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Biological Control of Weeds of Importance to the Wool Industry in Southern Australia

E. Bruzzese[1] and J.M. Cullen[2]

[1] Keith Turnbull Research Institute Department of Conservation and Environment, PO Box 48, Frankston, Victoria 3199, Australia
[2] CSIRO Division of Entomology, PO Box 1700, Canberra, ACT 2601, Australia

Weeds have been estimated to cause an annual loss of $570 million to the Australian Wool Industry due to control costs, decrease in pasture productivity, toxicity to sheep, changes in management practices and vegetable contamination of wool. Several weeds identified as being of economic importance to the wool industry in southern Australia have current biological control programs in various stages of implementation. These are thistles (*Carduus* spp., *Cirsium* spp., *Onopordum* spp. and *Silybum marianum*), Paterson's curse (*Echium plantagineum*), horehound (*Marrubium vulgare*), St. John's wort (*Hypericum perforatum*), common heliotrope (*Heliotropium europaeum*), blue heliotrope (*Heliotropium amplexicaule*), docks (*Rumex* spp.), spiny emex (*Emex australis* and *E. spinosa*), blackberry (*Rubus fruticosus* agg.), Bathurst burr (*Xanthium spinosum*) and Noogoora burr (*Xanthium occidentale*). Progress towards biological control of these weeds in southern Australia is discussed.

Introduction

Woolgrowing is one of the major primary industries which makes use of the 43 million ha of pastures in southern Australia. In a recent survey of the impact of pasture weeds, pests and diseases on the Australian wool industry, Sloan, Cook and King (1988) estimated the annual loss from weeds to be $570 million. The majority of this loss ($447 million) was caused by vegetable fault in wool and 5 grass species with awned seed which readily penetrate the fleece and skin of sheep. A $7 million loss was caused by unspecified woody weeds while the remainder ($116 million) was caused by 16 widespread weed species of the 167 identified during the study. Biological control has been identified as an effective, economic and environmentally acceptable management method for widespread species of weeds and as a consequence increasing resources have been allocated to implement biological control of weeds in Australia. Although biological control programs in Australia are mainly carried out by State and Federal organisations, much of the funding has been supplied by rural industries, in the case of wool by the Wool Research and Development Corporation (WRDC). This paper discusses progress towards biological control of weeds of importance to the wool industry in southern Australia and gives an indication of the level of support given to some of these projects by the industry in the last decade (Table 1).

Thistles

A number of annual and biennial thistles (Asteraceae: Cardueae) of European origin are serious pasture weeds in southern Australia. Biological control of a number of thistle species commenced in 1984 and is a co-operative project between the CSIRO Division of Entomology (CSIRO Entomology), CSIRO Division of Plant Industry (CSIRO Plant Industry) and the Victorian Department of Conservation and Environment (DCE Victoria). CSIRO Entomology is concentrating on biological control of nodding (*Carduus nutans*

L.), slender (*Carduus pycnocephalus* L. and *C. tenuiflorus* Curtis) and *Onopordum* (*Onopordum acanthium* L., *O. illyricum L.* and *O. acaulon* L.) thistles, DCE Victoria on variegated (*Silybum marianum* (L.) Gaertner) and spear (*Cirsium vulgare* (Savi) Ten.) thistles while CSIRO Plant Industry is researching the rust fungus *Puccinia cardui-pycnocephali* H. Sydow & P. Sydow (Uredinales) for slender thistles.

