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REVIEWING APPLICATIONS TO IMPORT AND/OR RELEASE BIOCONTROL AGENTS INTO AUSTRALIA

Introduction

This package is intended to be used in Australia as **an aid in decision making by reviewers of biological control agent import and/or release applications.** It aims to give sufficient information on biological control, the review process, and each section of the applications to import and release biological control agents **to allow reviewers to make informed, reasoned decisions** on acceptance or rejection of the applications. In some cases the decision may be to refer aspects of the application to other specialists for advice.

The package has been compiled in Adobe Acrobat. **System Requirements are:**

- x86-based personal computer (386 minimum; 486, Pentium, or Pentium Pro recommended)
- Microsoft Windows 3.1, Microsoft Windows for Workgroups, Microsoft Windows 95, Microsoft Windows NT 3.5.1 or 4.0
- 4 MB application RAM
- 7 MB hard disk space, plus 7 MB additional temporary disk space available during installation

Throughout this package, '**agent**' refers to the organism proposed as a biological control agent, and '**target**' refers to the pest target for the biological control program.

To discover how this package works, go to **How to use this package**

To examine the major topics covered in this package, move your cursor to and click on: **Main menu.**

The information may be examined simply by scrolling through the pages in sequence (i.e. by using "page down" button, or using the scroll bar at the right of the screen).

However, the package has been structured to allow the user to skip across related topics by moving the cursor to, and clicking on, highlighted parts of the text. Or you can use the bookmarks to skip to relevant pages. To view the bookmarks, go to VIEW and select Bookmarks with Page.

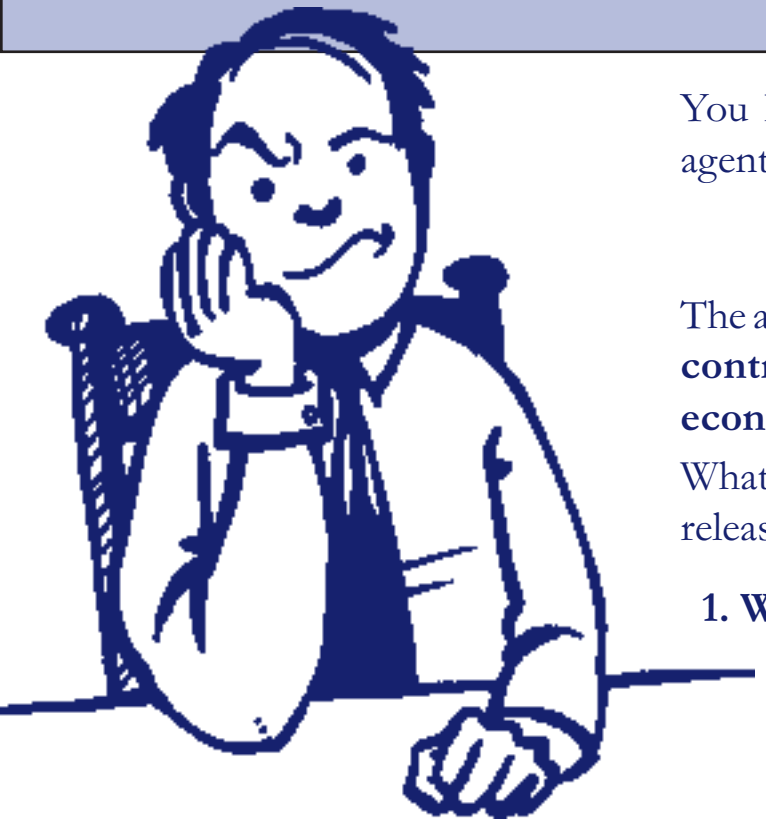
Text highlighted in pink leads to full references for citations and text highlighted in red leads to new pages and other sections of the package.

To return to your previous page after you have used the hot-linked text, click right mouse button and then click : **"Go back"**,
or simply click the button with two arrows on the menu bar: 

Different coloured headers are used for the different sections of the package.

Click on the small note paper at the top corner (either left or right) of each image to view the pop-up caption and acknowledgement. Try it out with this image.

What To Do



You have been sent an application to import and/or release a biological control agent in Australia to review.

WHAT NEXT?

