The use of pathogens native to Europe to control thistles in southern Australia

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Summary

Foliar pathogens of European thistles that have become significant weeds in southern Australia are listed and the potential for some of them to be classical biological control agents is discussed. Particular attention is paid to pathogens of slender, variegated and saffron thistles. In the case of the slender thistles, the current status of two recently released strains of *Puccinia cardui-pycnocephali* is presented. Control programs for variegated and saffron thistles are less advanced. Results of recent studies of *P. mariana* in Europe have thrown doubt on its suitability as a control agent for variegated thistle. In contrast, a survey of pathogens on saffron thistle has shown *P. sommeriana* to have some potential for biological control. Several pathogens in Europe may have potential to add to the effectiveness of biological control of certain thistles in southern Australian pastures, but only if their effects can be integrated with other methods of control, including biological control by insects.

Introduction

The CSIRO Divisions of Entomology and Plant Industry have been researching thistle control for over a decade. The program has emphasized classical biological control, using insects and fungi, in relation to the taxonomy and ecology of the major thistle groups as they occur in both Mediterranean Europe and southern Australia. The research has been jointly funded by CSIRO and also, for various periods, by both the International Wool Secretariat and the Meat Research Corporation. The program has been centred both in Canberra and Montpellier, France, the latter being the Mediterranean base of the CSIRO European Laboratory.

This paper reviews progress made on the thistle research program as it relates to:

i. the occurrence of certain foliar pathogens in Mediterranean Europe,
ii. the release in southern Australia of two strains of the pathogen *Puccinia cardui-pycnocephali* for control of the slender thistles *Carduus pycnocephalus* and *C. tenuiflorus*,
iii. the potential of several other pathogens to biologically control populations of variegated thistle (*Silybum marianum*) and saffron thistle (*Carthamus lanatus*) in southern Australia.

We review the foliar pathogens from Europe that are known to attack the introduced thistle groups that are the worst weeds in southern Australian pastures. These include nodding thistle (*Carduus nutans*), the slender thistles (*Carduus pycnocephalus* and *C. tenuiflorus*), Scotch, Illyrian and stemless thistles (*Onopordum acanthium, O. illyricum* and *O. acaulon* respectively), variegated thistle (*Silybum marianum*), spear thistle (*Cirsium vulgare*) and saffron thistle (*Carthamus lanatus*).

Thistle pathogens in Mediterranean Europe

The pathogens which have been recorded for the various thistles are listed in Table 1. This table draws on existing information (S. Hasan personal communication), supplemented by some recent records of pathogens from *Onopordum* and saffron thistle (Groves unpublished). It is obvious that there are many pathogens recorded for thistles in Europe, of which the rusts form the largest group; the rusts are also one of the most specific of all groups of fungi. It is not surprising, therefore, that research on the potential of fungi for biological control has tended to concentrate on the rusts.

Control of the slender thistles by the rust *Puccinia cardui-pycnocephali* in southern Australia

The closely-related taxa *Carduus pycnocephalus* and *C. tenuiflorus* both occur as short-season winter annuals in southern Australian pastures (Parsons 1977, Groves and Kaye 1989). Both species have a wide distribution in Europe and were introduced early to Australia. During this introduction stage, at least one strain of *Puccinia cardui-pycnocephali* was also introduced accidentally, but it has had little effect on the weediness and spread of slender thistle populations throughout southern Australia.

Research on the biological control of the slender thistles has fallen into three phases. The first was conducted at Montpellier, southern France, where the insects and fungi most damaging to populations of the thistles throughout their native range were identified. None of the insect species appeared to limit slender thistle populations (Sheppard *et al.* 1991); however, the rust *P. cardui-pyncocephali* was identified as having the most potential for biological control. Two of a total of 38 isolates of the pathogen collected in four European countries were selected for further testing, based on their capacity to inflict greater damage on accessions of the thistles collected in southern Australia than the relatively benign strain(s) already present in Australia (Chaboudez *et al.* 1993a). These isolates were each virulent on a different species of slender thistle; they reduced height, dry weight and seed production significantly under glasshouse conditions (Table 2) and also in a garden experiment. The specificity of these two aggressive strains (one for *C. tenuiflorus* from Italy and the other for *C. pycnocephalus* from France) was then exhaustively tested to ensure that economically important species (such as artichoke) or species native to Australia were not vulnerable to attack.

