Prospects for the Biological Control of Tutsan (*Hypericum androsaemum* L.) in New Zealand

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Abstract

The feasibility for biological control of tutsan, *Hypericum androsaemum* L., in New Zealand (NZ) was assessed. Conventional control methods are impractical and tutsan is not valued by any groups of society. It therefore makes a potentially good candidate for biological control. However, the lack of information about potential agents and the existence of four indigenous *Hypericum* spp. in NZ, including two endemics, are likely to prove challenging.

Introduction

Tutsan, *Hypericum androsaemum* L., is an evergreen or semi-evergreen shrub (up to 1.5 m) of the family Clusiaceae (alternatively Guttiferae). In New Zealand (NZ) tutsan has become a common weed in higher rainfall areas, growing in open forest, forest margins, scrub, waste places and garden surroundings. Tutsan is shade tolerant, unpalatable to stock, and tends to infest areas in which mechanical and/or chemical control options are impractical.

Tutsan's extensive native range includes Europe, Caucasia, Turkmenistan, Iran, Syria, Turkey, north-west Africa and temperate Asia (Davis, 1967; USDA ARS, 2009). The naturalised range includes Australia, NZ, Southern Africa, continental Chile and possibly part of the US (Thomas, 2007).

A climate similar to that of southern France, with average annual temperature of 13°C and annual rainfall of 910 mm, appears optimal for tutsan; however, tutsan can tolerate a wide temperature range (Van Der Veken et al., 2004). It is also tolerant of various soil types and acidity levels (e.g., Hutchinson, 1967). Tutsan is a shade-tolerant species and, in its native range is a component of mature forests (Olano et al., 2002). These findings suggest that large parts of NZ could prove to be suitable habitat for this species.

Tutsan is a garden escapee in NZ (Healy, 1972) and was first recorded as naturalised here in 1870 (Owen, 1997). The plant is well established throughout NZ (North and South Islands, Stewart Is, Chatham Islands, and Campbell Islands) (Sykes, 1982). It is currently of greatest concern in the Taumarunui District in the North Island of NZ.

In NZ tutsan is considered a major pest in a range of bioclimatic zones from warm- to cool-temperate (ranging from latitude 31° to 50° S, maritime climate, below 600 m with average annual temperatures ranging between 12.5 and 22.5°C). Plant community types identified as prone to invasion by tutsan include shrublands, tussock grasslands and bare land. Tutsan can impact on the structure (i.e., on the dominant growth form of forest, shrubland etc.), or have a "major effect on many native species or on the composition or density of dominant species" (Owen, 1997).

A 1995 survey of weeds of conservation land determined its national distribution status as: "established, widely distributed throughout NZ and extending its range into new habitats and areas". Tutsan is a problem in regenerating forest (Sullivan et al., 2007). Its biological success is mainly attributed to the high seeding ability per plant, seedbank persistence of >5 years, and its tolerance of semishade conditions, hot or cold temperatures, high to moderate rainfall, damage and grazing. In addition, its fleshy fruits are effectively dispersed by birds, and possibly also by goats, possums, and soil and water movement (Whatman, 1967; Owen, 1997). Classical biological control is therefore a desirable option.

In NZ there are four indigenous *Hypericum* spp. (Webb et al., 1988; Heenan, 2008, 2011):

- *Hypericum involutum* (Labill.) Choisy, native to NZ, Australia, Tasmania and New Caledonia
- *Hypericum pusillum* Choisy, native to NZ, Australia and Tasmania.
- *Hypericum rubicundulum* Heenan, endemic to the South Island of NZ (and known from one locality in the North Island) and considered naturally uncommon
- *Hypericum minutiflorum* Heenan, endemic to NZ, restricted to the central North Island Volcanic Plateau and considered nationally critically endangered

A high degree of host specificity would be required of any agent introduced against tutsan, if we were to avoid significant non-target risks to the indigenous *Hypericum* species. There are no other indigenous representatives in the Clusiaceae family in NZ.