The aim of the review process is: **"To promote release of safe agents for biological control by ensuring that risk of damage to non-target species, including economic, beneficial, and native species, is defined and acceptable".**

What **questions** should you be asking as you read the application to import and/or release biological control agents in Australia?

1. Was the host testing adequate?

Factors involved :
i. was the test approved?
ii. are there at least three replicates in each test?

Go to:
Host specificity overview
Observations in the country of origin
Background to host specificity testing
Host specificity testing: methodology for insects
Host specificity testing: methodology for pathogens for weeds
Host test list

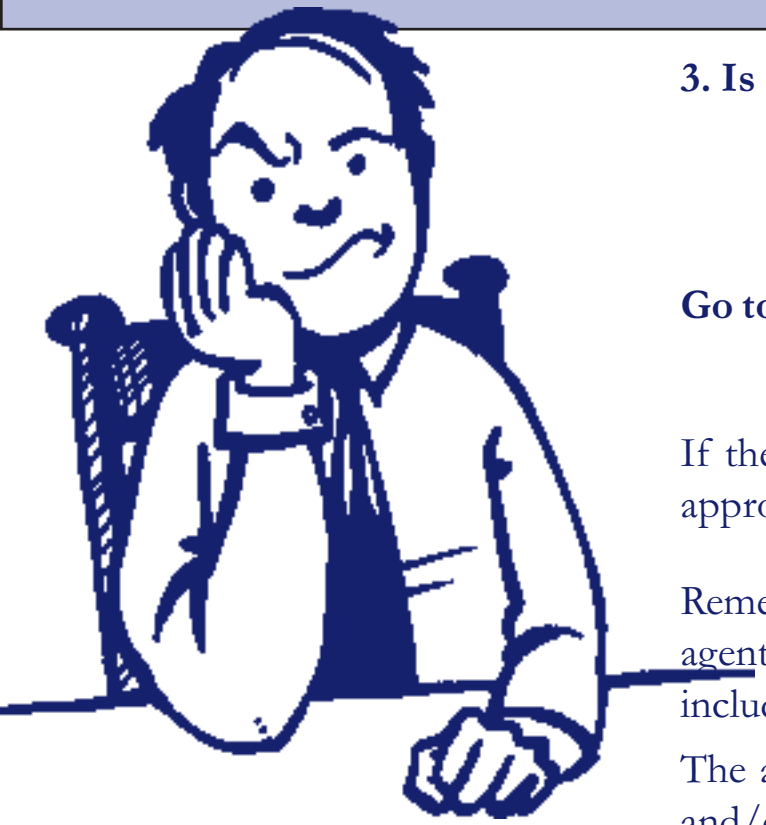
2. Are non-target organisms (plants and animals) at risk?

Factors involved:
i. any attack on non-targets?
ii. likely to breed in the field?

Go to: **Risk analysis**

More questions on next page

What To Do (continued)



3. Is this risk acceptable?

Factors involved:
i. how damaging is the pest?
ii. how damaging are alternative control methods?
iii. how effective are alternative control methods?

Go to: Risk analysis

Positive and negative impacts of biological control: Rubbervine

If the answers to the previous questions are satisfactory, then the approval should be approved.

Remember that the aim of the review process is to: "To **promote release** of safe agents for biological control **by ensuring that risk of damage** to non-target species, including economic, beneficial, and native species, **is defined and acceptable**".

The aim of this package is to help the process of reviewing applications to import and/or release bioogical control agents in Australia

The application and the package provide information that may not be of direct relevance to making your decision, but may be useful background material.

e.g. Legal background to biological control
Current protocols and procedures
Basic concepts and methods in a biolgical control program

Goto: Main Menu

Main Menu

Select from the major topics covered in the package:

- Introduction;
- Legal background to biological control;
- Current protocols and procedures;
- Basic concepts and methods in biological control;
- Positive and negative impacts of biological control;
- Host specificity - overview;
- Risk analysis;

or proceed to a detailed examination of:

- Sections of guidelines/applications

Legal background to biological control

The importation and release from quarantine of biological control agents in Australia is regulated by the Quarantine Act 1908, the **Wildlife Protection (Regulation of Exports and Imports) Act** 1982, and the **Biological Control Act** 1984.

The Australian Quarantine and Inspection Service (AQIS) of the Department of Primary Industries and Energy administers the Quarantine Act and the Biological Control Act, and Environment Australia (formerly the Australian Nature Conservation Agency (ANCA) and before that National Parks and Wildlife Service (NPWS), administers the Wildlife Protection (Regulation of Exports and Imports) Act.

