Improving release strategies to increase the establishment rate of weed biocontrol agents

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Summary Establishment of weed biocontrol agents is influenced significantly by the release strategy. Release methods should consider plant attributes, such as flowering or fruiting times, insect biology and behaviour, and abiotic factors such as climate, season and even time of day when the release is conducted. The CRC for Australian Weed Management is studying a range of methods to improve the establishment rate of weed biocontrol agents, using gorse (Ulex europaeus L.), lantana (Lantana camara L.), mimosa or giant sensitive plant (Mimosa pigra L.), Paterson’s curse (Echium plantagineum L.) and bitou bush (Chrysanthemoides monilifera (L.) Norl. ssp. rotundata (DC.) Norl.) as model systems. Research is being undertaken to determine the most appropriate developmental stage and number of insects to release at any one time, as well as maximising initial rates of population increase. This may be achieved by preventing dispersal and minimising predation and/or parasitisation by natural enemies through various types of caging, and by supplementing food to increase adult longevity and fecundity during the initial establishment phase. The number of insects required to achieve establishment is dependent on the type of agent released and defining the optimal release size is critical to any release strategy. This may range from 10s to 1000s of individuals, depending on the species.

Keywords Biocontrol agents, release strategies, Allee effects, predation, survival, fecundity.

INTRODUCTION

Release strategies used in weed biocontrol programs are not well studied. Yet, just over two-thirds of all biocontrol agents have established (Julien et al. 1984) and little is known of the reason why others do not. Studies by Memmott et al. (1998), Grevstad (1999) and Shea and Possingham (2000) have tried to address some of the factors affecting establishment, concentrating on the optimal number of individuals in a release event. However, many factors can influence establishment, including target weed and agent attributes, as well as abiotic factors such as temperature and rainfall (Simberloff 1989).

The life history of the weed (annual/perennial, evergreen/deciduous) will determine when releases are likely to be possible or most effective. The taxonomy, feeding guild, biology and behaviour of an agent are also important considerations when conducting field releases. Insects with adult stages that feed on the target weed could be released as adults directly onto the weed, where they are likely to remain, feed and oviposit. Species with active adults that do not necessarily feed on the target weed (e.g. many moths and flies) tend to be dispersed in air currents, and may need to be released into field cages to confine adults to overcome Allee effects (Grevstad 1996), where females fail to find a mate. Furthermore, the appropriate part of the plant needs to be present and at the right stage for the particular agent e.g. some bruchids prefer green seed pods, while others require more mature pods.

Agents should be released at their most appropriate stage and age. For many release programs, adults are released. Therefore, it is necessary to consider the age of females used. Old females reared in culture may have already laid their complement of eggs, prior to release and so only a few eggs may be laid in the field. However, for other programs, eggs and/or larvae can be
released with positive results. *Cactoblastis cactorum* (Bergroth) was released as egg sticks placed on prickly pear bushes, while the larvae of the moth *Carmenta mimosa* Eichlin and Passoa were placed in holes drilled in stems of mature giant sensitive plants.

To increase survival and fecundity, additional food sources, such as honey solution, nectar or pollen granules can be supplied, similar to those used in rearing programs. Furthermore, free-living life stages of insects are highly vulnerable to predation in Australia, particularly by spiders and ants (Briese 1986), and may need assistance to ensure that an establishing population survives and increases in size.

Finally, abiotic factors such as temperature and rainfall may be critical and some insects are best released under cool conditions or placed in protected areas to help achieve establishment.

Research is currently being undertaken by members of the Co-operative Research Centre for Australian Weed Management (Weeds CRC) to increase the rate at which biocontrol agents establish. Specifically, research is being conducted to test theories proposed by Grevstad (1999) and Shea and Possingham (2000) as outlined below. Other activities are improving methods to reduce predation and to increase survival and fecundity through the provision of additional food sources. This paper discusses some of the activities being addressed and how they may impact on future weed biocontrol programs.

**DETERMINING OPTIMAL RELEASE NUMBERS**

Shea and Possingham (2000) suggested that in the initial stages of a release program, different sized releases should be made. It is possible that with some agents, too few insects are being released in any single release for establishment to occur. Conversely, they speculated that by determining the minimum number of insects that are required to achieve establishment, release strategies could be more efficient, by releasing at more sites.