History of biological control of tutsan in NZ

Biological control of tutsan in NZ was attempted opportunistically in the late 1940s, using a St John's wort biological control agent *Chrysolina hyperici* (Forst.) (Julien and Griffiths, 1998). Adult beetles were observed feeding on tutsan, and subsequently, an attempt was made to release *C. hyperici* in areas where tutsan was considered a problem. Beetles released on tutsan between 1947 and 1950 all failed to establish on the weed (Miller, 1970).

Early instar larvae of both the lesser and greater St. John's wort beetles, *C. hyperici* and *Chrysolina quadrigemina* (Suffrian) suffered high mortality when offered tutsan in recent no-choice laboratory feeding experiments, and the survivors' development was severely impeded (Groenteman et al., 2011), confirming that tutsan is a sub-optimal host for the beetles, and explaining why beetles released on tutsan in the late 1940s quickly died out.

History of biological control of tutsan worldwide

The state of Victoria, Australia, initiated a biological control programme against tutsan in the early 1990s. This programme was discontinued at an early stage, prior to any surveys in the native range of the weed being carried out, after the rust fungus *Melampsora hypericorum* (De Candolle) Winter was discovered to have self-introduced there. While the use of *M. hypericorum* as a biological control agent has generated mixed results, the fungus has largely successfully controlled tutsan in Victoria (Bruzzese and Pascoe, 1992; McLaren et al., 1997; Casonato et al., 1999; David McLaren pers. comm.).

Objectives

Given the difficulties to control tutsan using conventional methods, and given it is rapidly expanding its range, classical biological control emerges as an attractive option. The objectives of the current study were, therefore, a) to review the literature to identify potential biocontrol agents for tutsan and assess the feasibility of their release in NZ and, b) to assess the prospects of achieving successful biological control of tutsan in NZ.

Methods

Identifying fungal pathogens of tutsan

The information was obtained by searching online databases and Internet sites. Online databases searched were:

USDA Fungus-host database or FDSM (which includes most NZ plant disease records): http://nt.ars-grin.gov/fungaldatabases/fungushost/FungusHost.cfm

Fungal Records Database of Britain and Ireland or FRDBI (Cooper, 2006): http://www.fieldmycology.net/FRDBI/assoc.asp

IMI fungal herbarium (CABI Bioscience, 2006) http://194.203.77.76/herbIMI/index.htm

NZ fungi and bacteria database or NZFUNGI

(Landcare Research, 2009): http://nzfungi.landcareresearch.co.nz/html/mycology.asp; this database was also used to determine which species were already present in NZ

In addition, CAB abstracts, Current Contents, ISI Proceedings, Web of Science, Agricola, Science Direct, Google and Google Scholar were searched, using the terms "*Hypericum androsaemum* or tutsan" and sub-searched using the terms "pathogen* or fung*". Once a list had been created, further information about each fungus was sought in the published literature as well as in the following online databases:

Index Fungorum database (Index Fungorum, 2004): http://www.indexfungorum.org/Names/Names.asp

Global Biodiversity Information Facility or GBIF (Global Biodiversity Information Facility, 2009): http://data.gbif.org/species/

Identifying arthropod biological control agents for tutsan

Unlike for fungal pathogens, comprehensive online databases for all arthropod herbivores do not exist. However, the following databases were searched:

For Lepidoptera, the Natural History Museum's world listing (Natural History Museum London, 2007): http://www.nhm.ac.uk/jdsml/research-curation/research/projects/hostplants/

Database of Insects and Their Food Plants Biological Records Centre (UK) (Biological Records Centre (BRC), 2009) http://www.brc.ac.uk/dbif/Interpreting_foodplant_records.aspx

Plant-SyNZ™ http://www.crop.cri.nz/home/plant-synz/database/hostplant.php

In addition, CAB abstracts, Current Contents, ISI Proceedings, Web of Science, Agricola, Science Direct, Google and Google Scholar were searched using the terms "*Hypericum androsaemum* or tutsan" and sub-searched using the terms "invertebrate* or herbivor*". Checklists of NZ fauna were referred to, to determine whether any of the species recorded feeding on/infecting tutsan already occurs in NZ.