The Quarantine Act takes precedence over the other two Acts. The Biological Control Act, which obviously deals specifically with biological control, provides guidelines for decision making about effects of biological control agents on non-target organisms including native species. On the other hand, the Wildlife Protection (Regulation of Exports and Imports) Act deals in general terms with export and import of organisms, and mentions biological control specifically only as an exclusion from parts of the Act. Although the philosophy of the Biological Control Act is generally used as the primary guide in making decisions about biological control agents, it has been invoked in two cases (biological control of Patterson's Curse / Salvation Jane, and the release of rabbit calicivirus).

Australia is a signatory to the **FAO International Plant Protection Convention** of November 1997. As such, Australian laws must conform with the convention. Australia is also a signatory to the International Standards for Phytosanitary Measures (Part 1- Import Regulations. Code of Conduct for the Import and Release of Exotic Biological Control Agents), and the procedures and protocols implemented by AQIS conform with these standards.

NB Interpretations and recommendations presented in this package have no legal authority!

Return to: Main menu

Related topics: Current protocols and procedures

Article VII - Requirements in relation to imports

1. With the aim of preventing the introduction and/or spread of regulated pests into their territories, contracting parties shall have sovereign authority to regulate, in accordance with applicable international agreements, the entry of plants and plant products and other regulated articles and, to this end, may:

a) prescribe and adopt phytosanitary measures concerning the importation of plants, plant products and other regulated articles, including, for example, inspection, prohibition on importation, and treatment;

b) refuse entry or detain, or require treatment, destruction or removal from the territory of the contracting party, of plants, plant products and other regulated articles or consignments thereof that do not comply with the phytosanitary measures prescribed or adopted under subparagraph (a);

c) prohibit or restrict the movement of regulated pests into their territories;

d) prohibit or restrict the movement of biological control agents and other organisms of phytosanitary concern claimed to be beneficial into their territories.

Return to: Main menu

Quarantine Act

Under the Quarantine Act, importation and release of biological control agents is covered by Plant Quarantine Regulation 28 and Animal Regulation 86.

REGULATION 28

Importation of Insects

28. (1) Insects and parasites shall not be imported unless:

(a) the importer, prior to shipment, has certified the present state of knowledge concerning the life history, hosts, hyper-parasites (if any) and the economic value of the insects or parasites together with a description of the experiments which it is proposed to conduct and the precautions which are to be taken during the course of the experiments to prevent escape of any insect or parasite;

(b) the importer, prior to shipment, has made an application for permission and has obtained the consent of the Director for that importation;

(c) the importer has given at least 2 days' notice of the arrival of the insects or parasites;

(2). The insects shall remain in quarantine for such time as the Director requires.

Wildlife Protection Act 1982 (Regulation of Exports and Imports)

The relevant "object of this Act" (Section 3) is "to further the protection and conservation of the wild fauna and flora of Australia ... by-

> (e) regulating the import of animals and plants of a kind the establishment of which in Australia .. could have an adverse effect (otherwise than by reason of a disease) on, or on the habitats of, native Australian animals or native Australian plants".

A **permit to import** is required under the Act before a biological control agent is imported or released from quarantine.

Return to: Main menu
Background to biological control

Related topics: Protocols and procedures
Biological Control Act

Biological Control Act 1984

The Biological Control Act is administered by the Commonwealth Department of Primary Industries and Energy (DPIE), under streamlined **procedures** with most powers delegated (Section 10) to the Australian Quarantine and Inspection Service (AQIS). Parallel legislation has been enacted in each State.

The relevant significant parts of the Act are:
Part III - **declaration of target organisms**
Part III - **declaration of agent organisms**
Part V - release of agent organisms

Pest organisms are declared to be **targets** for biological control under the Act if control (of the pest organisms) would cause no significant harm, or if any harm caused would be significantly less than the harm in not controlling the (pest) organisms. Similarly, biological control agents are declared to be **agent organisms** under the Act if the agent has potential for control, and if the agent would not cause harm or if any harm caused would be less than the harm in not controlling the pest (organisms) or less than the harm in using alternative control measures.

