Blackberry: treading a prickly path to effective biological control in Australia

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Summary European blackberry taxa (*Rubus fruticosus* L. agg.) are a major threat to natural and agricultural ecosystems in Australia. Biocontrol has achieved some advances in their suppression, but greater impacts are required particularly in low light and moisture-stressed habitats. Organisms attacking crowns and primocanes are likely to have greater impact on infestation characteristics. Primocane damage should occur early in the growth season for maximum impact. The planned development of commercial berry fruit cultivars resistant to biocontrol agents would vastly improve biological control prospects of blackberry in Australia.

Keywords Blackberry, *Rubus fruticosus*, *Phragmidium violaceum*, biological control.

INTRODUCTION

In Australia, European Blackberry species consist of a complex aggregate of closely allied taxa (Evans *et al.* 2004), which collectively have invaded around 8.8 million hectares (Page and Lacey 2006), mostly in south-eastern Australia. Blackberries are weeds of natural ecosystems, particularly riparian habitats, and high-rainfall forests and cause a reduction in biodiversity and recreational values. In agricultural ecosystems, blackberries reduce grazing capacity, hinder access and provide habitat for noxious animals. In 1984, economic losses due to blackberry in Australia were estimated at $42 million per annum, but losses had increased to around $70 million per annum by 1990 (Page and Lacey 2006). The large-scale distribution, difficulties associated with control and substantial economic losses caused by invasions of *R. fruticosus*, designate European blackberry as a Weed of National Significance (WoNS).

In accessible areas, blackberry can be effectively suppressed by a range of herbicide options, particularly when integrated with pasture renovation and managed grazing regimes (Amor *et al*. 1998). However, control costs can be high ($10–$250 ha^{-1}), require regular maintenance, and have limited application in areas of native vegetation where the risk of non-target damage is high. As a consequence, large areas of blackberry, particularly in native vegetation and rugged terrain remain untreated in Australia.

A biological control program for blackberry commenced in the 1970s where the blackberry rust fungus (*Phragmidium violaceum* (Schultz) Winter) and other agents were investigated for suitability for release in Australia (Amor *et al*. 1998). In 1984, *P. violaceum* was first detected in West Gippsland, Victoria, most likely the result of an illegal introduction (Marks *et al.* 1984). However, in 1991, after resolution of conflicts of interest with proponents of the apiary and berry industries, the F15 strain of *P. violaceum,* selected for virulence against *R. anglocandicans* Newton (= *R. procerus*) was legally released. Six years after the introduction of the F15 strain, DNA fingerprinting of *P. violaceum*, failed to detect the genotype of F15 in eastern Australia, although a descendent of F15 appears to be present on blackberry in southwest Western Australia (Gomez *et al.* 2006). In 2004, eight additional selections of *P. violaceum*, isolated from Australian-derived *R. fruticosus* and infected naturally in French trap gardens, were released in Australia after host-specificity evaluation (Morin 2006). The establishment of new isolates of *P. violaceum* is expected to enhance the biological suppression of blackberry in Australia by broadening the genetic base of *P. violaceum* and facilitating the evolution of new Australian pathotypes that may cause greater defoliation to more blackberry taxa.

This paper examines the impact of the current biological program for European blackberry in Australia, considers whether additional agents may be warranted, and discusses issues associated with future expansion of biological control.

IMPACT OF BIOLOGICAL CONTROL

Few quantitative data are available documenting the impact of *P. violaceum* in Australia. However, in a high-rainfall region of Victoria, *R. polyanthemus* Lindeb. and a form of *R. leucostachys* Schleich. ex Sm. showed a 56% and 38% reduction in total biomass, respectively, and a 96% reduction in daughter plant production after 10 years of rust infection (Mahr and Bruzzese 1998). No data are available for *R. anglocandicans*, the most problematic blackberry species in southern Australia, although preliminary data from a fungicide-exclusion trial replicated across an environmental gradient in Victoria, indicates *P. violaceum* has a significant impact on light penetration, canopy luxuriance and cane vigour in some seasons (Adair, unpublished data).

Climatic and ecological constraints restrict the impact of *P. violaceum* in Australia to regions with high annual rainfall and mild daily summer temperatures (Piggot *et al*. 2003). Based on direct observation, the greatest impact of *P. violaceum* occurs in large infestations receiving full-sun, while blackberry in shaded habitats and those experiencing temperature or moisture stress during summer, appear to be weakly affected. Introduction of new selections of blackberry rust is unlikely to increase efficacy in shaded or stressed habitats, leaving vast areas of Australia prone to the impacts of blackberry invasions. Hence, we explore expansion of the biocontrol program for blackberry, and examine criteria that could be used to define a successful program against this weed.

