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BENEFITS FROM BIOLOGICAL CONTROL OF WEEDS IN AUSTRALIA

Rachel E. Cruttwell Mcfadyen[1]

ABSTRACT

Australia has a long and successful history in weed biological control, second only to the USA. A new book reviews all 73 weeds targeted in Australia, listing the >200 insect and pathogens released as biocontrol agents. Biocontrol programs have targeted agricultural, pastoral, rangeland, aquatic, and environmental weeds in tropical and temperate Australia. Despite so many releases over more than 100 years, there has been very little damage to non-weedy plants. In an economic impact assessment done in 2006 on the 36 programs for which there was economic data, only nine gave few or no economic benefits. Thirteen programs resulted in very large economic benefits, including those against blackberry and lantana which had been considered failures. Biocontrol against parthenium started in 1977 and cost over $11 million, but benefits from reduced control costs and increased pasture production exceed $39 million. Parthenium is still abundant in central and north Queensland but is now much easier for landholders to manage, and the economic benefits are very great. Overall, biocontrol has returned annual benefits of $95.3 million from an annual investment of $4.3 million. The Australian experience demonstrates that weed biocontrol is very cost-effective, most programs are successful and the risks are very small. Costs and risks are even smaller when using biocontrol agents already successful in another country. Asian countries could benefit from proven agents against weeds of importance in this region, such as parthenium, chromolaena, mikania, and mimosa, to gain the economic benefits already captured by Australia.

Key words: economic benefits, parthenium, chromolaena, mimosa

INTRODUCTION

Biological control of weeds using introduced insects and, later, pathogens has a long and successful history in Australia (Julien *et al.,* 2012). The first deliberate introduction was the cochineal insect *Dactylopius ceylonicus* in 1903, which failed but was followed by the release in 1914 of another strain which resulted in the successful control of drooping tree pear *Opuntia vulgaris*. This was followed in the 1920s by the introduction of up to 30 separate insect species, and the successful control of common pest pear *Opuntia stricta* by the moth

[1] Cooperative Research Centre for Australian Weed Management
PO Box 88, Mt Ommaney Qld 4074, Australia
Corresponding author's email: rachel.mcfadyen@live.com.au

Cactoblastis cactorum, and of other cacti by this moth and different *Dactylopius* species. Careful testing was undertaken with each insect to ensure that they would not feed on other plants. Australia was the first country in the world to use these tests, and has continued their use ever since.

After the great success of the prickly pear control, governments and scientists in Australia continued to support biological control, and by the 1980s Australia was a world leader in weed species targeted and new agents introduced (McFadyen, 1998). Australia also led the world with the first deliberate introduction of a plant pathogen as a biocontrol agent, the rust *Puccinia chondrillinae* released in 1971 to control skeleton weed *Chondrilla juncea*. Despite the success of this introduction, and the complete absence of attack on non-target plants, doubts about the safety of pathogens stifled further introductions for 20 years. As a result of the complete blocking of the legal pathways, there were two illegal introductions, the rust *Puccinia xanthii* against Noogoora burr *Xanthium strumarium* in 1974, and in 1984 the rust *Phragmidium violaceum* against blackberry *Rubus fruticosus* agg.. The result was excellent control of Noogoora burr in the high rainfall coastal districts, but only poor control of blackberry The second legal introduction was the release of the rust *Puccinia abrupta* against parthenium *Parthenium hysterophorus* in 1991. Since then, at least 10 plant pathogens have been released, with varying success, but the majority of agents used were insects.

The 1970s and 1980s saw the successful control of the waterweeds water hyacinth *Eichhornia crassipes*, salvinia *Salvinia molesta* and pistia *Pistia stratiotes*, all with different species of weevils; of harrisia cactus *Harrisia martini* with a mealybug; of giant sensitive plant *Mimosa (invisa) diplotricha* with a psyllid; and partial or developing control of St John's wort *Hypericum perforatum*, various thistles, *Sida acuta*, and annual ragweed *Ambrosia artemisiifolia*. In the 20 years since, successful control is being achieved against ragwort *Senecio jacobaeae*, groundsel bush *Baccharis halimifolia*, bridal creeper *Asparagus asparagoides*, rubber vine *Cryptostegia grandiflora*, giant mimosa *Mimosa pigra*, and parthenium (Briese, 2000; Julien *et al.,* 2012).

Within the Asian-Pacific region, Australia is the leading country working with biocontrol of weeds of tropical and sub-tropical climates, and Australian expertise has helped in biocontrol programs in many countries in the region, resulting in some notable successes. This review of the benefits gained by Australia from 100 years of weed biocontrol is therefore relevant and important for all Asian-Pacific countries.

