The New biocontrol solutions for sustainable management of weed impacts to agricultural profitability project is a $13 million, five-year project, managed by AgriFutures Australia, which aims to improve the long-term profitability of primary producers affected by the target weeds through the development of novel biocontrol solutions that will reduce recurrent costs of weed control.

Weeds threaten Australia’s natural environment and rural industries. They displace native species, contribute significantly to land degradation, and reduce agricultural productivity.

AgriFutures Australia, through the Australian Government Rural R&D for Profit Program, is working with departments of agriculture in NSW, Queensland and Victoria, and the CSIRO to develop new biocontrol agents to target 10 weed species that are significant on a national level — weeds that are difficult to control with current methods and have substantial impacts across agriculture sectors.

The target weeds are: African boxthorn, cabomba, prickly acacia, sagittaria, silverleaf nightshade, fleabane, sowthistle, mother-of-millions, giant rat’s tail grass and ox-eye daisy.

Learn more
agrifutures.com.au/weeds-biocontrol
Biocontrol of weeds — behind the scenes

The successful development of novel biocontrol solutions can improve the long-term profitability of primary producers affected by invasive weed species. However, this is a complex process and certainly one that does not happen overnight.

In this autumn 2019 update of the New biocontrol solutions for sustainable management of weed impacts to agricultural profitability project, we review the essence of biocontrol as a weed management concept and outline the process that forms the discovery-to-delivery pipeline.

It goes without saying that undertaking a biocontrol effort is not without its risks. A rigorous risk management process is built into the integrated multi-weed and multi-agency model that sits behind this project.

What is biological weed control (biocontrol)?

In their native range, plant populations are regulated by a variety of natural enemies, such as insects and pathogens, which attack the seeds, leaves, stems and roots of a plant.

When plants are introduced to new locations where these natural enemies do not occur, their populations can grow unchecked to a level where they are regarded as 'weeds'.

Biocontrol involves identifying and introducing naturally-occurring enemies to help reduce the impact of the introduced plant in its new location.

A key advantage of biocontrol over other weed control options (e.g. chemical, mechanical and grazing pressure) is that when natural enemies (agents) are widely established they exist permanently in the ecosystem and are mostly self-replacing.

At a high level, weed biocontrol programs involve: identifying new effective agents (Phase 1), assessing the risk and efficacy of such agents (Phase 2), followed by approval for release in Australia, mass-rearing, large-scale release and redistribution of these agents (Phase 3).

The New biocontrol solutions for sustainable management of weed impacts to agricultural profitability project specifically targets Phases 1 and 2. When Phase 3 is supported and agents approved for release, the anticipated outcomes from the project will reach nation-wide.
Nominating the species — which weeds?

Weed biocontrol programs are expensive. The New biocontrol solutions for sustainable management of weed impacts to agricultural profitability project is a $13 million, five-year project. A collaborative and consultative process, focussed on clear selection criteria, determines which weeds will be the target of such a significant investment.

For this project, consultation with industry stakeholders identified and prioritised 10 target weed species. The criteria included addressing significant impacts across multiple industry sectors and the likelihood of successful control.

The target weeds impact cropping (fleabane, sowthistle, silverleaf nightshade), pasture (African boxthorn, mother-of-millions, ox-eye daisy, giant rat’s tail grass, prickly acacia) and water resources (cabomba, sagittaria), and collectively their impacts cost Australian agriculture more than $400 million/year.

What do we already know?

After selecting the target species the research team undertakes a review of existing knowledge regarding the plant through a comprehensive literature review. The type of information sought includes: current geographical distribution, naturally-occurring enemies, reproductive mechanisms and propensity to spread.

“The literature review for African boxthorn (Lycium ferocissimum) identified 49 organisms attacking or feeding on the plant, while 71 organisms were identified for fleabane and 147 for sowthistle.”