SUCCESSFUL BIOLOGICAL CONTROL OF BLACKBERRY

We propose that three basic components are involved in a successful biocontrol program for blackberry: impact on life history attributes of the host, impact on habitat range of the host, and reliability or durability of impact effects over seasonal variation in climate.

Life history attributes Blackberry taxa vary considerably in infestation characteristics, with 108 crowns m^{-2} and 50–80 canes m^{-2} for *R. leucostachys*, to 1–18 crowns m^{-2} and 10–15 canes m^{-2} for *R. anglocandicans* (Amor 1971, Bruzzese 1998). Cane length varies from 1.5–7 m (Amor *et al*. 1998) depending on the species. Reduction in crown and cane density, and cane length to a level where movement by stock, large native mammals and humans is possible, would contribute significantly to a successful biocontrol program. This could be defined generally by crown densities to less than 1 m^{-2}, cane lengths to an average of less than 1 metre, and no more than two canes per crown. By reduction of cane and crown dimensions, light penetration to the ground stratum should increase, but the minimum light intensities required for the establishment of desirable vegetation, particularly in native plant communities is not well known.

Asexual reproduction by formation of daughter-plants on primocane stem apices in autumn contributes substantially to the lateral expansion of blackberry thickets and high crown densities within infestations. Suppression of daughter plant production constitutes an important element of successful biocontrol. Significant reduction has been achieved by *P. violaceum* in some taxa in some areas, but larger-scale impacts are required. Although sexual and agamous reproduction leads to seed production, seedlings are prone to competition and contribute little to thicket development apart from long-distance seed dispersal. Direct biological control of seed production is unlikely to be accepted in Australia because of brambleberry harvesting industries in Victoria, New South Wales and Tasmania, even though the industry benefit:invasion cost ratio is in the order of 0.08:0.1 (Page and Lacey 2006, ARGA 2000).

Habitat range Blackberry occupies a broad range of habitats and climatic zones within southern Australia, but predominantly those in the higher rainfall (>760 mm) districts of south-eastern Australia (Amor *et al*. 1998). Infestations occur both in open and frequently disturbed agricultural habitats and relatively intact natural ecosystems with closed over-storey canopies. Habitat parameters vary enormously within the plants distribution. However, effective biological control of blackberry, by necessity, should operate across the range of habitats in which the weed occurs, particularly where infestations are most severe. While *P. violaceum* is effective in regions with high summer rainfall and moderate temperatures, substantial areas of blackberry in low summer rainfall regions, shaded habitats, and high altitude areas are unaffected by the fungus.

Reliability of impact Blackberry is a robust plant capable of strong seasonal growth. Therefore, effective biocontrol will require persistent action by agents both within and between seasons. Agents strongly or regularly influenced by climatic or ecological variables, such as rainfall or parasitism, may allow the host opportunities to secure the resources required to retain a competitive position in the environment, and thus maintain 'weedy' characteristics. As the distribution of blackberry in Australia encompasses a broad range of habitats, it is unlikely a single agent will be capable of exerting sufficient pressure in all situations to provide effective control. *P. violaceum* can cause severe defoliation of blackberry, but this only occurs when climatic conditions are favourable to extended growth of the host and therefore increased asexual reproductive cycles of the fungus. This occurs in 50% or less of seasons in south-eastern Australia (Page and Lacey 2006, pers. obs.).

ACHIEVING EFFECTIVE BIOCONTROL

We propose that effective biological suppression of blackberry will require the introduction of additional species of agents that directly or indirectly impact on the growth of young primocanes and of crowns. Now that the blackberry industry has observed the safety of the rust biocontrol program and that environmental stewardship is integral to commercial production, the industry is likely to work with weed biocontrollers to achieve benefits nationally.

Crown-damaging organisms are likely to affect the growth and reproduction of blackberry, as crowns are the only perennial biomass of the plant, and a sink for nutrients during the growth season. Agents that cause significant crown damage are also likely to impact on primocane and floricane vigour. Agents acting directly on primocanes are also likely to contribute to successful suppression as these stems form the framework of the blackberry canopy, lead to floricane production in subsequent seasons, and are the vector for the development of daughter plants. Agents that deform primocane meristems, particularly by the formation of galls, are likely to have significant indirect effects on crown development and thus could affect infestation characteristics.