REVIEW METHODS

In 2005 the Weeds CRC commissioned a major economic analysis of all weed biocontrol programs undertaken in Australia (Page and Lacey, 2006). Data on the costs of research and releases was obtained from scientists working in biocontrol and with access to unpublished material including internal reports, field results, budgets and financial statements. Where data were unavailable or incomplete, the duration of the research in years and the number of staff employed (obtained from internal reports) was used to calculate costs, using a factor of Aus$300,000 per scientist-year whether employed in Australia or overseas. Only economic costs and benefits were considered: other benefits were listed but not included in the analysis. Completed programs where no agents were released or established were included and costs included in the analysis. All economic data throughout the study were converted to 2005 Aus$ values.

In 2010 a major review of all weed biocontrol programs in Australia was undertaken and will be published shortly (Julien *et al.,* 2012). Numerous reviews of selected programs had been published over the years, but this will be the first comprehensive review since that by F. Wilson in 1960 (Wilson, 1960). The intention was to collect together all essential information on each program, referring to earlier published material where this exists, and summarizing critical data such as duration and resources for each program, overseas exploration localities and dates, personnel involved, agents tested and released, and outcomes achieved. Much of this information is hidden in internal reports and never published, and, since the 1980s, is increasingly inaccessible as a result of old electronic data storage media that have never been adequately indexed or archived. This review therefore aimed to publish critical summaries, with each chapter written by scientists who were actively involved in the biocontrol programs and had access to the unpublished files.

RESULTS

Economic Study

The major message from the economic study (Page and Lacey, 2006) was the huge overall benefit/ cost ratio, 23:1 for the 28 programs where data was available, an astonishing result. Even if the iconic prickly pear success is excluded, the overall benefit/ cost ratio is 12:1. Out of the total 36 programs, only nine were failures, ie resulted in few or no economic benefits.

Also important was the demonstration of the large economic benefits that result from even partial control of widespread weeds with high economic impacts, eg lantana and blackberry. Weed scientists tend to assume that if the weed is still a major problem despite biocontrol, then biocontrol has been a failure. But the economic analysis demonstrated that reductions in the vigour of a weed, or destruction of stands in some years but not all, still caused a significant reduction in the costs of managing the weed, or in the losses due to the weed. For example, it was calculated that $13.6 million has been spent on biocontrol of lantana (*Lantana camara*) in eastern Australia from 1914 to 2005. Losses due to lantana in 2005, in pasture, forestry, cattle poisoning and control costs, were at least $23.2 million per year, and this does not include biodiversity impacts in natural vegetation where control is not undertaken. As a result, although biocontrol is estimated to have resulted in only 10% reduction in lantana and only over the northern half of its range in Australia, this nevertheless results in sufficient savings in control costs and lost production to give an overall benefit/ cost ratio of 6:1 – ie $6 gained for each $1 invested. As biocontrol agents gradually increase and spread, these benefits continue to rise. Results for blackberry are similar.

A third finding was the importance of documenting the economic impact of target weeds at the start of a biocontrol program. It is essential to quantify the economic costs of the target weed at the start, so that the benefits from any reduction in its abundance can in turn be quantified. This is best done as an initial benefit/ cost study by independent economists prior to starting any biocontrol program, which should be part of the decision whether or not to undertake biocontrol (Jarvis *et al.,* 2006). Such analyses clarify where data are not available, as well as identifying the critical issues for successful control, e.g. is total control required, or would any reduction in impact have important economic benefits. For most weeds, even non-production impacts have an economic aspect; if control was cheap or easy, the community would not permit weeds to overrun environmental areas. Economic impact is the sum of many factors: loss of agricultural productivity; actual and potential extent of infestation; spread rate; cost of removal; and frequency of recurrence. Initial measurement of these is essential to make future assessments possible. Analyses can then be repeated when more information is available (e.g. whether suitable agents can be found; spread rate of weed). Initial studies, using realistic probabilities of success based on historic rates for the country and type of weed, and including the full range of potential costs and benefits, are powerful tools to convince funding agencies to undertake a biocontrol program. Later analyses based on these data will clarify the true probabilities of failure and therefore the true return-on-investment for weed biocontrol programs.

The analysis also showed that program costs varied greatly. Some programs continued over decades, with years of overseas research and the employment of several scientists; the most expensive being that against *Mimosa pigra*, with a total cost of Aus$21.6 million. The cheapest successful program was against annual ragweed, with a total cost of only Aus$0.6 million. This cost was low because the successful agents were imported for the control of the closely related weed parthenium, and the only additional costs were for extra releases in ragweed areas. However, overall the median cost for each of the 17 successful programs was Aus$7 million and the duration was 14 to 27 years. This demonstrates that it is unrealistic to expect good results from programs run for a short time or 'on the cheap', except where agents have already been tested and successful in another country, eg the biocontrol of salvinia in Sri Lanka (Doeleman, 1990), or the biocontrol of *Mimosa diplotricha* in Papua New Guinea (Kuniata and Korowi, 2004).

Overall Review

A total of 73 weeds have been targeted for biocontrol in Australia, and between 1903 and 2010 more than 200 insect and pathogens have been released as biocontrol agents against these weeds. Biocontrol programs have targeted agricultural, pastoral, rangeland, aquatic, and environmental weeds in both tropical and temperate Australia. Despite so many releases over more than 100 years, there has been very little damage to non-weedy plants, with only one example of minor economic losses and none of environmentally significant damage.