Several strains of the thistle receptacle weevil (*Rhinocyllus conicus* Froel., Coleoptera: Curculionidae)) have been imported with 3 strains probably established on nodding thistle (Woodburn and Cullen 1992) while the variegated thistle and spear thistle strain have failed to establish to date. The seed-head gall fly *Urophora solstitialis* (L.), (Diptera: Tephritidae) was recently released on nodding thistle while *U. stylata* (F.) is undergoing specificity tests for possible release on spear thistle. For *Onopordum* thistles, specificity tests are almost complete for the seed head weevil *Larinus latus* F. (Coleoptera: Curculionidae) and the seed fly *Tephritis postica* Loew (Diptera: Tephritidae) will soon be imported for specificity tests. Preliminary biology and specificity studies have also been carried out on the leafhopper *Tettigometra sulphura* Muls. (Hemiptera: Tettigometridae) and the stem boring weevil *Lixus cardui* Olivier (Coleoptera: Curculionidae). A pathogenic strain of the rust *P. cardui-pycnocephali* has been found for *C. tenuiflorus* and a strain more pathogenic for *C. pycnocephalus* than existing strains has also been found. Specificity testing is currently under way in Europe.

Table 1. Financial support of biological control of weeds by the Australian wool industry.

Period	Weed Species	Organisation[1]	Funds ($AUS)
1984-87	St John's wort	CSIROENTO	172,200
1984-94	Thistles	DCEVIC	369,000
1987-93	Nodding and slender thistles	CSIROENTO	706,800
1988-94	*Onopordum* thistles	CSIROENTO	565,500
1988-94	Slender thistle	CSIROPLANT	508,300
1985-92	*Xanthium* spp.	DANSW	250,000
1987-90	Docks and doublegees	DAWA	197,000
1987-93	Paterson's Curse	CSIROENTO	690,200
1989-92	Paterson's Curse	DCEVIC	139,000
1990-93	Horehound	DCEVIC	389,600
1987-88	Quarantine/glasshouse complex	CSIROENTO	700,000
1989-92	Relocation of European laboratory	CSIROENTO	446,600
	Total funds approved or committed		5,134,200

[1]Organization Codes: CSIROENTO = CSIRO Division of Entomology; CSIROPLANT = CSIRO Division of Plant Industry; DANSW = Department of Agriculture and Fisheries, New South Wales; DCEVIC = Department of Conservation and Environment, Victoria; DAWA = Department of Agriculture, Western Australia.

Horehound

Horehound (*Marrubium vulgare* L.; Labiatae) is a perennial European herb which is considered as both a pasture and environmental weed in southern Australia. A co-operative project between DCE Victoria and CSIRO Entomology commenced in 1990 with the former carrying out specificity tests with agents and ecological studies with the weed in Victoria and the latter selecting candidate agents in Europe. The plume moth *Pterophorus spilodactilus* (Curtis) (Lepidoptera: Pterophoridae) is currently undergoing host-specificity studies in quarantine (Weiss, personal communication).

Paterson's Curse

Paterson's Curse (*Echium plantagineum* L.; Boraginaceae) is an annual herb of European origin. The project commenced in 1973 but implementation was delayed from 1980-8 due to lengthy conflicts of interest (Delfosse 1988). The leaf-mining moth *Dialectica scalariella*

(Zeller) (Lepidoptera: Gracillariidae) was released in 1988 and is now widely established in southern Australia. The root weevil *(Ceutorhynchus larvatus* Schultze, Coleoptera: Curculionidae) was released initially in small numbers in 1989, and in 1991 in larger numbers. Recoveries have so far been made at 1 site searched following the 1991 releases. The similar species *C. geographicus* (Goeze) is currently being reared for field releases as is the flea beetle *Longitarsus aeneus* Kutsch (Coleoptera: Chrysomelidae). The 2 tingid bugs, *Dictyla nassata* Puton and *D. echii* Schrank (Hemiptera: Tingidae), will be the next species imported for release, while specificity testing is under way for the moth *Ethmia bipunctella* Fabr. (Lepidoptera: Ethmiidae)

Xanthium spp.