Results

Extensive searches of the literature and online databases yielded very few records of organisms attacking tutsan. This could reflect scarcity of herbivores and pathogens attacking tutsan; but it could also reflect lack of interest in tutsan on behalf of entomologists and plant pathologists, and consequently a potential array of agents to discover. All but one of the organisms recorded from tutsan were not specific to this species (see also Groenteman, 2009).

Fungi

Only 10 species of fungi have been reported in association with tutsan (Table 1). One was an endophyte, which does not cause disease symptoms. Five others could not be considered either because their host range is too broad or they are unlikely to be sufficiently damaging.

Four other pathogens may hold some potential as biological control agents. The powdery mildew *Erysiphe hyperici* (Waller.) Fr. attacks various *Hypericum* species, and is troublesome for *H. perforatum* L. where the latter is cultivated for its medicinal values (e.g., Radaitienë et al., 2002). It may be worthwhile investigating whether a virulent tutsan-specific strain exists.

Another powdery mildew, *Leveillula guttiferarum* Golovin, has only been recorded from three *Hypericum* spp. That it has not been recorded from the highly studied *H. perforatum* suggests, perhaps, a relatively narrow host range. There is no information regarding the virulence of this pathogen and, its native range is not well matched to NZ climate.

The brown leaf spot *Diploceras hypericinum* (Ces.) Died. was recorded from tutsan in NZ and Japan, and in the Netherlands in the form of *Pestalotia hypericina* Ccs. It attacks other *Hypericum* species and can cause severe dieback in *H. perforatum*. The virulence of this pathogen to tutsan in NZ is not known, but could relatively easily be tested. In the Netherlands, conditions of nearly 100% relative humidity were necessary to create infection on tutsan in the laboratory (Van Kesteren, 1963) so conditions for natural infection in the field might rarely be met. Developing this pathogen into a bioherbicide is an avenue that could potentially be explored to overcome this limitation; however, this is an expensive pathway, unlikely to be economically viable for tutsan.

Finally, the rust *M. hypericorum* was the most common species recorded from tutsan, including in NZ. *M. hypericorum* was first recorded in NZ in 1952 (Baker, 1955). It is unclear how the fungus has arrived here, and its effectiveness in controlling tutsan is variable (Baker, 1955; Whatman, 1967).

M. hypericorum is also found in Australia, first recorded in Victoria in 1991. By 1992 it had already shown phenomenal potential as a biocontrol agent of tutsan (Bruzzese and Pascoe, 1992). Once a very common and invasive weed in south-western Victoria, by 1997 tutsan was difficult to find in that region, resulting in "possibly the most spectacularly successful example of weed biocontrol ever witnessed in Victoria" (McLaren et al., 1997).

Further attempts to use the rust as a biocontrol agent had mixed results: genetic variation between tutsan populations suggested intrinsic resistance, and various rust isolates varied in virulence (Casonato et al., 1999).

The findings from Australia highlight the importance of compatibility between genotypes and strains of fungal pathogens and their weedy hosts, and suggest that as part of a biological control programme against tutsan in NZ it should be determined what strains of tutsan and *M. hypericorum* are present here and how they compare to those known from Australia. The hypothesis that observed variation in the impact of the rust against tutsan is attributed to genetic variability of the weed, the rust, or both should be examined. In addition, if rust strains from Australia are absent from NZ, their virulence against NZ tutsan should be tested.

Arthropods

Only nine species of insects have been recorded from tutsan, four of which can be immediately precluded as potential agents due the breadth of their host range (Table 2).

The remaining five insect species are oligophagous, but restricted to the genus *Hypericum*. Four of these species are chrysomelid beetles, two of which, *Chrysolina quadrigemina* Suffrian and *Chrysolina hyperici* Forster, are well established in NZ and their performance on tutsan is poor. *Chrysolina varians* Schaller failed to establish in Australia and North America as a biological control agent against *H. perforatum* (Currie and Garthside, 1932; Currie and Fyfe, 1938; Coombs et al., 2004). San Vicente (2005) mentions tutsan and as host of *C. varians* in Spain, yet does not explicitly treat *H. perforatum* as a host. Whether the Spanish *C. varians* is a biotype adapted to tutsan is perhaps an avenue to pursue. Lastly, *Cryptocephalus moraei* L. thrives on *H. perforatum* but not on tutsan (Tillyard, 1927).