Memmott *et al.* (1998) examined the effect of release size on the probability of establishment of the gorse thrips, *Sericotherips staphylinus* Haliday, in New Zealand. They noted that a single large release could become extinct by chance, but it was unlikely that a large number of small releases would do so over the same time period. Based on this work, a release batch size of 300 was initially used for releases of gorse thrips in Tasmania and post-release surveys showed that this batch size resulted in an acceptable level of field establishment of ca. 83%. Gorse thrips are slow to spread however, being found only within a few metres of the central release point up to three years after release. As a result, larger release batch sizes of ca. 1000 thrips are being trialled in Tasmania to determine if they can trigger more rapid dispersal and are able to offset the impact of natural enemies on the establishing population.

During the release and redistribution program of the Paterson’s curse crown weevil, *Mogulones larvatus* Schultze, experiments were conducted to look at optimal release size, season of release and the benefits of using cages. Season and method of release were important, as adults emerged in spring but did not mate until the following autumn. Adults released in autumn had a better chance of establishing than adults released in spring, as adults started to encounter mates immediately and therefore tended not to leave the release area. The use of cages was more effective for adults released in spring, as mating occurred in autumn and the use of cages through spring-summer reduced Allee effects. Larger releases did increase establishment rates, but interestingly also increased the rate of population increase (offspring per female) giving larger releases a slight advantage over small releases, even when the rate of establishment per release was constant (M. Smyth and A. Sheppard unpublished data).

**DETERMINING OPTIMAL RELEASE AREAS**

For many agents, there are strict environmental parameters that may influence whether an agent will establish or persist in an area. Computer modelling programs such as CLIMEX can assist in determining areas that are likely to be favourable for a particular agent. However, these programs do not necessarily distinguish microclimates within a potentially suitable region.

Releasing agents over a wide geographical range may still be necessary, particularly as a complexity of factors may determine the success of a biological control agent. The ragwort flea-beetle, *Longitarsus flavicornis* (Stephens), has established widely in Tasmania and is able to control ragwort at many sites (Ireson *et al.* 2000). However, in Victoria, it has only established in high altitude, high rainfall areas from where it has spread very slowly and has not had a significant impact (McLaren *et al.* 2000). Subsequent studies showed that a CLIMEX model could not provide any clear climatic explanation for variation in the establishment of *L. flavicornis* between the two states and it was concluded that subtle interactions between site, soil and climate factors influence population densities and that no single factor or group of factors is dominant (Potter 2003).

The mirid *Falconia intermedia* Distant, a biocontrol agent for lantana, was released in varying numbers over many sites in Queensland and New South Wales.
establishment of the moth. Plants retain leaves all year round. However, Numbers are increasing, albeit slowly at sites where the agent has persisted for several years and appears to survi

during drought. In north Queensland, however, the agent has persisted for several years and appears to be increasing in numbers, albeit slowly at sites where plants retain leaves all year round.

Environmental conditions have also affected the establishment of the moth Tortrix sp., a biocontrol agent for bitou bush. Large numbers of insects have been released throughout coastal NSW, but due to on-going drought conditions, the agent has established at only a few sites. Furthermore, it has been unable to establish at any site for the control of the related subspecies boneseed in the cooler climate of Tasmania.

IMPROVING INSECT PERFORMANCE THROUGH ADDITIONAL FOOD SOURCES

Weed biocontrol agents are selected primarily because of their host specificity, i.e. they utilise only one or a few closely-related host-plant species to complete their life cycle. It is presumed in the selection of agents that both the adult and immature stages of the insect will feed entirely on the target weed. However, there are cases, such as moths, where the adults only feed on pollen and nectar. These adults may then require supplemental foods such as pollen and nectar in order to increase their longevity and fecundity. Supplying supplemental foods in the laboratory in mass-rearing programs to increase longevity and fecundity is a common practice and applying this principle during field release may increase an agent’s chance of establishment.

The lack of supplemental food has been implicated in the failure of establishment of Tephritis dilacerata (Loew) on perennial sowthistle (Sonchus arvensis L.) in Canada (McClay and Peschken 2002), while the field establishment of Apion miniatum Germar, a biocontrol agent for spiny emex (Emex australis Steinh.), has been difficult to achieve. Adult weevils appear to disperse rapidly after release (Yeoh et al. 2002). However, in the laboratory, the adults are provided with supplemental sugars to maintain the colonies. There is often little food available for the adults in the field at the time of release. Adults may therefore disperse to find food, lowering the chances of mating or maintaining viable population size.

