</em></td>
<td>Bulgaria</td>
</tr>
</tbody>
</table>

CABI Bioscience database 15 July 2006:

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Associated organism</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acroconidiella tropaeoli</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Jamaica, Mauritius, Papua New Guinea, Uttaranchal</td>
</tr>
<tr>
<td>Acroconidiella tropaeoli</td>
<td><em>Tropaeolum majus</em></td>
<td>Australia, Azores, Buenos Aires, Ethiopia, Great Britain, Haiti, India, Jamaica, New Zealand, Sri Lanka, Tanzania, Uganda</td>
</tr>
<tr>
<td>Alternaria</td>
<td><em>T. majus</em></td>
<td>West Bengal</td>
</tr>
<tr>
<td>Aspergillus awamori</td>
<td><em>Tropaeolum</em> (associated with rhizosphere)</td>
<td>Egypt</td>
</tr>
<tr>
<td>Aspergillus flavus</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Egypt</td>
</tr>
<tr>
<td>Aspergillus terreus</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Egypt</td>
</tr>
<tr>
<td>Cercospora tropaeoli</td>
<td><em>T. majus</em></td>
<td>West Bengal</td>
</tr>
<tr>
<td>Cercospora tropaeoli</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Zambia</td>
</tr>
<tr>
<td>Cladosporium</td>
<td><em>T. majus</em></td>
<td>West Bengal</td>
</tr>
<tr>
<td>Coleosporium tussilaginus</td>
<td><em>Tropaeolum</em> peregrinum (on leaf)</td>
<td>Great Britain</td>
</tr>
<tr>
<td>Colletotrichum capsici</td>
<td><em>T. majus</em></td>
<td>India</td>
</tr>
<tr>
<td>Fusarium solani</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Egypt</td>
</tr>
<tr>
<td>Glomerella cingulata</td>
<td><em>T. majus</em></td>
<td>Borneo</td>
</tr>
<tr>
<td>Humicola fuscoatra</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Egypt</td>
</tr>
<tr>
<td>Leveillula taurica</td>
<td><em>T. majus</em></td>
<td>Ethiopia, India, Kenya, Mauritius, Tanzania, Zambia,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leveillula taurica</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Kenya, Madhya Pradesh, Sudan, Zimbabwe</td>
</tr>
<tr>
<td>Leveillula taurica</td>
<td><em>Tropaeolum pentaphyllum</em></td>
<td>Jammu &amp; Kashmir, India</td>
</tr>
<tr>
<td>Penicillium funiculosum</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Egypt</td>
</tr>
<tr>
<td>Phyllosticta</td>
<td><em>T. majus</em></td>
<td>Pakistan</td>
</tr>
<tr>
<td>Pleospora tropaeoli</td>
<td><em>T. majus</em></td>
<td>Kenya</td>
</tr>
<tr>
<td>Oidium</td>
<td><em>T. majus</em></td>
<td>Kenya</td>
</tr>
<tr>
<td>Sclerotinia</td>
<td><em>T. majus</em></td>
<td>Uganda</td>
</tr>
<tr>
<td>Thielavia</td>
<td><em>Tropaeolum</em> sp.</td>
<td>Egypt</td>
</tr>
</tbody>
</table>
Appendix 5  Selection of websites containing information on Chilean flame creeper in New Zealand

Auckland Regional Council
http://www.arc.govt.nz/arc
(accessed 15 July 2006)

Biosecurity New Zealand:
– pest and diseases watchlist
– National Pest Plant Accord August 2001
(accessed 31 March 2006)

Christchurch City Council
(accessed 31 March 2006)

Environment Southland
http://www.es.govt.nz/Departments/Biosecurity
(accessed 15 July 2006)

http://www.ew.govt.nz/policyandplans/rpmsintro/rpms2002/operative5.2.3.htm
(accessed 31 March 2006)

Greater Wellington Regional Council
http://www.govt.nz
(accessed 15 July 2006)

Horizons Regional Council
(accessed 31 March 2006)