Concluding remarks

Available information about prospective biological control agents for tutsan is slim, and makes it difficult to assess the prospects of successful biological control at this time. However, it is clear that tutsan has never been the target of any extensive surveys, and it is possible that a suite of potentially useful agents would be discovered should such a survey take place.

The genus *Hypericum* has four indigenous representatives in NZ, therefore highly specific agents are likely to be required.

Opposition to biological control of tutsan is unlikely. It is not grown here for medicinal purposes, nor is it highly valued as a garden plant. It is highly unpalatable to stock and therefore not valued for fodder, nor is it valued for beekeeping.

In a significant part of its range in NZ, tutsan is a problem on terrain where mechanical and chemical control methods are impractical. Therefore, bioherbicides are not likely to be a practical (or economic) solution and are not recommended as an avenue of future research for this weed.

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References

Baker, S. D. (1955) Note on tutsan rust in New Zealand. New Zealand Journal of Science and Technology Section A **36,** 483–484.

Biological Records Centre (BRC) (2009) Database of Insects and their Food Plants. Accessed: 05 Mar 2009.

Bruzzese, E. & Pascoe, I. G. (1992) *Melampsora hypericorum*, a rust fungus with potential in the biological control of tutsan, *Hypericum androsaemum*. In Proceedings of the First Weed Control Congress (eds J. H. Combellack & R. G. Richardson), pp. 101–102 Weed Science Society of Victoria, Melbourne.

CABI Bioscience (2006) IMI fungal herbarium Accessed: 05 Mar 2009.

Casonato, S. G., Lawrie, A. C. & McLaren, D. A. (1999) Biological control of *Hypericum androsaemum* with *Melampsora hypericorum*. In Proceedings of the 12th Australian Weeds Conference (eds A. C. Bishop, M. Boersma & C. D. Barnes), pp. 339–342 Tasmanian Weed Society Publishing, Hobart, Tasmania, Australia.

Coombs, E. M., Clark, J. K., Piper, G. L. & Cofrancesco Jr, A. F. (eds), (2004) Biological Control of Invasive Plants in the United States. Oregon State University Press, Corvallis, OR. 467 pp.

Cooper, J. (2006) The fungal records database of Britain and Ireland (FRDBI). Accessed: 05 Mar 2009.

Currie, G. & Garthside, S. (1932) The Possibility of the Entomological Control of St. John's Wort in Australia: Progress Report. Melbourne, Australia 28 pp.

Currie, G. A. & Fyfe, R. V. (1938) The fate of certain European insects introduced into Australia for the control of weeds. Journal of the Council for Scientific and Industrial Research **11,** 289–301.

Davis, P. H. (ed) (1967) Flora of Turkey and the East Aegean Islands. Edinburgh University Press, Edinburgh.

Global Biodiversity Information Facility (2009) GBIF. Accessed: 07 Mar 2009.

Groenteman, R., (2009) Prospects for biological control of tutsan (*Hypericum androsaemum* L.). contract report, Landcare Research, Lincoln, New Zealand. 25 pp.

Groenteman, R., Fowler, S. V. & Sullivan, J. J. (2011) St. John's wort beetles would not have been introduced to New Zealand now: A retrospective host range test of New Zealand's most successful weed biocontrol agents. Biological Control **57,** 50–-58.

Healy, A. J. (1972) Weedy St. John's worts (*Hypericum* spp.) in New Zealand. Proceedings of the New Zealand Weed and Pest Control Conference **25,** 180–190.

Heenan, P. (2011) Taxonomic notes on the New Zealand flora: *Hypericum gramineum* and *Hypericum involutum* (Hypericaceae). New Zealand Journal of Botany **49**, 133–139.

Heenan, P. B. (2008) Three newly recognised species of *Hypericum* (Clusiaceae) from New Zealand. New Zealand Journal of Botany **46,** 547–558.

