

Integration of biological and other weed control against *Emex australis* in annual pasture-crop rotations

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Abstract. In the Mediterranean-climate of south-western Australia, agricultural production is largely based on a rotation of annual crops with annual pastures. An important annual winter-weed in this system is *Emex australis* (Polygonaceae) (doublegee or three-cornered jack), which is difficult to control because of its long-lived seed. Biological control of *E. australis* is being investigated within the context of integration with existing weed-management techniques of grazing intensity, cultivation and herbicides. Significant biological control agents, already present, are a stem-blight fungus, *Phomopsis emicis*, and an aphid, *Brachycaudus rumexicolens*, both of which were accidental introductions. The fungus kills up to 30% of the seed. The aphid causes a significant reduction in achene (fruit) size in *E. australis*. One indirect effect of a reduction in achene size is a loss of seed dormancy. A reduction in the population of long-lived seed produced during the pasture phase would enable herbicides to remove most of the weed during the crop phase of the rotation. Farmers could increase the effectiveness of the aphid as a biological control agent by encouraging the presence of local populations of alternative host-plants. New biological control agents are being studied to see if they are suitable to include in the pasture-crop rotation and thus further reduce *E. australis* seed production in south-western Australia.

Introduction

Biological control is reputed to be unsuccessful against annual species in agroecosystems due to the high degree of disturbance caused by farming practices. Also, annual weeds are considered difficult targets for biological control due to their ability to escape in space and time from biotic factors influencing the population ecology of the weed (Crawley 1989; Wapshere *et al.* 1989).

Agricultural production and economics in the Mediterranean-type climate of Western Australia are dominated by annual cereal, legume or oilseed crops in annual rotation with crops or with pastures composed entirely of self-sown annual species. Farmers sow a range of crops in late autumn that are harvested in late spring; the summer period being too dry for crop growth. Sheep are grazed on the pasture and crop stubbles, throughout the year. One of the principal weeds of this system is *Emex australis* (Polygonaceae) (doublegee or three-cornered jack). This annual plant of South African origin reproduces only by seed that can persist for three or more years in the soil (Cheam 1987). The plant produces seeds at the base of the

rosette within six weeks of germination in autumn and at nodes along the stems that grow until the whole plant senescences, due to the summer drought. The plant is able to survive the false breaks (rains in late summer and autumn that are followed by dry weather) due to a vigorous tap root (Gilbey and Weiss 1980). The weed is a competitor in crops and pasture, a contaminant, particularly of pulse crops, and the spines cause injury to sheep (Gilbey 1974; Gilbey and Weiss 1980).

Emex australis, and the only other species in the genus, *E. spinosa*, have been successfully controlled in Hawaii by using the South African weevil, *Perapion antiquum*, (Julien 1992). The failure in Australia of this widely-released weevil is attributed to its inability to survive over summer (Julien 1981; Scott 1992). The agroecosystem of south-west Australia, including *E. australis*, is already subjected to intensive weed-management by cultivation and herbicide techniques (Dodd, Martin and Howes 1993). Measurable, but insufficient reduction of seed-set already occurs on the weed due to organisms such as the fungus, *Phomopsis emicis*, and the aphid, *Brachycaudus rumexicolens*, (Scott and Shivas unpublished) A number of potential biological control agents are known, but have not been

released yet in Australia (Scott and Shivas 1990; Scott and Yeoh 1994). These biological control agents need to be considered in the context of the other control and management methods. The aim of this paper is to examine the strategies and integration of biological control of *E. australis* into farm management in the annual crops and pastures of south-western Australia.

Selection criteria for biological control agents

The strategies for implementing biological control against *E. australis* in south-western Australia are as follows.

The biological control agent must have the ability to survive over summer in proximity to the weed infestation or have exceptional dispersal abilities since the host plant will be absent for up to four months in most years.

The potential agent should cause a reduction in seed-set or should stress the plant such that the quality of viable seed is decreased, leading to reduced survival in the seed-bank or reduced seed dormancy. Panetta and Randall (1993a) found that *E. australis* was a poor competitor against pasture species. Indeed, lack of competing plant species in the first year of pasture is the primary cause of the *E. australis* problem. Thus lessening the plant's competitive ability by the actions of biological control agents is unlikely to be a useful tactic unless there is an economic incentive to increase the seed-bank of pasture species by sowing new pastures, instead of relying on the pasture seed-bank surviving the crop phase.

In determining the host-specificity of an agent, the risk to species closely-related to the genus *Emex*, such as the native Australian *Rumex* species, should be taken into account (Scott and Yeoh 1995).