A number of annual *Xanthium* species (Asteraceae) from North and South America are particularly troublesome to the wool industry because the spiny fruits are contaminants of wool. Several isolates of the fungus *Colletotrichum orbiculare* (Berk et Mont.) v. Arx (Coelomycetes) are being investigated by the Department of Agriculture and Fisheries, New South Wales, with the view of developing mycoherbicides for the control of *Xanthium spinosum* L., *X. occidentale* Bertol., *X. italicum* Moretti, *X. orientale* L. and *X. cavanillensii* Schouw (Anonymous 1991). *X. spinosum* has also been surveyed recently in Argentina and Chile by CSIRO Entomology for classical biological control agents. Several have been found that show potential, but the project is currently inactive awaiting further support.

St. John's Wort

St. John's wort, (*Hypericum perforatum* L.; Guttiferae) is a perennial herb of European origin. Biological control of this weed in Australia commenced in the 1920s with 3 insects now commonly found attacking the plant. These are the leaf-feeding beetles *Chrysolina quadrigemina* (Suffrian) and *C. hyperici* (Foster) (Coleoptera: Chrysomelidae) and the gall midge *Zeuxidiplosis giardi* Kieffer (Diptera: Cecidomyiidae), while the root boring *Agrilus hyperici* (Creutzer) (Coleoptera: Buprestidae) persists in 1 locality. These agents were unsuccessful in giving economic control of the weed, especially in shaded situations and so in late 1970s CSIRO Entomology reviewed the earlier work and re-surveyed the area of origin of the weed for further candidate agents. As a result, the aphid *Aphis chloris* Koch (Hemiptera: Aphididae) established and spread at most release sites and the eriophyid mite *Aculus hyperici* (Liro) (Acari: Eriophyidae) has recently established at several sites. The moths, *Anaitis efformata* Guenée (Lepidoptera: Geometridae) and *Actinotia hyperici* Schiff. (Lepidoptera: Noctuidae) were also released but have not established. Further releases of *Agrilus hyperici* have been made and considerable specificity testing has been carried out on the moth *Aristotelia morphochroma* Wals. (Lepidoptera: Gelechiidae).

Docks

Four perennial *Rumex* species (Polygonaceae) of European origin are targets for biological control in Australia. These are *R. conglomeratus* Murray, *R. crispus* L., *R. obtusifolius* L. and *R. pulcher* L. (Scott 1990). The root-boring moths, *Bembecia chrysidiformis* (Esper) and *Chamaesphecia doryliformis* (Ochsenheimer) (Lepidoptera: Sesiidae), were imported and have been shown to be sufficiently host-specific for release. *C. doryliformis* has been reared and released in large numbers in Western Australia and more recently in the eastern States and recoveries have been made at release sites (Fisher, personal communication). *B. chrysidiformis* is still being reared in quarantine for release.

Spiny Emex

Emex australis Steinheil and *E. spinosa* (L.) Campdera (Polygonaceae) are annual herbs of southern African and north African origin respectively. The former occurs in all Australian States while the latter is less widespread. The spiny fruits of both species can injure animals while the leaves contain oxalates and can poison sheep if eaten in quantity (Auld and Medd 1987). A biological control program

commenced in 1973 (Harley and Kassulke 1975) with the introduction of the weevil *Perapion antiquum* (Gyllenhal) (Coleoptera: Curculionidae). Several introductions and releases were made and establishment has occurred but the weed has not been successfully controlled by this species (Shepherd 1989*a*). Studies on the host-specificity of the moths *Microthrix inconspicuella* Ragonot (Lepidoptera: Pyralidae) and *Rhodometra sacraria* (L.) (Lepidoptera: Geometridae) has shown that they are specific to the Polygonaceae but not sufficiently specific for release in Australia (Shepherd 1989*b* and personal communication). Recent work has concluded that there are no further potential biological control agents available in South Africa, but several species found on *E. spinosa* in north Africa and the near East offer some potential (J.K. Scott, personal communication, 1990).