Hutchinson, T. C. (1967) Lime-chlorosis as a factor in seedling establishment on calcareous soils. I. A comparative study of species from acidic and calcareous soils in their susceptibility to lime-chlorosis. New Phytologist **66,** 697–705.

Index Fungorum (2004) World database of fungal names. Accessed: 05 Mar 2009.

Julien, M. H. & Griffiths, M. W. (1998) Biological control of weeds: A world catalogue of agents and their target weeds. CABI Publishing, Wallingford, U.K. 223 Pp.

Landcare Research (2009) NZFUNGI - New Zealand Fungi (and Bacteria). Accessed: 07 Mar 2009.

McLaren, D. A., Bruzzese, E. & Pascoe, I. G. (1997) The potential of fungal pathogens to control *Hypericum* species in Australia. Plant Protection Quarterly **12,** 81–83.

Miller, D. (1970) Biological Control of Weeds in New Zealand 1927–48. Department of Scientific and Industrial Research, Wellington.

Natural History Museum London (2007) HOSTS - a Database of the World's Lepidopteran Hostplants. Accessed: 07 Mar 2009.

Olano, J. M., Caballero, I., Laskurain, N. A., Loidi, J. & Escudero, A. (2002) Seed bank spatial pattern in a temperate secondary forest. Journal of Vegetation Science **13,** 775–784.

Owen, S. J. (1997) Ecological weeds on conservation land in New Zealand: a database. Department of Conservation, Wellington, New Zealand.

Radaitienë, D., Kacergius, A. & Radušiene, J. (2002) Fungal diseases of *Hypericum perforatum* L. and

H. maculatum Crantz. in Lithuania. Biologija **1,** 35–37.

San Vicente, I. U. (2005) Coleópteros fitófagos (Insecta: Coleoptera) de los encinares cantábricos de la Reserva de la Biosfera de Urdaibai. A. N. A. N. Elkartea Zapatari, Spain 201 pp.

Sullivan, J. J., Williams, P. A. & Timmins, S. M. (2007) Secondary forest succession differs through naturalised gorse and native kanuka near Wellington and Nelson. New Zealand Journal of Ecology **31,** 22–38.

Sykes, W. R. (1982) Checklist of dicotyledons naturalised in New Zealand 12. Haloragales, Myrtales, Proteales, Theales, Violales (excluding Violaceae). New Zealand Journal of Botany **20,** 73–80.

Thomas, P. (2007) Global Compendium of Weeds Accessed: 05 Mar 2009.

Tillyard, R. J. (1927) Biological Control of St. John's Wort. New Zealand Journal of Agriculture **35,** 42–45 pp.

USDA ARS (2009) GRIN - Germplasm Resources Information Network. Accessed: 09 Apr 2009.

Van Der Veken, S., Bossuyt, B. & Hermy, M. (2004) Climate gradients explain changes in plant community composition of the forest understory: An extrapolation after climate warming. Belgian Journal of Botany **137,** 55–69.

Van Kesteren, H. A. (1963) Leaf spot and bark necroses on *Hypericum* spp. associated with *Festalotia hypericina*. Verslagen van de Plantenziektenkundige Dienst te Wageningen **138,** 187–189.

Webb, C. J., Sykes, W. R., Garnock-Jones, P. J. & Given, D. R. (1988) Flora of New Zealand. Volume IV, Naturalised Pteridophytes, Gymnosperms, Dicotyledons. Botany Division D.S.I.R., Christchurch, N.Z. 1365 Pp.

Whatman, A. (1967) Tutsan - economic control of a problem weed. New Zealand Journal of Agriculture **115,** 24-7.

Table 1. Fungi recorded on tutsan, *Hypericum androsaemum*, and their potential usefulness for biological control.