An autumn flush of weed germination is characteristic of the strongly seasonal Mediterranean climate of south-western Australia (Rossiter 1966). If the agent cannot increase its abundance rapidly in autumn and winter which is a sub-optimal time for growth of *E. australis*, then a large proportion of the plant population would escape attack.

At a farm-scale, the agent needs good dispersal ability because an *E. australis*-infested pasture may become a crop the following year, with little *E. australis* due to herbicide treatments.

An ability of agents to avoid predators may be important, especially as the ant fauna of disturbed areas, while less diverse than in surrounding native

vegetation, is often represented by aggressive species (Scougall *et al.* 1993).

Resident biological control agents

The fungus *P. emicis*, which has a limited host-range and has spores able to survive over summer, was being assessed as an exotic biological control agent when it was discovered to be widespread on *E. australis* in Australia (Shivas, Lewis and Groves 1994). The fungus does not affect the seedlings or rosette stages of the plant, but develops in the stem and seed, contributing up to 30% of seed loss in Western Australia (Shivas and Scott 1994). Since the fungus is readily cultured in the laboratory, it was considered for development as a mycoherbicide until the discovery that it contained the powerful mammalian toxin, phomopsin A (Shivas, Allen *et al.* 1994).

Another organism present on *E. australis* in Australia is the pergid sawfly, *Lophyrotoma andis*. This leaf-feeding sawfly is occasionally so abundant on plants that farmers enquire about the new biological control agent. The insect is native to Australia and has probably extended its host-range from perennial, native *Muehlenbeckia* and *Rumex* species (Polygonaceae) to include introduced *Emex* and *Rumex* species. Conservation or planting of *Muehlenbeckia* species in remnants of native vegetation, such as along fence lines and in road reserves would ensure that this insect, which appears to have continuous generations, is available in autumn to colonize *E. australis*. A closely-related sawfly, *Lophyrotoma interrupta*, contains the toxin lophyrotomin that causes cattle poisoning (Oelrichs and Valley 1977). It is not known if the species on *E. australis* is similarly toxic and this would need to be investigated before attempts were made to increase its abundance.

Perhaps the most useful of the biological control agents already established in Australia is the aphid *B. rumexicolens*. This aphid appeared in Australia in 1985 and in Western Australia in 1987 (Berlandier and Scott 1993). It is widespread and causes up to 30% reduction in the weight of seeds. There are indications that reduced seed-weight in *E. australis* leads to reduced length of seed-dormancy (Scott, Berlandier and Hollis 1994). Augmentation of aphid abundance is being considered, especially to see if aphid numbers can be increased in autumn when the weed is proliferating. The host-specificity and bionomics of the aphid are being assessed to ensure that augmentation is

feasible and without risk. In the laboratory and in cages, the aphids will survive on wheat and lupins as well as on *E. australis* and related plants (Scott and Yeoh unpublished). However, aphid populations do not develop on crops in the field and the host-range is largely restricted to *Emex* and *Rumex* species, with *Muehlenbeckia* species being occasional hosts. The aphid is able to increase its populations at a higher temperature than those suitable for growth of *E. australis* (Yeoh and Scott unpublished) which implies that alternative hosts, present over the summer period, might provide source material for reinvasion.

Potential exotic biological control agents

The weevils, *Apion miniatum* and *Perapion neofallax*, stem-attacking species from Israel and Morocco respectively, are two agents under consideration in quarantine in Western Australia. Both species come from parts of the world with dry summer climates similar to that found in *E. australis*-infested areas of Australia and both appear to have obligatory summer diapause (unlike the failed *P. antiquum*). Other agents that could be considered include the weevils, *Coniocleonus excoriatus* and *Perapion violaceum*, the aphid, *Dysaphis emecis*, and the fungi *Cercospora tripolitana* and *Peronospora emicis*. Priority is being given to species such as *A. miniatum* which appears to have many of the characteristics identified as suitable for the environment of south-western Australia, but ultimately the host-specificity tests will determine which species are released, because of the difficulty of finding organisms with a sufficiently restricted host-range (Scott and Shivas 1990).

Impact of vertebrates on seed-set

Vertebrates, while not usually considered biological control agents, nevertheless contribute to a reduction in *E. australis* seed-abundance. The seeds of *E. australis* are now an important part of the diet of the red-tailed black-cockatoo, *Calyptorhynchus magnificus*, (Ford 1980) and at one site Scott and Shivas (unpublished) measured a consumption of up to 974 fresh seeds m⁻² (19% of the total). Perhaps the provision by farmers of nesting sites for red-tailed black-cockatoos could achieve conservation objectives (Saunders 1994) and contribute to reduction of *E. australis* seed-numbers. Field mice also consume up to 50% of seeds on the soil surface at some sites (Weiss 1981). However, field

mice, unlike the red-tailed black-cockatoo, are an agricultural pest of crops and are sometimes found in plague proportions.