The benefits of collaboration

Australian researchers are piggy-backing on more than 10 years of research into biocontrol agents for ox-eye daisy by joining forces with the Centre for Agriculture and Bioscience International (CABI), Switzerland. Local researchers are benefiting from a vast body of existing work carried out by Swiss researchers for the US and Canada.

Instead of starting from scratch, Australian researchers have a bank of test data to draw from, which will fast-track the progress of local biocontrol efforts against the invasive weed.

Comparing apples with apples

Like any organism, individual weed species vary enormously in terms of their genetic make-up. In order to refine the search for suitable biocontrol agents, researchers must first identify the specific ecotype of the target weed and then compare their findings with overseas populations to hone the search for the most promising biological control agents.

This process can involve DNA profiling of the weeds in Australia and comparing the profile with overseas populations.

“The genetic analyses and bioclimatic modelling indicated the likely origins of the specific biotypes of the following target weeds: African boxthorn (Western Cape, South Africa), Cabomba (Southern Brazil, Paraguay, Uruguay and Argentina, sowthistle (Italy, Morocco, Croatia and France) and silverleaf nightshade (Argentina and the USA).”
The hunt begins

Armed with knowledge regarding the genetics of target weeds and their prospective origins, researchers now begin the localised hunt for potential agents.

Many of these agents will be new to science, but through modern techniques such as DNA barcoding, it is possible to learn so much more about them, such as the genetic relationships between related agents from different locations and whether these may have different host ranges or adaptations to different climates.

“Across the range of target weeds being investigated in the New biocontrol solutions for sustainable management of weed impacts to agricultural profitability project, native range surveys have identified more than 20 potential biocontrol agents. Among these are insects (including weevils and thrips), fungi (including rust fungi), and mites.”

Risk management

A rigorous risk management process is built into various stages of the integrated multi-weed and multi-agency model that sits behind the New biocontrol solutions for sustainable management of weed impacts to agricultural profitability project.

When potential agents have been identified in the weed’s native range, researchers make a request to import the agents into a secure quarantine facility in Australia. Upon arrival into Australia the research team embarks on developing techniques for rearing and propagating the agents. Agents need to be able to complete their life cycle on the target plant and produce a population sufficient for further testing.

As part of the risk-management process, potential agents undergo meticulous testing, including host-specificity testing and developmental threshold testing.

Development threshold tests investigate the impact of various temperature regimes on the development and growth of the agents. This is useful to determine the climatic conditions required for successful reproduction of the organism and where the agent has the best chance of establishing.

Closely related species (including native and economically significant species) are tested to see if there is an impact of the agent on these species.

Host-specificity tests can include:

- a no-choice test – agents are given access only to one species at a time. Observations are made regarding feeding behaviour and egg laying. If there is successful development into adults, the process is repeated to see if further generations develop
- multiple choice testing including the target weed to determine preferences. This may be done in Australian quarantine facilities and/or in a field setting in the native range of the weed.

This work is often carried out through a combination of studies in Australia and in the country of origin of the target weed.

If there are no significant impacts on non-target species, such as native species or commercially important crops, then an application is made to release. If testing reveals a potential impact on any non-target species, the agent is no longer a suitable candidate and the search turns to other potential agents.

As of January 2019 the following candidates for control agents were undergoing host-specificity testing:

- a weevil and a moth (ox-eye daisy)
- a newly discovered flea beetle (mother of millions)
- a rust fungus (African boxthorn)
- a weevil (cabomba)
- a gall thrips and a gall mite (prickly acacia)
- a stem galling wasp (giant rat’s tail grass)
- two weevil species (sagittaria).

A number of potential agents for sowthistle are currently undergoing host specificity testing in France and on silverleaf nightshade in Argentina.
“Using community ecology, advanced genomics and food web models to compare the network of interactions between plants and insects associated with sowthistle in Europe and Australia, the project may shed light on how biocontrol could function in a real-world setting, helping researchers to better anticipate benefits and risks.”