Once targets and agents have been declared under the Act, **legal proceedings** to prevent release of the agents or to recover damages resulting from effects on non-target organisms can be instituted only if damage to non-target organisms was predictable but not considered when declaring the agent.

Return to: **Main menu**
Legal background to biological control

Related topics: **Wildlife Protection Act**

Streamlined procedures under the Biological Control Act

Procedures have been streamlined since the legislation was enacted: non-controversial applications are handled by AQIS without reference to either Standing Committee on Agriculture and Resource Management (SCARM) (Australian Agricultural Council in the Act, particularly Sections 24, 25) or the Commonwealth Biological Control Authority, whose powers are currently exercised by the Minister for DPIE (Section 8).

Return to: Main menu
Legal background to biological control
Biological Control Act

Related topic: Current protocols and procedures

Declaration of target organisms under the Biological Control Act

On the recommendation of SCARM and after calling for submissions and, if necessary, setting up an inquiry, AQIS may (Section 20.2) "declare organisms .. to be target organisms" for biological control if (Section 20(1)e)

> "(i) the control throughout Australia of organisms of that kind would not cause any significant harm to any person or to the environment; or
>
> (ii) any harm caused to persons or to the environment by the control throughout Australia of organisms of that kind would be significantly less than the harm caused , or likely to be caused, by failure to control organisms of that kind throughout Australia".

Declaration of target organisms is **not subject to the same review process** as applications to import and release agents, the subject of this package.

Return to: Main menu
Legal background to biological control
Biological Control Act

Declaration of agent organisms under the Biological Control Act.

AQIS decides, on the basis of review by all State and Commonwealth primary industry and conservation authorities (see Current protocols and procedures), whether a potential biological control agent, proposed in a formal application, should be declared as a biological control agent under the Act (Sections 26-29) and released (Section 35) if (Section 29(1)d)

> "(i) the release of the relevant organisms would not cause any significant harm to any person or to the environment, other than the harm (if any) resulting from the control throughout Australia of target organisms of that kind or those kinds; or
>
> (ii) any harm caused to persons or to the environment by the release of the relevant organisms, other than the harm (if any) resulting from the control throughout Australia of target organisms of that kind or those kinds, would be significantly less than-
>
> > (A) the harm caused, or likely to be caused, by failure to control target organisms of that kind or those kinds throughout Australia; and
> >
> > (B) where target organisms of that kind or those kinds can be controlled by the release of other organisms or otherwise than by biological means- the harm (if any) caused, or likely to be caused, by controlling target organisms of that kind or those kinds throughout Australia by the release of those other organisms or by those other means."

i.e. Agents will be declared if:

- ***there are no detrimental effects to non-target organisms or,***
- ***if there are detrimental effects, the harm caused is less than the harm in not controlling the target pest or the harm caused by other control measures.***

Return to:

Main menu
Legal background to biological control
Biological Control Act

Related topic:

Current protocols and procedures

Legal proceedings under the Biological Control Act: release of agent organisms

Under Section 36(1) "no action or other proceeding shall be instituted or continued in any court-

(a) to prevent the release of agent organisms in accordance with section 35;

(b,c) to recover damages in respect of any loss incurred, or any damage suffered, in a Territory (b) or State (c) by reason of the release of agent organisms in accordance with that section."

However, under sub-section 36(3) "Nothing in sub-section (1) prevents the institution or continuation in any court of an action or other proceeding to recover damages in respect of any loss incurred, or any damage suffered, by reason of the release of agent organisms of a particular kind in accordance with section 35 where-

(a) the loss incurred or the damage suffered was the result of the release having had a significant effect on other organisms;

(b) at the time of the release, the persons in Australia having a reputation for special knowledge of the biology of organisms of that kind knew, or had reasonable grounds to expect, that such a release could have such an effect; and

(c) in making the declaration **declaring organisms of that kind to be agent organisms**, the Authority did not take into account (whether because of the state of scientific knowledge or otherwise) the factor that such a release could have such an effect."

i.e. legal action may be taken if:

**** applicants (for release of an agent) had reasonable grounds to expect damage to non-target organisms but permission to release was granted without taking this information into account.***

N.B. THESE SECTIONS PROVIDE A LEGAL REQUIREMENT FOR A REVIEW PROCESS

Return to:

Main menu
Legal background to biological control
Biological Control Act

Related topics:

Current protocols and procedures;

Current protocols and procedures: background

Procedures for processing applications to import and release biological control agents (see **Flowchart of protocols and procedures** and **Administrative procedures**) were agreed to in 1987 by Australian Quarantine and Inspection Service (AQIS), Environment Australia (formerly ANCA and NPWS), State agricultural and conservation authorities, and CSIRO.