Phylum Order Family	**Species (and other names)[1]**	**Range on *H. androsaemum*[2]**	**Likely to be damaging?**	**Likely to be host specific? (and comments)**	**Found in New Zealand/ biocontrol potential?**
Ascomycota Botryosphaeriales Botryosphaeriaceae	*Guignardia endophyllicola* Okane, Nakagiri & Tad. Ito	Japan	Endophytic. Does not cause disease symptoms in *H. androsaemum*	No. Recorded from a wide range of hosts from various plant families	Not yet recorded here / No
Ascomycota Erysiphales Erysiphaceae	*Leveillula taurica* (Lév.) G. Arnaud (= *Erysiphe taurica*)	Iran	Insufficient information	No. Attacks multiple genera in multiple families	Yes, exotic / No
Ascomycota Erysiphales Erysiphaceae	*Leveillula guttiferarum* Golovin	Iran	Insufficient information	Possibly genus specific. Two records in FDSM[3]: one from *H. androsemum*, one from *H. helianthemoides*; one record in IF[4] from *H. scabrum*	No / ?
Basidiomycota Pucciniales Melampsoraceae	*Melampsora hypericorum* (DC.) J. Schröt.	UK, Ireland, Scotland, Canada (BC), Australia, Bulgaria, Japan, New Zealand, USSR	Yes. Has been highly successful in controlling *H. androsaemum* in Victoria, Australia. Highly damaging in parts of New Zealand.	Yes, highly specific (to *H. androsaemum* strains). Note that the species had been recorded from various other *Hypericum* spp., including *H. perforatum*; however, the *H. androsaemum* strain failed to infect *H. perforatum* in Australia	Yes, since early 1950s / Offers partial control in some areas
Chromista Oomycota Pythiales Pythiaceae	*Phytophthora cinnamomi* Rands	Japan	Yes, a highly aggressive species	No. Attacks many unrelated woody plant species. Not classified strictly as a fungus anymore, due to a mobile life stage (akin to brown algae). Highly invasive (classified as a 'Key process threatening biodiversity in Australia')	Yes / No!

Phylum Order Family	Species (and other names)[1]	Range on *H. androsaemum*[2]	Likely to be damaging?	Likely to be host specific? (and comments)	Found in New Zealand/ biocontrol potential?
Ascomycota Erysiphales Erysiphaceae	*Erysiphe hyperici* (Wallr.) S. Blumer	England, Scotland	Yes, considered a troublesome disease of *H. perforatum* and gets sprayed with fungicides where the latter is cultivated for its medicinal values. A powdery mildew	Yes, at the genus level. FRDBI[5] has 8 records from *H. androsaemum* but 39 from *H. perforatum* and additional 91 from various other *Hypericum* spp. FDSM has 149 records from various *Hypericum* spp., none from *H. androsaemum*	No / Possibly, if a specific strain is found
Ascomycota Xylariales[6]	*Melomastia mastoidea* (Fr.) J. Schröt.	Ireland	No, saprobe[7]	No, associated with plants from various families	No / No
Ascomycota Xylariales Amphisphaeriaceae	*Diploceras hypericinum* (Ces.) Died. *Pestalotia hypericina* Ces. *Hyaloceras hypericinum* (Ces.) Sacc. *Seimatosporium hypericinum* (Ces.) B. Sutton	Netherlands (as *P. hypericina*), New Zealand, Japan	Causes leaf blight and severe stem dieback in *H. perforatum*. Not virulent to *H. androsaemum* - requires 100% RH post-inoculation to produce symptoms (in the form of *Pestalotia hipericina*). Brown leaf spot	Attacks other *Hypericum* spp. Had been collected from *Fragaria* (strawberry) plants in Canada (as *P. hypericina*)	Found in New Zealand as *D. hypericinum*
Basidiomycota Hymenochaetales Hymenochaetaceae	*Hymenochaete cinnamomea* (Pers.) Bres.	New Zealand	Probably not. Wood rot (attacks dead and decaying wood, but also live wood). Not likely to be very damaging.	No. Attacks hosts from multiple families.	*Yes/No*

