A strategy for the biological control of blue heliotrope (*Heliotropium amplexicaule*)

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Summary Blue heliotrope, *Heliotropium amplexicaule* Vahl, an herbaceous perennial plant of South American origin, is becoming an increasingly serious weed problem in grazing lands of northern NSW South Wales and southern Queensland, where it competes with desirable summer pasture species and is toxic to stock. Herbicides have had limited success in reducing its impact and have not stopped its spread.

Surveys conducted throughout the range of blue heliotrope in Argentina during 1998–2000, coupled with preliminary ecological studies, identified four insect species and one pathogen as having potential for biological control.

Based on the lifecycle of the target weed and field studies on the candidate control agents in Argentina, two insects, the leaf-beetle, *Deuterocampta quadrijuga*, and the root-feeding flea-beetle, *Longitarsus* sp., were prioritised for the biological control of *H. amplexicaule* in Australia.

The strategy is to have a two-pronged attack on the target weed; on the above ground biomass (photosynthetic tissue), primarily by the leaf beetle with added pressure from the adult flea-beetles, and on the below ground biomass (root reserves) by the larvae of the flea-beetle. This complementary action should increase the chances of successful biological control of this toxic weed. An agent that causes chronic lower level damage, such as the leaf-blotch fungus, *Pseudocercosporella* sp., could also reduce the competitiveness of blue heliotrope and warrants investigation as a third prong in this strategy.

The leaf-beetle was selected for introduction into Australia, and successfully tested in quarantine to determine whether it posed a risk to non-target plant species. Following approval by Australian plant biosecurity authorities, it was first released in the Western Slopes region of NSW in October 2001.

Keywords *Heliotropium amplexicaule*, *Deuterocampta quadrijuga*, *Longitarsus* sp., biological control.

INTRODUCTION

Blue heliotrope (*Heliotropium amplexicaule* Vahl) is a perennial, spreading herbaceous plant, native to temperate South America (Johnston 1928). It became naturalised following its introduction into Australia as an ornamental plant in the late 1800s, and is continuing to expand its range; widespread and damaging infestations occur over several hundred thousand hectares in south-east Queensland and northern New South Wales (see Da Silva 1991, Newell 1997, Holmes 1999), with scattered colonies extending into Victoria and South Australia (Parsons and Cuthbertson 1992). Blue heliotrope is a declared noxious weed in 14 local government areas of New South Wales. It contains pyrrolizidine alkaloids that are toxic to livestock, causing liver damage and stock death (Ketterer *et al.* 1987). In agricultural systems, production losses occur due to competition by blue heliotrope with more desirable cropping and pasture species and through a decline in animal performance as a result of its toxicity. This weed is already a serious weed of pastures and can adversely affect other production systems such as peanuts and sugar cane (Jones 1971).

Why biological control? Control methods for blue heliotrope have to date been based on the application of chemical herbicides. However, the herbicides currently registered for blue heliotrope have had limited success and are not selective. Moreover, cultivation encourages spread by stimulation of germination and regeneration from decapitated rootstocks and plant fragments. Its continued spread, and the increasing rate at which this is occurring, indicates that current control methods are not successful, and Newell (1997) considers the weed to be on the verge of becoming a much more serious problem for agriculture in eastern Australia. Briese and Zapater (2001) modelled the predicted distribution of blue heliotrope in Australia, based on the climate profiles of its current range, and confirmed the risk of more widespread infestations of the weed to Australian agriculture throughout eastern Australia.

An integrated management approach is seen as the only way to combat this weed (Da Silva 1991, Newell 1997). An important part of such a strategy would be biological control, which would be both environmentally benign and self-perpetuating. However, as well as providing potentially high benefits, biological control carries a high risk of failure (see Briese 2000, Syrett *et al.* 2000), and the development of an appropriate strategy for control prior to agent selection is essential to maximise the chances for success and reduce unnecessary costs due to research on and testing of ineffective agents (Briese *et al.* 2002). It also provides a focus for the subsequent evaluation of the project, and an analysis of how outcomes followed or differed from strategy expectations can be a powerful tool for improving the science of biological control.

Selecting control agents Agent selection depends not only on demonstrating minimal risk to non-target plant species, but also on demonstrating the potential for appropriate impact on the target weed and an ability to complement other selected agents (Briese 2000). Briese *et al.* (2002) have argued that, for agents to have an effective impact on the target weed, three factors must be considered; target weed ecology, agent ecology and the environmental conditions that occur in the area of weed introduction.

Surveys in Argentina during 1990–91 (Wapshere 1993) and 1998–2000 (Briese *et al.* 2000) identified four insects and one pathogen as possible candidate control agents (Table 1), and their biology and impact on *H. amplexicaule* have been described (Briese and Zapater 2001). In addition, climate matching showed that the areas surveyed for blue heliotrope and its natural enemies were closely matched to the principal infested areas in Australia (Wapshere 1993).