In Europe, 144 phytophagous organisms are known to be associated with blackberry, including generalist and oligophagous feeders, but few species are restricted to blackberry taxa from Australia (Amor *et al*. 1998). A recent reassessment of biological agents for Australian blackberry identified several organisms with potential for control. These include the leaf-deforming eriophyid mite *Eriophyes rubicolens* (Canestrini), the primocane-mining cephid *Hartigia albomaculata* (Stein) and the stem-girdling anthracnose fungus *Septocyta ruborum* (Lib.) Petr. If these organisms are host-specific, they may cause sufficient damage to invasive blackberry (Sagliocco and Bruzzese 2004). Buprestrids associated with blackberry in Europe are known (Niehuis 1999), but remain a difficult group because of problems associated with their detection, life-cycle, rearing requirements and taxonomy. Their potential for control of blackberry in Australia could not be fully assessed, despite two short surveys in southern Europe focusing on crown and root-dwelling organisms (Sagliocco 2005). The potential of *S. ruborum* is being assessed in Europe with the specific objectives to determine the phylogeny of accessions collected from cultivated and wild blackberry taxa in Europe and the UK, the susceptibility of Australian native blackberry, and commercial cultivars of berry fruits utilised in Australia and Europe. *S. ruborum* is a pathogenic fungus that attacks and kills blackberry canes in Europe and North America, but a range of commercial cultivars of blackberry are either resistant or susceptible to varying degrees.

KNOWLEDGE GAPS

Biological control An understanding of the taxonomic status of Australian blackberry taxa improved with the application of DNA fingerprinting procedures, and recent advances clarifying the origin and status of the *R. anglocandicans* (Evans *et al*. 2004). However, field-based survey data on the biota associated with Australian blackberry taxa and their close relatives requires further attention. In particular, the organisms or biotypes associated with blackberry growing in shaded habitats and those also occurring in moisture-stressed habitats. Our understanding of the host specificity of biological control agents, particularly to modern blackberry cultivars, is limited and requires investigation if advances biocontrol in Australia are to be achieved. Understanding the performance and ecology of the new *P. violaceum* isolates released in Australia would influence future directions in the biological control of this plant and benefit other biocontrol programs utilising pathogens.

Blackberry ecology In the short-term, biocontrol of blackberry is most likely to affect infestation characteristics rather than broad-scale distribution. The extent to which blackberry infestation characteristics need to be modified to induce beneficial changes in vegetation succession are not known. While this paper proposes target conditions for suppression, evaluation is required to verify their adequacy. Similarly, modelling of agent impacts on blackberry performance, particularly for new organisms, would assist in the selection of effective biocontrol agents.

WORKING WITH THE BLACKBERRY INDUSTRY

Biological control of invasive blackberry in Australia requires the co-operation of blackberry-based industries. While issues associated with the target plant have been resolved, others remain for the importation of new agents for blackberry, and are primarily related to host-specificity. Many commercial brambleberry cultivars, especially thornless ones, contain European blackberry in their pedigrees; therefore the risk of attack by insects or pathogens collected from wild blackberry is high. High levels of specificity can mitigate potential conflicts of interest, demonstrated by the absence of productivity impacts by *P. violaceum* on berry crops 22 years after its introduction in Australia.

Importantly, developments in blackberry breeding programs that reduce the incidence of European blackberry genes in cultivars are likely to improve the range of organisms available for biocontrol of invasive blackberry. The incorporation of greater proportions of American or Asian blackberry genes into cultivar lines for improved fruit production and quality purposes may inadvertently improve the potential prospects of biocontrol of European blackberry in Australia. There is a potential opportunity for the Australian blackberry industry and weed-control agencies to achieve a 'win-win' outcome, if the susceptibility of new cultivars to attack by selected specialist agents can be removed, while productivity standards are maintained or improved. The opportunity also exists to produce new cultivars that display less weedy characteristics and that cannot cross-breed with European blackberry thus potentially creating new weeds for Australia. Rather than leave it to chance for the development of new generation crops of brambleberry cultivars, industry and weed control agencies have a unique opportunity to act co-operatively to reduce the heavy economic burden of invasive blackberries in Australia. The time has come for this approach to commence.

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