Phylum Order Family	Species (and other names)[1]	Range on *H. androsaemum*[2]	Likely to be damaging?	Likely to be host specific? (and comments)	Found in New Zealand/ biocontrol potential?
Ascomycota Hypocreales Monoliniaceae	*Verticillium* sp. Nees [stat. anam.]	New Zealand	Insuffcent information. Plant-pathogenic Verticillium spp. exists in various strains with variation in virulence and host range. They are known to cause severe wilting in susceptible hosts, but no symptoms in tolerant hosts.	Possibly not. Veticillium spp. attack woody hosts of various plant families. A number of Verticillium spp. are listed on the Unwanted Organism register. http://www1.maf.govt.nz/uor/searchframe.htm	Yes/No

[1]Many fungi have more than one Latin name because they can produce more than one type of spore. The name given when they are producing 'sexual' spores is called the teleomorph, whereas the stage producing 'asexual' spores is called the anamorph. The two stages often look completely different. Fungi are classified according to their 'teleomorph' name, unless the 'anamorph' is the only form known. So, Table 1 gives the taxonomy of the teleomorph, but column 2 uses whichever name/names were recorded when the fungus was found on *H. androsaemum*. If a fungus was listed under an out-of-date name (synonym) this is also stated in column 2.

[2]Only the places where the organism was found associated with *H. androsaemum* are listed here. It may also be found elsewhere on other hosts.

[3]FDSM = USDA Fungus-host database at http://nt.ars-grin.gov/fungaldatabases/fungushost/FungusHost.cfm

[4]IF = Index Fungorum, World database of fungal names at http://www.indexfungorum.org/Names/Names.asp

[5]FRDBI = the Fungal Records Database of Britain and Ireland (FRDBI) at http://194.203.77.76/fieldmycology/FRDBI/FRDBI.asp

[6]Insertae sedis = of uncertain taxonomic position within a higher taxonomic order (e.g. Phylum known, but order within that phylum uncertain).

[7]Saprobe: An organism using dead organic material as food and commonly causing its decay (Kirk et al. 2001). Unlikely to cause disease and therefore probably insufficiently damaging to be useful for biocontrol.

Table 2. Records of invertebrates feeding on tutsan *Hypericum androsaemum.*

Order and Family	Species	Type of organism	Range	Likely to be sufficiently host specific?
HEMIPTERA				
Aleyrodidae	*Aleyrodes fragariae* Walker (=lonicerae)	Whitefly	Europe, Northern Asia, Mediterranean Basin	No. Polyphagous. A pest of strawberry.
HETEROPTERA				
Lygaeidae	*Kleidocerys truncatulus* ericae (Walker)	Ground bug	Isle of Wight (UK), Dutch West Frisian Isles (as K. ericae)	No. Feeds on Erica spp. and Calluna spp.
LEPIDOPTERA				
Nepticulidae	*Ectoedemia* (=*Fomoria*) *septembrella* (Stainton)	Leaf mining moth	Palaearctic	Possibly not. Feeds on various *Hypericum* spp. Possibly more common on H. perforatum.
Tortricidae	*Ctenopseustis herana* Felder & Rogenhofer and *C. obliquana* Walker	Leafrollers	New Zealand (endemic), Australia (introduced)	No. Highly polyphagous. Pests of many crops
	Planotortrix excessana Walker and P. Octo Dugdale			
COLEOPTERA				
Chrysomelidae	*Chrysolina varians* (Schaller)	Leaf beetle	Europe (from Spain to West Siberia)	Possibly not. Feeds on various *Hypericum* spp., and more common on H. perforatum. Possibility of an *H. androsaemum* biotype in Spain?
	Cryptocephalus moraei (L.)	Leaf beetle	Europe	Possibly not. Feeds on various Hypericum spp. Does not thrive on *H. androsaemum*
	Chrysolina quadrigemina (Suffrian)	Leaf beetle	From North Africa to Denmark. Introduced to Australia, New Zealand and North America	No. Prefers H. perforatum. Performs poorly on H. androsaemum. Reported feeding on H. involutum (indigenous to Australia and New Zealand) in Australia
	Chrysolina hyperici (Forster)	Leaf beetle	Native to northern and central Europe and western Asia. Introduced to Australia, New Zealand and North America.	No. Prefers H. perforatum. Performs poorly on H. androsaemum