Invasive willows in Australia: could they be targets for biological control?

Jean Louis Sagliocco[1] and Eligio Bruzzese[1,2]
[1] Keith Turnbull Research Institute, Department of Natural Resources and Environment, PO Box 48, Frankston, Victoria 3199, Australia
[2] CRC Australian Weed Management

Summary Willows are trees and shrubs native to the northern hemisphere and invasive in Australia. The national strategic plan on willow management considers biological control as a cost-effective method with considerable potential. To assess the potential for biological control, a literature search has examined the organisms recorded on the six most invasive taxa. This literature search has revealed that over three hundred organisms are specific to the targeted taxa and could be considered as potential biological control agents.
Keywords *Salix*, willows, biological control, Australia.

INTRODUCTION

Willows (*Salix* spp., Salicaceae) are dioecious, deciduous trees and shrubs principally native to the northern hemisphere, originally introduced into Australia for basket-making, cricket-bat production, stream stabilisation, as ornamental trees or for shelter. Today in Australia, over 45 taxa are available in the nursery trade and thirty-one taxa are currently naturalised in permanently or seasonally wet, waterlogged sites mostly in Victoria, Tasmania and New South Wales, with minor occurrences in Queensland, South Australia and Western Australia. With the exception of *Salix babylonica*, *S.* × *calodendron* and *S.* × *reichardtii*, willows are listed as Weeds of National Significance. Willows cause water degradation and loss of biodiversity. Management along waterways by mechanical and chemical methods has been estimated at $5 million annually. Among the naturalised taxa, six are considered as particularly invasive: *Salix cinerea*, *S. alba* var. *vitellina*, *S. fragilis* var. *fragilis*, *S. rubens*, *S. nigra* and *S. viminalis*. It is considered that their potential for spread is far beyond their current distribution. The national strategic plan on willow management (ARMCANZ 2001) has identified biological control as potentially the most cost-effective control method for invasive willows and a method with considerable potential as part of an integrated management strategy for these riparian weeds.

The targeting of weedy willows for biological suppression in Australia presents a number of challenges that lead to different options.

These challenges are:

a) Conflicts of interest through the need to protect three desirable willow taxa (*S. babylonica*, *S.* × *calodendron* and *S.* × *reichardtii*), some of which are hybrids of important targeted weedy willows. For example, *S.* × *calodendron* is an hybrid of *S. cinerea* × *S. viminalis* × *S. purpurea* while *S.* × *reichardtii* is the result of hybridisation of *S. cinerea* and *S. caprea.*
b) The large number of weedy taxa, some of which are hybrids where the exact parentage needs to be established. Sexual reproduction is currently producing 'Australian' taxa of willows not found elsewhere in the world.
c) The need to target a small number of widespread willow taxa in the first instance, instead of targeting all the weedy species.
d) The fact that some weedy taxa originated in Eurasia while others originated in North America causing the need to select natural enemies over large areas of the northern hemisphere.

Protocols on the implementation of a biological control program, administered by the Australian Weeds Committee, the Australian Quarantine and Inspection Service (AQIS) and Environment Australia (EA) would have to be followed throughout the program. Initially, the taxa of targeted willows will have to be nominated as targets for biological control through the Australian Weeds Committee to identify potential conflicts of interest. Such conflicts are likely to be identified because of the need to protect ornamental willows and the fact that the community has a low awareness of the impact of weedy willows. It is therefore likely that willows will have to be declared as targets for biological control under the *Commonwealth Biological Control Act* 1984.

In addition, protocols on the importation, testing and release of biological control agents administered by AQIS and EA will have to be followed for each candidate agent imported.

MATERIALS AND METHODS

A literature search concentrated on the six most invasive *Salix* taxa was conducted using electronic databases (CAB abstracts, Agricola, Australian Plant Disease Collection) and floras and faunas reference works published. Several thousand references were examined and organisms already recorded attacking the three desirable *Salix* taxa (*Salix babylonica*,

S. × *calodendron* and *S.* × *reichardtii*) were excluded from the results.

RESULTS

Organisms recorded on *Salix* spp. in Australia Literature and databases revealed that one bacterium, 51 fungal pathogens and two nematodes are already present on *Salix* species in Australia. The recent establishment of two exotic sawfly species, *Pontania proxima* (Lepeletier) on *Salix fragilis* in Tasmania and *Amauronematus viduatus* (Zetterstedt) (Hymenoptera: Tenthredinidae) on *Salix babylonica* in NSW has recently been confirmed (Naumann *et al*. 2002).

Organisms recorded on targeted *Salix* spp. in their region of origin

Fungi Forty-five species of fungi have been recorded attacking *Salix* spp. in the northern hemisphere including leaf and stem spots, cankers, blights, a powdery mildew and several rust species (Table 1). A number of *Melampsora* rust fungi are recorded, some of which are known to have no alternate hosts (e.g. *M. amygdalina*). These should be considered only after the taxonomic situation with *Melampsora* rusts in Australia is clarified.

Nematodes The willow cyst nematode, *Heterodera salixophila* Kirjanova, has been recorded on a range of willow species in Estonia (Krall and Krall 1971), but not much information on its impact is available.

Acari Thirty-nine species of acari (36 Eriophyidae and three Tetranychidae) are reported attacking the targeted species in Europe and North America (Table 1).

Insects 252 species of insects from six orders and 19 families are also recorded in the literature and some are considered as having strong potential for the biological control of willows in Australia (Table 1).

Table 1. Organisms, by Order and Family, recorded in the regions of origin of *Salix* spp.