Table 1. Fungi recorded on thistles in Mediterranean Europe with potential for biological control (in part from S. Hasan, unpublished).

Fungal species	Known hosts
Ophiobolus cirsii (Sphaeriales)	*Carduus* spp., *Cirsium* spp.
Phyllosticta cirsii (Coelomycetes)	*Cirsium* spp.
Puccinia acanthii	*Onopordum acanthium*, *O. acaulon*
P. cardui-pycnocephali	*Carduus pycnocephalus*, *Carduus tenuiflorus*
P. carduorum	*Carduus* spp. (incl. *nutans*)
P. carthami	*Carthamus* spp.
P. cirsii	*Cirsium* spp.
P. cnici	*Cirsium* spp.
P. cruchetiana	*Silybum marianum*
P. mariana	*Silybum marianum*
P. sommieriana (Uredinales)	*Carthamus lanatus*
Ramularia cardui	*Carduus* spp.
R. cirsii	*Cirsium vulgare*
R. onopordi (Hyphomycetes)	*Onopordum acanthium*
Septoria cardui	*Carduus nutans*
Septoria centrophylla	*Carthamus* spp.
Septoria cirsii	*Cirsium* spp.
Septoria onopordonis	*Onopordum* spp.
Septoria silybi (Coelomycetes)	*Silybum marianum*
Ustilago cardui	*Carduus* spp., *Cirsium* spp., *Silybum marianum*
U. onopordi (Ustilaginales)	*Onopordum* spp.

The second phase of the program began in 1992 with the granting of quarantine approval to introduce pathogen isolates into high security quarantine facilities on the CSIRO Black Mountain site, Canberra. Host specificity was tested on a total of 46 species, and in September 1993 permission was jointly obtained from the Australian Quarantine and Inspection Service and the Australian Nature Conservation Agency to make field releases (Chaboudez *et al.* 1993b).

The third phase of the project focused on field releases of the rust and the continuous generation of inoculum in the glasshouse to cope with the demand for spores from co-operating agencies and collaborators. Field releases were made subsequently in all southern Australian States, albeit at a time of severe drought in the region. Once the drought broke (in autumn 1995), monitored releases in southern New South Wales showed good pathogen establishment and spread to uninoculated thistle stands more than 800 m away. At this site disease levels failed to build up sufficiently quickly to prevent normal growth or to reduce seeding of infected plants. However, verbal reports suggest that, at some release sites in south-western Victoria, the rust has established well, has spread by as much as 20 km and has reduced plant vigour and seeding. Although funding for the project has formally ceased, new releases continue to be made through Landcare groups and other collaborators.

We conclude that, except in particularly favourable localities, the main contribution of the recent release of the two strains of this pathogen will be through a general reduction in the vigour and seed production of the two slender thistle taxa known to occur in southern Australia.

Is *Puccinia mariana* a potential biological control agent for variegated thistle in southern Australia?

Variegated thistle (*Silybum marianum)* is widely distributed in Mediterranean Europe and north Africa, where it occurs primarily on disturbed and nutrient-enriched land. The species has been introduced to other regions with a Mediterranean climate, such as California, Chile and southern Australia where it is a weed of grazing lands.

While based at the CSIRO European Laboratory, Montpellier, Groves investigated populations of variegated thistle in Spain and southern France for the incidence of the pathogens listed in Table 1, especially *Puccinia mariana.* We considered that the effects of this rust may complement those of a host-specific strain of the seed-eating weevil *Rhinocyllus conicus*, which had already been introduced to California (Goeden and Ricker 1977) and for which several attempts at introduction have been made in Victoria (Bruzzese 1996).