The third factor, an understanding of the ecology of the target weed, is critical to this exercise. This paper describes the lifecycle of blue heliotrope in Australia, emphasising those transitional stages vulnerable to biological control. It further outlines the rationale for the selection of biological control agents and their expected impact the target weed.

Table 1. Potential biological control agents for *Heliotropium amplexicaule*.

Agent	Effect
Deuterocampta quadrijuga (Coleoptera: Chrysomelidae)	defoliator
Dictyla sp. (Homoptera: Tingidae)	sap-sucker
Haplothrips heliotropica (Thripidae)	shoot and bud deformation
Longitarsus sp. (Coleoptera: Halticini)	defoliator (adult) root-feeder (larvae)
Pseudocercosporella sp. (Mitosporic fungi: Hyphomycetous anamorph)	leaf-blotch fungus

THE LIFECYCLE OF BLUE HELIOTROPE

The lifecycle of *H. amplexicaule* is shown in Figure 1. It is a perennial plant with a deep root system and, once mature, plants can undergo several annual cycles of growth and die-back of aerial vegetation. The plant produces new shoot and leaf growth from spring to autumn, and can flower several times during this period. Briese and Zapater (2001) found that three-quarters of flowering and seed production occurred in the first flush, which finished by late spring. Newly fallen seed may be dispersed via animal movement or water (e.g. flooding), while remaining seed becomes incorporated into a relatively long-lived seed bank. Blue heliotrope either reproduces from this seed bank or vegetatively from root buds (Figure 1). In winter the foliage of the plant partially dies back or is killed by frost, to regenerate the following spring from the rootstock.

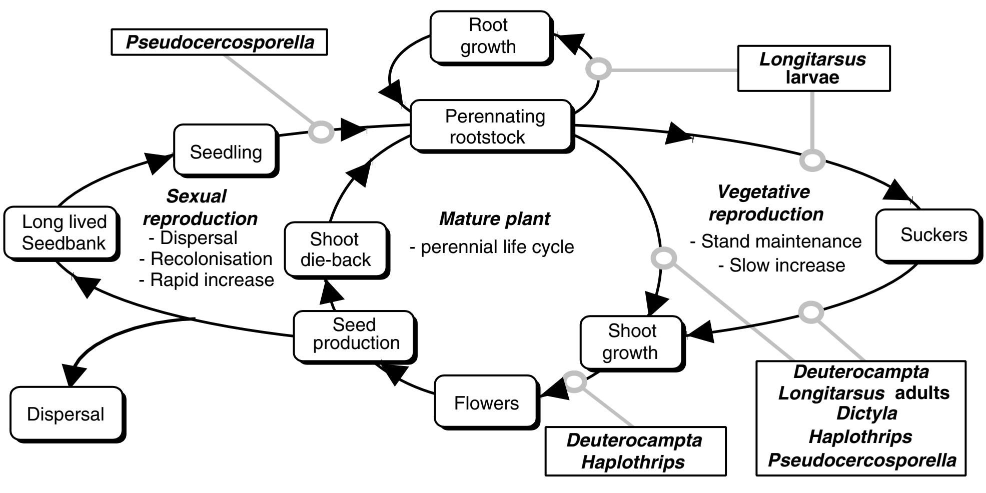

Figure 1. Lifecycle of blue heliotrope, showing transitions that might be vulnerable to biological control agents.

Field observations in Australia suggest that older infestations of blue heliotrope comprise fairly stable populations of perennating plants, with replacement mainly by suckering and significant seedling recruitment occurring only after disturbance. Moreover in the absence of disturbance, such as animal grazing, the weed is eventually displaced by other more competitive vegetation (Moss 1997).

In its native range in Argentina, blue heliotrope is a coloniser of recently disturbed areas, but populations either do not persist or remain at low levels with individual plants being much shorter-lived than in Australia. This appears to be partly due to the inability of blue heliotrope to compete with later-successional vegetation, but also to continued levels of natural enemy attack, which reduces its competitiveness even more.

BIOLOGICAL CONTROL

Figure 1 indicates the key transition stages of *H. amplexicaule* and shows those points where the plant can be targeted by particular biological control agents.

Biological control of blue heliotrope has both short- and long-term aims. In the short-term, any reduction in above-ground biomass will reduce the toxicity problem as well as reducing photosynthetic capability, which should render the plant less competitive with other pasture species. This would require the 'root-stock → shoot' and 'root-stock → sucker' transitions to be targeted. In the longer term, it would also be desirable to target the important 'seed production → soil seed bank' transition to drive down the size of the soil seed reserves. This should lead to an eventual decline in local blue heliotrope infestation densities and reduce the spread of the weed into new areas; the current large seed bank increasing the risk of dispersal via contamination of farm machinery and grazing animals (both domestic and native) or through natural events such as flooding. Finally, directly targeting the root system would interfere with nutrient uptake from the soil, reduce the capacity of the plant to store these nutrients in the rootstock and further reduce plant longevity.