Organisms	No. of species	Region of origin	Plant association
Fungi	45	E, A, NA	l, st, sh
Nematodes	1	E	r
Acari			
Eriophyidae	36	E, NA	l, b, c
Tetranychidae	3	NA, A	u
Homoptera			
Cicadellidae	14	E, NA, EA	l
Deltocephalidae	1	J	l
Triozidae	28	E, EA, NA	l
Psyllidae	35	EA	l, c
Aleyrodidae	2	E, fUSSR	l
Aphididae	30	E, NA, A	l, t, tw
Coccoidae	2	fUSSR, C	l
Thysanoptera			
Thripidae	4	EA	l
Coleoptera			
Chrysomelidae	2	E	l
Curculionidae	1	E	c
Diptera			
Cecidomyiidae	36	E, NA	b, st
Lepidoptera			
Gracillariidae	6	E	l
Nepticulidae	5	E	l
Sesiidae	3	E, P	st
Noctuidae	4	E, EA	sh, l, c
Notodontidae	1	EA	l
Hymenoptera			
Tenthredinidae	78	E, EA, NA	l
Total	337		

A = Asia, E = Europe, EA = Eurasia, fUSSR = former USSR, J = Japan, NA = North America, b = buds, c = catkins, l = leaves, r = roots, sh = shoots, st = stems, t = trunk, tw = twigs, u = unknown.

DISCUSSION

The review of literature and databases (Sagliocco and Bruzzese 2001) has identified a large flora of willow-specific pathogens already present in Australia while the knowledge on willow-specific arthropod fauna in Australia is practically non existent. At the same time, the literature has allowed to identify in the areas of origin of willows, a large number of insects and mites and additional fungal pathogens that have potential as candidate biological control agents.

This feasibility study has identified that a large number of candidate natural enemies of the targeted weedy willows are available in Europe and North America. Insect species have been identified that will allow:

1) the direct targeting of the sexual reproduction of willows through the attack of male and female flowers,
2) the indirect targeting of sexual and clonal reproduction by weakening trees through destruction of buds, defoliation early in the season and the use of galls as energy sinks, and

3) the reduction of current biomass by attack on buds, leaves and stems.

Biological control of willows has enormous scope as no members of the willow family (Salicaceae) are native to Australia. An Australian program on biological control of willows would by necessity have to have the long-term plan due to the complexity of the target, and the need to protect desirable willow taxa. Experience with other biological control programs in Australia indicates that a conservative estimate of the research phase of the program is a period of 9–12 years. An extended survey and selection phase overseas in Eurasia and North America will be necessary. This would allow the simultaneous selection of several natural enemies in the areas of origin, their study to determine their host specificity and their release and establishment.

Additional studies to determine the host range and impact of the three *Melampsora* rust fungi already recorded on willows in Australia is recommended. This is required to decide whether additional rust species or pathotypes should be introduced into Australia.

Although biological control of willows has never been attempted elsewhere in the world, the potential for success of a biological control program can be ranked as high, if we follow the criteria listed by Peschken and McClay (1992):

- The number of known promising biological control agents is high.
- Willows are weeds growing in relatively undisturbed habitats which would assist the establishment of candidate biological control agents.
- There are very few economic species in the same genus, although conflicts of interest over the targeting of willows is likely to occur.
- There are no native species in the same genus present in Australia.
- The geographic area of origin of willows is very large allowing for the selection of appropriate biotypes of candidate biological control agents.

Biological suppression has a specific role in integrated weed management plans (Bruzzese 1993). It is most successfully targeted at widespread, dense infestations of weeds that have a longer-term priority for management due to the high cost of immediate control or the inaccessibility of infestations. Biological suppression does not lead to eradication of the target weed, but over time, the infestations are reduced to a more acceptable level, or to a level where they can be further reduced by chemical and cultural techniques.

ACKNOWLEDGMENTS

This study was funded by the following Victorian Catchment Management Authorities: Corangamite, East Gippsland, Glenelg Hopkins, Goulburn Broken, North Central, North East, West Gippsland, and Melbourne Water and the Department of Natural Resources and Environment, Victoria.

REFERENCES

ARMCANZ, ANZECC and Forestry Ministers (2001). Weeds of National Significance, Willows (*Salix* taxa excluding *S. babylonica*, *S.* × *calodendron* and *S. reichardtii*) Strategic Plan. Launceston, Agriculture and Resource Management Council of Australia and New Zealand, Australian and New Zealand Environment and Conservation Council and Forestry Ministers, National Weeds Strategy Executive Committee, Launceston.

Bruzzese, E. (1993). The role of biological control in weed management – what is success*? Plant Protection Quarterly* 8, 147-150.

Krall, E. and Krall, H. (1971). The willow cyst nematode (*Heterodera salixophila* Kirjanova) in Estonia, *Faunistilisi Markmeid* 1 (4-5), 285-287.

Naumann, I., Williams, M.A. and Schmidt, S. (2002). Synopsis of the Tenthredinidae (Hymenoptera) in Australia, including two newly recorded, introduced sawfly species associated with willows (*Salix* spp.), *Australian Journal of Entomology* 41, 1-6.

Peschken, D.P. and McClay, A.S. (1992). Picking the target: A revision of McClay's scoring system to determine the suitability of a weed for classical biological control. Proceedings of the Eight International Symposium on Biological Control of Weeds, 2–7 February 1992, Lincoln University, Canterbury, New Zealand, DSIR/CSIRO Melbourne (1995).

Sagliocco, J.L. and Bruzzese, E. (2001). Biological control of (*Salix* spp.) in Australia, a feasibility study. Unpublished report, 63 pp.