Not all agents need supplemental foods. Adults of the Paterson’s curse crown weevil Mogulones geographicus (Goeze) lived significantly longer and survived aestivation better when given access to flowers prior to when the flowers would normally be present in the field. Its close relative, M. larvatus however, does not appear to require supplemental food to survive over summer.

For many agents that have had difficulty establishing, the effect of supplemental foods on longevity or fecundity and population establishment has not been evaluated, in either the laboratory or in the field.

MINIMISING PREDATION

Predation by ants and spiders has often been implicated in the failure of biocontrol agents to establish. The geometrid Macaria pallidata Warren is the latest insect released against giant sensitive plant in the Northern Territory. The larvae are soft bodied, slow moving and feed externally on the leaves. Ants have been observed to remove most larvae when the moth is reared in the laboratory, and birds were observed feeding on larvae in the field. Field experiments were conducted to determine if predation does reduce larval survival in the field. We found that larval survival increased substantially when sticky gel was applied around the base of the weed to exclude ants. Excluding birds with netting resulted in slightly higher larval survival.

Unfortunately, using gel when releasing M. pallidata is not feasible because late instar larvae crawl down the trunks and pupate in the soil, so gel would block this process. Attempts to create artificial pupation areas above the gel have so far been unsuccessful.

Larvae of Crioceris sp., a biocontrol agent for bridal creeper, are also external feeders and are vulnerable to predation by ants. Field experiments determined that releasing the beetles into exclusion cages was an effective method of reducing predation of larvae and pupae (Reilly et al. 2004).

Experimental releases of Tortrix sp. larvae on bitou bush in NSW have also attempted to quantify the impact of predation and parasitism by comparing caged versus non caged releases. Initial indications are that predation and/or parasitism are significant factors in the establishment of Tortrix sp. Future experiments will also examine the potential for exclusion of predators, such as ants and spiders, using insecticides.

Trials to determine the most effective means of reducing predation are necessary as no one method will necessarily work for all agents.

INTERSPECIFIC COMPETITION

Crioceris sp. is the third agent to be released against bridal creeper. The other two agents, a leafhopper and a rust fungus, are well established and are already having an impact on the plant. In glasshouse experiments, it
was found that *Crioceris* sp. females were less likely to lay their eggs on plants infested with the leafhopper but expressed no preference for uninfected plants over those infested with the rust. However, the survival of larvae to pupation was negatively affected by the presence of the rust and even more so by the leafhopper (T. Reilly *et al.* *unpublished data).

Similar studies have been conducted with agents released against Paterson’s curse. *Mogulones geographicus* females could distinguish between plants infested with *M. larvatus* and preferentially avoided laying their eggs on those plants. However, *Longitarsus echii* Koch did not distinguish between host plants with *M. larvatus* and those without (Hawley *et al.* 2004). The survival of *M. geographicus* or *L. echii* was not reduced in the presence of *M. larvatus*. However, the survival of the two *Mogulones* species was reduced in plants where *L. echii* was also present (J. Hawley *et al.* unpublished data). Such studies suggest that when multiple agents are released, the behavioural and biological interactions of the agents should be considered before selecting sites for release, particularly in the initial stages of establishment.

**RELEASING PATHOGENS**

While much of the literature has cited examples of insect releases, there have been few studies on the appropriate techniques for releasing pathogen biocontrol agents (*e.g.* Sheppard *et al.* 1993). Like insects, the biology of the pathogen influences the optimal release strategy. The rubbervine rust was successfully released from a light plane or helicopter while the groundsel bush rust was often released on potted plants placed amongst groundsel bush thickets.

The lantana rust is highly specific and only infects some varieties of pink-flowering lantana. These types are indistinguishable in the field and so pre-inoculations are conducted first, to determine the susceptibility of a lantana patch to the rust. Once susceptible varieties of lantana are located, establishment can be achieved through inoculating using spores mixed with talc, spores mixed with distilled water or placing infected plants within an infestation.

With all rust releases, moisture is essential to achieve germination and bagging plants may assist in the initial establishment phase. However, bags must eventually be removed and the persistence of the rust in the field is dependent on follow-up periodic moisture through rain or dew.

**CONCLUSION**

The activities of the Weeds CRC are intended to elicit information on the optimal release strategies for weed biocontrol agents. These strategies will consider plant and insect attributes as well as abiotic factors. From these studies, it is anticipated that weed control programs across Australia and the world will benefit.

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**REFERENCES**