Sheep feed readily on the leaves of young *E. australis* rosettes. Panetta and Randall (1993b) showed that sheep eat less *E. australis* leaves as the season progresses and the plants mature. It is not known what factors effect this sheep behaviour but it is either a change in plant taste (possibly due to oxalic acid) or the presence of spiny achenes or that sheep favour other late-maturing pasture species. Heavy grazing by sheep can prevent shoot production and reduce the number of seeds produced to less than two per plant (Weiss 1981). Only the most severe defoliation causes a reduction in seed production (Weiss 1976) and high grazing-intensities are unlikely to be maintainable throughout the year without the cost of supplementary feed. Despite this, it would be possible for the farmer to manage the grazing pressure to reduce seed production in heavily-infested paddocks.

Provision of alternative hosts

In most years, there are no *E. australis* plants from senescence in late spring (November) to the principal germination time in autumn (May). On average, each fifth year there is substantial summer rainfall (50 mm rainfall events between January and March (Panetta 1988)). Heavy rain in early autumn can cause germination of *E. australis* and the plant can be grown during summer under irrigation from mid-summer onwards (Panetta 1990). This was attempted in order to aid the establishment of *P. antiquum*, but the insect failed to survive (Panetta 1990). The presence of suitable food-plants early in autumn would favour the development of the aphid *B. rumexicolens*, and possibly other agents, but it is unlikely that farmers would countenance the irrigation and production of *E. australis*. *Muehlenbeckia* species and *Rumex* species, in particular *R. crispus*, may be suitable alternative hosts for biological control agents over the summer. *Rumex* species, in particular *R. pulcher*, are important weeds in Western Australia, but *R. crispus* is non-invasive and associated with permanent water sources in the northern wheat belt, the region most affected by *E. australis*. It might be possible for farmers to plant or protect *R. crispus* around farm dams to provide suitable over-summering sites or alternative food for biological control agents early in autumn

before *E. australis* has germinated. This could be achieved without incurring the loss of arable land and without the threat that maintaining summer crops of *E. australis* would entail.

Integration with chemical and cultural control

Biological control agents may contribute to a reduction in the longevity of the seed-bank which, at present, survives for longer than the crop-pasture rotation cycle. Panetta and Randall (1993b) found that seed-banks decreased after seasons when *E. australis* contributed less than 25% to pasture dry-matter, whereas at 30% of pasture dry-matter there was a net increase in the seed-bank. Also, they observed that the decay rate of the seed-bank was estimated to be 70% per year. There is an indication from field data that the aphid, *B. rumexicolens*, causes a reduction in seed dormancy (Scott, Berlandier and Hollis 1994). Increasing the effectiveness of biological control agents in the pasture phase, either by providing alternative hosts or by reintroduction, could have the joint aim of reducing seed-set and the quality of the seeds. Herbicides for the control of *E. australis* are more effective or economically viable in crops than in pastures and could be used to reduce a greater proportion of seed than would be possible without biological control in the previous pasture phase.

Herbicides may be sprayed on pasture early in the season in a method called 'spray-grazing'. The objective is to distort the *E. australis* rosettes and lift the leaves from the soil, making them more readily accessible to sheep (Gilbey 1995). For grasses with short-lived seed-banks, the practice of spraying pasture ('spray-topping') to prevent seed-set the year before sowing crops has also become widespread. Prophylactic aphidicides are sometimes added to the herbicide. The harmful impact of these treatments on biological control agents will need to be assessed as part of an integrated approach (Messersmith and Adkins 1995).

Conclusions

Emex australis could become an insignificant weed under conditions of continuous cropping or continuous pasture (Gilbey 1995). However, to provide economic diversification, to allow the contribution of annual legumes to raise soil-nitrogen levels and to break crop-disease life-cycles, it is likely that crop-pasture

rotations will remain a feature of south-western Australian agriculture. Unfortunately, *E. australis* is favoured by this management system. Biological control is already contributing to a reduction in the abundance of seed and the task of the future is to maximize the contribution of agents that are already present and to introduce new agents that are likely to contribute to a further reduction in the seed-bank. Many of the ways this could be achieved will require the active participation of farmers to provide environments conducive to the survival of biological control agents.

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