Three of the insect species identified as candidate agents in Argentina by Briese and Zapater (2001) feed on foliage shoots, though occupying different niches: *D. quadrijuga* is a defoliator, *Dictyla* sp. sucks phloem from leaf tissue and *H. heliotropica* feeds on plant cells causing shoot deformation. *D. quadrijuga* was found to be the most damaging of the three agents in its native range and is capable of rapid population increase, causing complete defoliation relatively early in the growing season (Figure 2). While no agent was found that directly destroyed seed, both *D. quadrijuga* and *H. heliotropica* indirectly affected seed production by feeding on or deforming developing flower buds, respectively.

A fourth agent, *Longitarsus* sp., feeds on shoots as an adult, but importantly feeds on the roots during the larval stage. It also was shown to be very damaging to blue heliotrope in the native range (Figure 3). While defoliation by adults was slower than that caused by *D. quadrijuga*, plants were killed, possibly due to the addition impact of root-feeding larvae.

The leaf-blotch fungus, *Pseudocercosporella* sp., infects vegetative shoots, although preliminary studies suggest that the development of symptoms is slow (L. Morin, pers. comm.). However, it may the only agent capable of inflicting sufficient mortality during the 'seedling → established rootstock' transition, if it can cause epidemic outbreaks in the field. At the moment too little is known of its biology to speculate on this.

CONCLUSIONS

Based on the lifecycle of the target weed and field studies on the candidate control agents in Argentina, the leaf-beetle, *D. quadrijuga*, and the root-feeding flea-beetle, *Longitarsus* sp., were prioritised for the biological control of *H. amplexicaule* in Australia.

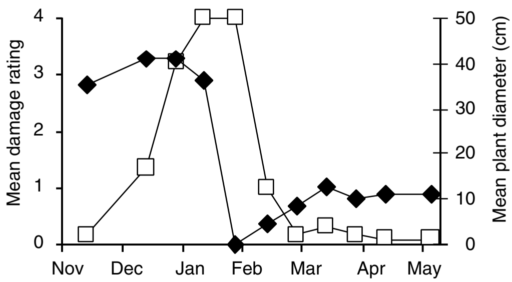

Figure 2. Impact over time of *Deuterocampta quadrijuga* on blue heliotrope foliage (open symbols = insect feeding damage, solid symbols = plant size).

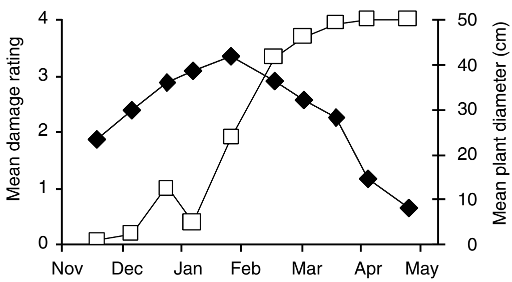

Figure 3. Impact over time of *Longitarsus* sp. on blue heliotrope foliage (open symbols = insect feeding damage, solid symbols = plant size).

The strategy is to have a two-pronged attack on the target weed, *H. amplexicaule*; on the above ground biomass (photosynthetic tissue), primarily by the leaf beetle with added pressure from the adult flea-beetles, and on the below ground biomass (root reserves) by the larvae of the flea-beetle. This complementary action should increase the chances of successful biological control of this toxic weed, by reducing the biomass of established infestations over summer, thereby reducing the risk of stock poisoning and making desirable pasture species more competitive. Appropriate pasture management, however, is critical to its success. The indirect reduction in seed production should eventually reduce seed soil reserves and lower the rate of spread of the weed. Finally, an agent that causes chronic lower level damage, such as the leaf-blotch fungus, *Pseudocercosporella* sp., could also reduce the competitiveness of blue heliotrope and warrants investigation as a third prong in this strategy.

The leaf-beetle was selected for introduction into Australia, and successfully tested in quarantine to determine whether it posed a risk to non-target plant species. Following approval by Australian plant biosecurity authorities (Briese and Walker 2002), it was first released in the Western Slopes region of NSW in October 2001. Once establishment has been confirmed, redistribution networks will be established for this and subsequent agents in New South Wales and Queensland. A colony of flea-beetle is currently being held in quarantine for host-specificity testing and release, while a culture of the leaf-blotch fungus is undergoing preliminary assessment for virulence and specificity in quarantine.

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