At one site in southern Spain, a rust was found on both variegated thistle and on *Notobasis syriaca*, an annual thistle similar to and co-occurring with variegated thistle at the site. This fungus, tentatively identified as *Puccinia notobasidi*, was able to infect variegated thistle seedlings in the field and the glasshouse, but always at a level insufficient to control seeding. Spores were not carried over from one season to the next. In an annual species such as variegated thistle, seeding must be significantly reduced and year-to-year survival of the spores must occur if biological control is to be at all effective.

Table 2. Effect of *Puccinia cardui-pycnocephali* infection on plant height (cm), dry weight (g) and production of viable seeds of the slender thistles, *Carduus pycnocephalus* and *C. tenuiflorus* (from Chaboudez *et al.* 1993).

	Control	Inoculated
C. pycnocephalus (*n*=20)		
Height	87.3 ± 4.5	38.8 ± 2.7
Dry weight	19.4 ± 1.1	11.3 ± 0.8
Seed production	174 ± 23	32 ± 10
C. tenuiflorus (*n*=21)		
Height	52.9 ± 3.7	25.4 ± 4.0
Dry weight	16.9 ± 0.8	7.3 ± 0.6
Seed production	84 ± 12	21 ± 8

Means + standard errors are presented. All pairwise means differ at the 1% level, based on one-way ANOVA.

Subsequently, a further two isolates of the fungus were obtained—one from *N. syriaca* from Turkey, and one from *S. marianum* from Greece—but the same result was obtained (Hasan and Groves unpublished). The same fungus was also consistently ineffective on seedlings of *S. eburneum*, the only other species known in the genus. It is concluded that *P. mariana* may be a strain of the wider taxon *P. notobasidi*. The two fungal taxa are most likely two extremes of the one species, despite having been given different names, probably because of the two different hosts on which they have been recorded. On the basis of results of our pathogenicity tests, the taxon *P. mariana* may represent a less aggressive strain of *P. notobasidi.* The two *Puccinia* species are separated on the basis of spore size. More collections are needed to determine dimensions of spores collected from the two hosts over a range of site conditions. In conclusion, the chances of finding a strain of this fungus suitable for biological control of variegated thistle in regions such as southern Australia are slight.

A second fungus, *Septoria silybi* (Table 1), also occurs commonly on variegated thistle in Europe as well as in California and southern Victoria, where it was apparently accidentally introduced. The fungus commonly occurs on older rosette leaves only. Consequently, it hastens leaf senescence, but has little effect on plant growth or seed production (Moscow and Lindow 1989). Thus, it does not seem a suitable candidate for biological control of variegated thistle.

Is control of *Carthamus lanatus* by fungi possible?

Saffron thistle (*Carthamus lanatus)* is closely related to the crop congener, safflower (*C. tinctorius).* It is the thistle that will be most difficult (and / or most expensive) to control biologically because of its close taxonomic affinity to an economically important crop in Australia. Furthermore, surveys over a number of years in France and Spain of the entomofauna associated with both safflower and saffron thistle have yielded only one record of a sufficiently host-specific arthropod that may be able to control the weed species without affecting in some way the crop species (J-P. Aeschlimann personal communication). The effectiveness of this insect (*Botanophilla turcica*, a crown fly) is being tested currently (J. Vitou personal communication). Whilst the rust fungi are sometimes highly specific to taxonomic variants of a host, no strain of *Puccinia carthami* (Table 1) has yet been identified which is specific to the weedy species. Are there other fungi that may fill this apparent gap?

The result of a recent survey commissioned by CSIRO (Evans, 1995) shows that *Puccinia sommieriana* may fulfil some of the requirements of a potential biological control agent for saffron thistle. Evans surveyed sites in southern Greece where the two recognised subspecies of saffron thistle and their hybrids overlap at a time when this annual thistle was present mainly as a rosette. Evidence of damage to young rosette leaves of saffron thistle as a result of infection by *P. sommieriana* was found, despite this taxon not being listed among the fungi recorded from Greece. Little is known about the biology of this pathogen and its biology, especially its possible effect on reduction of seeding.