**Controlled release**

If the full range of tests are successful, researchers apply to the Department of Agriculture (DoA) to release the agent from quarantine. Based on the recommendation from DoA, an application is made to the Department of the Environment and Energy (DoEE) to have the list of approved species for importation amended.

Approval to release has to satisfy the DoA, the DoEE, state governments and other bodies, and individuals potentially impacted by the release. The initial assessment of the scientific validity and rigor of the underpinning science is undertaken by an expert panel.

Release sites can be influenced by the climatic suitability of the site for candidate agents. CLIMEX, a modelling tool developed by CSIRO during 1985, in conjunction with an understanding of development thresholds, enables the prediction of likely establishment of candidate agents across the weed in Australia. This can also be extended to potential climate change scenarios.

**Taking to the field**

When release is granted, researchers establish trials to confirm the agent will establish in the field. If these field trials are successful, further activities are undertaken to distribute the agent, which may include collaboration with local interest groups.

The biocontrol program against Paterson’s curse demonstrates how farmer and Landcare participation in the release of hundreds of thousands of agents brought about the successful control of this weed across southern Australia. This program has given more than $1bn worth of benefits for the grazing industries, including reduced control costs, reduced animal deaths and increased pasture productivity, improved land values and improved social wellbeing in the affected farmer communities across the country.

**Monitoring and evaluation**

Following the release activities, researchers and project collaborators continue to monitor release sites and the surrounding areas for both target and non-target impacts. Monitoring can also include a citizen science component, with community volunteers mapping agent establishment and sharing their observations on the [Atlas of Living Australia’s Biocontrol Hub](#).

The timeframe from nomination to release of an agent can take less than 12 months if the agent has already been released in another country, and up to a decade, if the weed has not yet been the target of biocontrol elsewhere in the world. Once in the field, impact is generally assessable after 10 years. This means the time from nomination as a target weed through to tangible effects in the field can take up to 16–20 years.
Stop/Go points in the discovery-to-delivery pipeline

The passage from discovery to delivery of a successful weed biocontrol is not always clear sailing. There are various stop/go points along the way.

1. Can’t find an agent — this is unusual, but always a possibility.
2. Find an agent but can’t rear them — generally this doesn’t happen, but it can take time for researchers to develop a fail-safe rearing technique. Developmental threshold studies for *D. aeratana* were delayed due to adult moths from the culture not laying fertilised eggs. This issue has now been resolved.
3. Can rear, but not host specific — this is the biggest stop/go point. The failure during host-specificity testing of a promising biocontrol agent identified in an earlier project has meant a redoubling of effort to find suitable candidates for silverleaf nightshade control this time around.
4. Get released but don’t establish in the field — between 65 and 70% of biocontrol agents establish in the field. Once in the field, dependent on the agent, impacts can manifest themselves from between 5–10 years, but any benefits are perpetual.

Photo credit: John Heap, PIRSA

Research organisations

**CSIRO**
Sowthistle, African boxthorn, cabomba, fleabane

**Vic DJPR**
Silverleaf nightshade, sagittaria

**QDAF**
Prickly acacia, giant rat’s tail grass, mother-of-millions

**NSW DPI**
Mother-of-millions, ox-eye daisy, giant rat’s tail grass

Partner organisations

**PIRSA**

**SEQ Water**

**GRDC**

**Ravensthorpe Shire**

**USDA**

**Goulburn Murray Water**

**Murrumbidgee Irrigation**

**Coleambally Irrigation**

**Goulburn Broken Catchment Management Authority**

**North Queensland Dry Tropics**

**Central Coast Council**

**Murray Local Land Services**

**Murrumbidgee Landcare**

**Central Murray County Council**

**NSW Office of Environment and Heritage**

**NSW National Parks and Wildlife Service**

**NSW Biocontrol Taskforce**

**Bundaberg Council**

**North West Local Land Services**

**Gladstone Council**

**HQ Plantations**

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