Factors influencing the release and establishment of weed biological control agents

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Summary Under the auspices of the CRC for Australian Weed Management, we and other researchers around Australia have been investigating the factors influencing the release and establishment of weed biological control agents on a wide variety of weeds. In addition to improved understanding of post-release ecology of biocontrol agents, this project has generated a series of recommendations for best practice that will be presented at the conference.

Keywords Biological control, release strategies, establishment.

INTRODUCTION

The cost of a weed biological control program can be high in research years and monetary expenditure. If an agent fails to establish, a significant amount of time and money is lost, e.g. over 25 years, the cost for the selection, host-specificity testing, rearing and release of six agents for biocontrol of prickly acacia, *Acacia nilotica* (L.) Delile, was estimated at $5.3 million (Page and Lacey 2006). However, only two (33%) of the six agents have established and the program has not provided any substantial benefits to date (Page and Lacey 2006). In addition, only 17 (55%) of the 31 agents released against lantana, *Lantana camara* L., have established (Page and Lacey 2006).

Regardless of how we quantify successful establishment of agents across countries and programs, it is important to understand the reasons underpinning establishment success and failure. The methods used in releases and the reasons for establishment failure are rarely reported (Briese 2004) but those that have been cited include insufficient numbers of individuals released, high levels of predation and parasitism, unsuitable habitat and plant phenology (Day *et al.* 2004).

Since 2001, the CRC for Australian Weed Management has had a task in the Landscape Management Program to identify some strategies to improve the efficiency of biological control. One project within this task has been to explore the key principles underpinning successful releases of biocontrol agents and to determine release strategies to improve the probability of successful establishment. In the seven years of this project, there have been several studies to investigate some (but not all) of the factors that influence successful establishment (Day *et al.* 2004). These have been undertaken on a wide variety of weeds, such as blackberry (*Rubus fruticosus* agg), bridal creeper (*Asparagus asparagoides* (L.) Druce), bitou bush (*Chrysanthemoides monilifera* (L.) Norl.), lantana, mimosa (*Mimosa pigra* L.), gorse (*Ulex europaeus* L.), bellyache bush (*Jatropha gossypiifolia* L.), ragwort (*Senecio jacobaea* L.), broom (*Cytisus scoparius* L.), and Paterson's curse (*Echium plantagineum* L.). This paper highlights some of the recent findings of this project.

HOST PLANT CHARACTERISTICS

The performance of agents can be drastically affected by the phenology and health (nutritional quality, growth rate) of the target weed, which in turn is determined by the habitat in which it is growing. For example, seasonal lack of food has likely hindered establishment of the seed sucking bug, *Agonosoma trilineatum* Fabricus, released against bellyache bush. Seed is present on bellyache bush throughout the year but in very low numbers for part of the year and may be difficult for insects to find or to support a viable population (C. Lockett pers. comm. 2007).

Higher plant growth rate in the spring/summer following release of the bitou bush leaf rolling moth *Tortrix* sp. is believed to have been a major factor leading to the establishment of this agent at one of five sites closely monitored in 2001–02 (Swirepik *et al.* 2004). Plant quality is also important for the establishment of rust fungi such as the blackberry leaf-rust *Phragmidium violaceum* (Schultz) Winter. In this instance, severe infections only occur on blackberry plants that are actively growing and not under stress (Morin *et al.* 2008).

EFFECTIVE RELEASE SIZE

The number of individuals comprising a founder population can be critical to initial establishment and will vary according to the species (Memmott *et al.* 1998). Ongoing studies on the establishment and dispersal of the gorse thrips, *Sericothrips staphylinus* Haliday in Tasmania have provided useful insights that can be applied to improve release strategies. Establishment of this agent was achieved after releasing numbers as low as 10 thrips per site (J. Ireson unpubl. data 2007). Although releases of approximately 500 thrips provided maximum recovery, releases of approximately 250 thrips ensured maximum population growth and have now been adopted as the minimum release size for establishment of the gorse thrips.

In the early stages of a program, release size may have to be an arbitrarily chosen figure determined by the number of suitable sites available at the time of release and the number of agents available for release. The optimum release size can be subsequently determined by conducting field trials using a range of release sizes.