Evans also found *Septoria centrophylla* to be damaging on saffron thistle in Greece, although he considered 'that the actual host range may turn out to be wider than that of the rust *Puccinia sommieriana*' (Evans 1995). These two pathogens seem to be the only possible candidates from Europe for biological control against saffron thistle in Australia. Given our limited knowledge of pathogen biology and the economic importance of saffron thistle, these pathogens warrant further study.

Conclusions

Host-specific fungal pathogens occurring in Europe may be effective biological agents that contribute to the control of at least some of the major thistles introduced to southern Australia. Slender thistle growth in Mediterranean Europe was more limited by the incidence of the rust than it was by the occurrence of more than 20 species of insects (Sheppard *et al.* 1991). Though it is still too early to predict the effectiveness of two strains of that same fungus on slender thistle populations in southern Australia, it seems probable that release of the rust will be insufficient on its own to control seeding of these annual thistles in any but the most favourable of environments. Such a conclusion may apply even more appropriately to the control of other thistle species.

Bendall (1973) found that a deferral of autumn grazing of pasture containing slender thistle was an effective control method, a result subsequently shown for some other thistles in pasture in other situations. A combination of deferred autumn-early winter grazing with application of an appropriate level of herbicide in early spring may achieve a greater level of control. If such a combined treatment is compatible with the continued effects of rust infection and the establishment of perennial pasture grasses, then even further control may be achieved and the weediness of at least one group of thistles reduced thereby. The challenge to research is to demonstrate the effectiveness of such integrated control methods in the field not only for slender thistle but also for other thistle groups with either annual or biennial life-cycles.

In conclusion, there is a role for imported fungal pathogens in thistle control, but only in an integrated weed management system. Pathogens operating in isolation are likely to be ineffective at controlling thistle populations in southern Australia.

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References

Bendall, GM. (1973). The control of slender thistle, *Carduus pycnocephalus* L. and *C. tenuiflorus* Curt. (Compositae), in pasture by grazing management. *Australian Journal of Agricultural Research* 24, 831-7.

Bruzzese, E. (1996). Ecology of *Cirsium vulgare* and *Silybum marianum* in relation to biological control. *Plant Protection Quarterly* 11, 245-9.

Chaboudez, P., Groves, R.H. and Burdon, J.J. (1993a). *Puccinia cardui-pycnocephali*, a potential agent for the biological control of slender thistles in Australia. Proceedings of the 10th Australian Weeds Conference, Volume 1, pp. 84-8.

Chaboudez, P., Burdon, J.J. and Groves, R.H. (1993b). Application for release of two strains of *Puccinia cardui-pycnocephali*, a rust fungus for the classical biological control of the noxious slender thistle weeds, *Carduus pycnocephalus* and *C. tenuiflorus.* CSIRO Division of Plant Industry, Internal Report, 13 pp.

Evans, H.C. (1995). Report on a survey for fungal pathogens of *Carthamus lanatus* (saffron thistle) in Greece. Report of Project CAR010, International Institute of Biological Control, Ascot, UK, pp. 1-4.

Goeden, R.D. and Ricker, D.W. (1977). Establishment of *Rhinocyllus conicus* on milk thistle in southern California. *Weed Science* 25, 288-92.

Groves, R.H. and Kaye, P.E. (1989). Germination and phenology of seven introduced thistle species in southern Australia. *Australian Journal of Botany* 37, 351-9.

Moscow, D. and Lindow, S.E. (1989). Infection of milk thistle (*Silybum marianum*) leaves by *Septoria silybi. Phytopathology* 79, 1085-90.

Parsons, W.T. (1977). The ecology and physiology of two species of *Carduus* as weeds of pastures in Victoria. Ph.D. thesis, University of Melbourne.

Sheppard, A.W., Aeschlimann, J-P., Sagliocco, J-L. and Vitou, J. (1991). Natural enemies and population stability of the winter-annual *Carduus pycnocephalus* L. in Mediterranean Europe. *Acta Oecologica* 12, 707-26.