Of these 73 programs, some (e.g. against *Mimosa pigra*, parthenium, lantana, skeleton weed, St John's wort and Paterson's curse *Echium plantagineum*) were large well-funded programs over many years, with many potential agents investigated and several imported and released. These weeds generally have a wide distribution in their native range with a large suite of native insects and pathogens to choose from. In other programs, the native range is very limited and as result, very few agents were found and less than five were released. However, some of these were nevertheless extremely successful, with one or two agents successfully establishing and resulting in almost complete control of the weed. Examples are the programs against docks *Rumex* spp., rubber vine, harrisia cactus, and the floating waterweed salvinia.

Several programs were hindered from the start by the presence of closely-related native plants or plants of economic value, e.g. fireweed *Senecio madagascariensis*, where there is a large complex of native senecios, or parthenium and annual ragweed which are both closely related to sunflower *Helianthus annuus*. On the other hand, other programs benefited from agents initially investigated for related weeds or by other countries, e.g. the successful control of annual ragweed using insects imported against parthenium weed, or control of alligator weed *Alternanthera philoxeroides* using insects already tested by the USA. At least one program, against the widespread tropical weed chromolaena *Chromolaena odorata*, was undertaken for countries in the Asian-Pacific region, by Australian scientists funded by Australian aid money, prior to any biocontrol program commencing within Australian territories. Australia has benefitted from reductions in the spread southwards of the weed and in the knowledge gained for the biocontrol program about to commence within Australia.

A result of major importance has been the complete absence of significant harmful impacts from the release of more than 200 plant-feeding insects and plant pathogens over the last 100 years. Minor damage has been caused by two agents released against lantana; the leaf-feeding beetle *Octotoma scabripennis* occasionally causes limited damage to commercially-grown herbs in the family Verbenaceae; and the sap-sucking bug *Acanophora compressa* damages the ornamental tree *Citharexylum spinosum* (Palmer *et al.,* 2010). In both cases, there is no environmental impact as the plants attacked are not native to Australia, and the economic damage is very minor. On the other hand, the successful control of the prickly pears and of tiger pear *O. aurantiaca*, achieved between 1903 and the 1930s, by the release of cochineal insects *Dactylopius* spp. and the cactoblastis moth, is still just as successful 80 to 90 years later, with no evidence of the development of resistance in the weedy cacti nor of increased host range in the insects. Other successful programs, such as the release in 1970 of the rust against skeleton weed or of the cactus mealybug in 1974 against harrisia cactus, also continue to give excellent control 40 years later with no evidence of the development of non-target impacts or plant resistance.

Implications for the Asian-Pacific Region

The main message for weed management in the Asian-Pacific region is that Australia has already achieved successful biocontrol of several weeds which are major problems in one or more countries of the region. Importation of the successful biocontrol agents would be easy and relatively cheap, as the agents can be easily obtained in Australia and as their biology and host-specificity is already known. For example, *Mimosa diplotricha* has been successfully controlled in northern Australia by the sucking bug *Heteropsylla spinulosa*, and similar results have been obtained in PNG (Kuniata and Korowi, 2004). The insect has been established in Fiji and the Solomon Islands, and recently in East Timor (McFadyen, 2012), but there are many countries where this weed is a problem for agriculture and forestry, and which would benefit from introduction of the biocontrol agent. Similarly, the release of several insects and two rust pathogens have resulted in a significant reduction in the problem caused by parthenium weed in Australia, and releases of these agents should be considered in other countries where parthenium is a problem (Dhileepan and Strathie, 2009; Dhileepan and McFadyen, 2012).

Another lesson is the large economic benefits from reduction in the vigour of a major weed, even if control is not complete. For example, in Indonesia and elsewhere, the weed chromolaena often replaced other weeds, such as lantana, when it first invaded. Once chromolaena has been successfully controlled by introduced biocontrol agents, lantana and other weeds may re-invade. However, control costs (or production losses) for chromolaena greatly exceed those from lantana; hence, there is still a benefit from its successful biological control even if other weeds subsequently re-invade.

With widespread invasive weeds, failure to use all successful control methods means that invasive plants continue to spread and cause increasing damage. In 2004, weeds cost the livestock industry in Australia $1.8 billion a year in lost production (Sinden *et al*., 2004), which represents many thousands of square kilometres of land effectively abandoned to weed invasion. The use of conventional control methods (herbicides, mechanical) results in increasing economic, environmental and health costs, especially in environmentally sensitive areas such as riparian lands or national parks.

The key messages from these two reviews, therefore, were that biological control of weeds is very cost-effective method and has given excellent returns-on-investment for Australian governments; it is safe; and the majority of programs achieve good levels of control. Governments in Asian-Pacific countries should put more effort and resources into biological control, starting with those weeds where success has already been achieved in Australia or elsewhere.

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