Common Heliotrope

Common Heliotrope, *Heliotropium europaeum* L. (Boraginaceae) is an annual herb native to the Mediterranean region which is widespread in southern Australia. The plant contains alkaloids which cause jaundice, photosensitisation and indirectly, copper toxicity in sheep and cattle (Auld and Medd 1987). The flea beetle *Longitarsus albineus* (Foudras) (Coleoptera: Chrysomelidae) is the most widespread natural enemy found on common heliotrope in southern Europe and north Africa and was the first species imported and released. Large numbers were released in 1979-81 and 1986-7 and some recoveries made in 1987-8 but no recoveries have been made for several seasons. It seems that it may have persisted at undetectable levels as fresh individuals have just been found at 2 sites. The specificity of the weevil *Pachycerus cordiger* Germar (Coleoptera: Curculionidae) has been studied extensively but there are still some doubts as to possible effects on non-target species. After several years of testing, the rust fungus *Uromyces heliotropii* Sredinski (Uredinales) was released in the field at 2 sites in 1991. There was some initial spread and the rust has been recovered again this season. Further spread is expected and further releases have been made. A second pathogen, *Cercospora heliotropii-bocconi* Scalia (Hyphomycetes) is currently being studied.

Blue Heliotrope

Blue heliotrope, *Heliotropium amplexicaule* Vahl (Boraginaceae) is a hairy, prostrate, perennial herb native of south America which is widespread in New South Wales. It contains alkaloids which are suspected of causing toxaemic jaundice in sheep (Auld and Medd 1987). Blue heliotrope was surveyed for natural enemies in 1990-1 in south America, at the same time as *Xanthium spinosum.* Although the plant was difficult to find, and few natural enemies were found, some of these seem to have potential as biological control agents. At present however, the project is on hold pending re-allocation of resources.

Blackberry

European blackberries (*Rubus fruticosus* L. agg.; Rosaceae) are a group of perennial, thorny brambles of importance in the wetter climatic areas of southern Australia where 8 species and several hybrids in the aggregate have become naturalised. The rust fungus *Phragmidium violaceum* (Schulz) Winter (Uredinales) was shown to be specific to European blackberry and 15 isolates of the rust were selected in Europe for possible introduction to Australia (Bruzzese and Hasan 1986*a,b*). The rust was illegally introduced into southern Victoria in 1984 and rapidly spread throughout the weed infestation in Australia (Bruzzese and Field 1985). Laboratory studies indicated that the illegally introduced isolate was not as pathogenic to *Rubus procerus* P.J. Mueller, the most widespread European blackberry species in southern Australia, as some of the isolates selected by Bruzzese and Hasan (1986*a*). Permission to import the more pathogenic isolates was received in 1990 after lengthy delays caused by conflicts of interest. One isolate from central France, highly pathogenic to *R. procerus* was widely released in southern Australia in November- December 1991 (Bruzzese 1992) and has established at many release sites.

Future Prospects and Discussion

Several other pasture weeds of importance to the wool industry have been the targets of preliminary studies with a view to possible biological control. These include saffron thistle, *Carthamus lanatus* L. (Asteraceae); capeweed, *Arctotheca calendula* (L.) Levyns (Asteraceae); onion weed, *Asphodelus fistulosus* L. (Liliaceae); caltrop, *Tribulus terrestris* L. (Zygophyllaceae); cape tulips, *Homeria* spp. (Liliaceae); and some grasses (Gramineae). There are also some woody weeds of importance but these are principally native Australian species. The situation has been extensively reviewed by Cullen (1991) with respect to sheep pastures and by Cullen and Delfosse (1990) with regard to weeds in general.

Adequate facilities to carry out biological control work are also important and both CSIRO Entomology and DCE Victoria have recently completed construction of quarantine and glasshouse complexes, primarily for biological control of weeds. WRDC has been a major financial contributor to CSIRO's facilities both in Canberra and in Europe where a new laboratory is being built in France for the overseas exploration phase (Table 1).

All Research Corporations in Australia include the development of biological control and environmentally acceptable management systems for pest and weed control as part of their priorities. It is therefore likely that support will continue, as it must to ensure maximum exploitation of a control system that will help preserve fragile Australian ecosystems.

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