INFLUENCE OF AGENT DISPERSAL

The dispersal capability of agents must also be considered when designing a release program as it contributes to establishment on a landscape scale. For example, due to the relatively slow dispersal capabilities of the bridal creeper rust, *Puccinia myrsiphylli* (Theum) Wint. compared to other rust species, a large number of releases had to be conducted to expedite establishment across the range of the weed (Morin *et al.* 2006). An extensive release program has also been necessary for the sedentary gorse thrips which disperses slowly from its release point in the early stages after establishment. Tasmanian surveys carried out at 18 sites in 2007, where releases had been made 3–6 years previously, revealed a mean dispersal distance of only 21 m (range 0–180 m) (J. Ireson unpubl. data 2007). This distance however, is probably an underestimate due to difficulties in locating the thrips when population densities are very low.

PREDATION AND PARASITISM

The impact of predation and parasitism on agents, particularly insects, can be devastating on founder populations thereby preventing establishment (via predation) and reducing effectiveness or dispersal (via predation and parasitism). For example, the possible causes for the low establishment rate of the *Crioceris* sp. leaf beetle on bridal creeper (it only established at three of 16 sites where it was released in 2002 and 2003) were recently explored in manipulative field experiments (Morin unpubl. data). This work was a follow-up from an earlier study (Reilly *et al.* 2004). Results indicated that predation may play a major role in limiting survival and establishment of the leaf beetle in the field. The release of 400–500 beetles onto actively growing bridal creeper is now recommended as part of the release strategy to compensate for any predation that may occur.

The dispersal of the leafhopper *Zygina* sp., another agent released against bridal creeper, has likely been affected by a native mymarid wasp parasitoid, *Stethynium* sp. Although rates of parasitism can be quite high (59%), results from recent laboratory experiments have shown that the leafhopper might be able to survive in the face of high parasitism and still contribute to the biocontrol of bridal creeper (Spafford Jacob *et al.* 2006). Nevertheless, given that the parasitoid is able to quickly find new populations of the leafhopper (A. Joder unpubl. data 2002), it appears that establishment and increase of leafhopper populations in new areas will remain a challenge.

CLIMATE AND HABITAT

As evidence of the importance of climate on successful establishment, research activities in this project were restricted due to drought conditions. This was particularly evident for the release of the rust, *Prospodium tuberculatum* (Speg.) Arthur, and the mirid insect, *Falconia intermedia* (Distant) against lantana. *Falconia intermedia* was initially released widely along the Queensland and northern NSW coast. However, the insect has established and persisted only in north Queensland where the climate is more comparable with its native range.

Unsuitable climatic conditions at time of release are frequently reported as a major factor preventing agents to establish. In such situations, releases should be performed in areas with a favourable microclimate. For example, the tingid, *Teleonemia scrupulosa* Stål, prefers open sunny areas as opposed to shaded and cooler areas. With drought conditions prevailing through most of eastern Australia, habitat selection was critical to the increase in the establishment rate of, *P. tuberculatum*. The rust prefers areas of high rainfall but establishment rates improved from 20 to 63% when the rust was released in sheltered gullies or on sheltered south-facing slopes where there was greater moisture retention following rain.

CONCLUSION

The research undertaken as part of this project has contributed to improved understanding of post-release ecology of biocontrol agents. From the experience gathered over the years, a series of recommendations for best practice has been developed and will be presented at the conference. A best practice guide will be produced by the CRC to assist practitioners in designing robust release strategies that will increase rates of establishment.

In spite of the losses due to failed establishment of one or more agents, the overall economic benefits outweigh the costs of biological control for those programs where some agents establish and exert some control (Page and Lacey 2006). For example, a 5% reduction in lantana will result in a benefit cost ratio of 9:1 (AEC group 2007). Whether this occurs by one or a number of the agents in combination does not matter. The overall aim of a biological control program is to successfully control the target weed and reduce its impacts.

Nevertheless, establishment failure reduces the potential reduction of the weed, limits opportunity to find another agent that will establish and, in the absence of another effective biocontrol agent, provides time for the weed to further expand its range. Thus, improved establishment rates would provide not only increased return on research investment but achieve the overall aim of reducing the weed's population.

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