Information requirements for applications (See "**Guidelines on the information to be provided with an application to import or release biological control agents**") were based on protocols developed by the Biological Control of Arthropod Co-ordination Sub-Committee in 1983, and which had Standing Committee on Agriculture endorsement. Specific "**Guidelines for the importation of fungal pathogens**" have also been produced. Current guidelines can be obtained from AQIS home page at: http://www.dpie.gov.au/aqis/homepage/quarantine/bcontrol.html

The protocols and guidelines have been developed through a relatively informal exchange of ideas between biological control practitioners and State and Federal senior pest management officers. Those involved were well aware of the issues involved, and the intended significance of the guidelines in addressing those issues. However, the documentation now available fails to explain the background to the guidelines and the significance of the required information. Even the fundamental **aim of the review** process has not been defined.

Return to: **Main menu**

Related topics: **Legal background to biological control**
Biological Control Act
Wildlife Protection Act
Flowchart of protocols and procedures
Administrative procedures
Guidelines on the information to be provided

Current protocols and procedures: administrative procedures

Under current procedures (see **Flowchart of protocols and procedures**) a research organisation wishing to import a biological control agent makes a single application to AQIS. In turn, AQIS registers the application, advises Environment Australia, and circulates the application to the respective nominated officer in each State agricultural and conservation authorities and CSIRO. The States provide individual responses to AQIS, following internal consultation, by a date specified by AQIS. These responses are copied and conveyed to Environment Australia for information. Issues raised in responses are taken up and resolved between the applicant and respondent; usually by means of an interim report to the applicants. AQIS on resolution of outstanding issues with respondents and in consultation with Environment Australia, draws up a permit to import the potential biological control agent into quarantine (See **Formal approvals**).

Formal approval of a suggested a **host-specificity test list** is usually sought at the same time as approval to import the agent, but may be submitted to the review process separately.

Whilst in quarantine, detailed testing is carried out to verify **host-specificity of the agent**. On completion of **host-specificity testing**, a further application is submitted to AQIS and Environment Australia. This application for release of the agent from quarantine is also registered and similarly referred to co-operating authorities for response, resolution of issues and consideration in consultation, prior to formal approval of release from quarantine. Input from senior scientists in AQIS is also sought to ensure continuity and to alleviate possible risks. In cases of serious disagreement, approval for release from quarantine is not granted. When there is a real conflict of interest the **Biological Control Act** allows for a public inquiry to be set up, ending in a decision at Ministerial level.

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Main Menu

Related topics:

Biological Control Act

Flowchart of protocols and procedures

Formal aprovals under current procedure

Formal approvals under current procedures

Formal approvals are required at various stages through a biological control project.

Firstly, approval may be sought to have the pest declared a target organism for biological control by the Standing Committee on Agriculture and Resource Management under the **Biological Control Act**. This is not subject to the formal review process shown in the **Flowchart of protocols and procedures**. This approval is only sought if a biological control project is expected to be opposed by sectional interests, and has rarely been sought.

Secondly, an application for a permit to import a potential biological control agent into quarantine under the Quarantine Act must be submitted to AQIS (Australian Quarantine and Inspection Service) and the review process (Step A in **Flowchart of protocols and procedures**). Approval of a suggested **host-specificity test** list is usually sought at the same time as approval to import the agent, but may be submitted to the review process separately.

If the Biological Control Act has been invoked, an application to **declare the agent as an agent organism** under the **Biological Control Act** must be made.

On completion of testing, an application to release the agent from quarantine (under the **Quarantine Act** and the **Wildlife Protection Act**) into the field is submitted to AQIS and the review process (Step B in **Flowchart of protocols and procedures**). At this stage evaluation of **host-specificity** of the agent is the focus of the review process.

Until 1997 pathogens for weed biocontrol were subject to a variation in general procedures in that host-testing was to be completed outside Australia and therefore approval of a host-testing list would precede an application to import to Australia. Since 1997 pathogens can be tested at AFRS (Alan Fletcher Research Station)

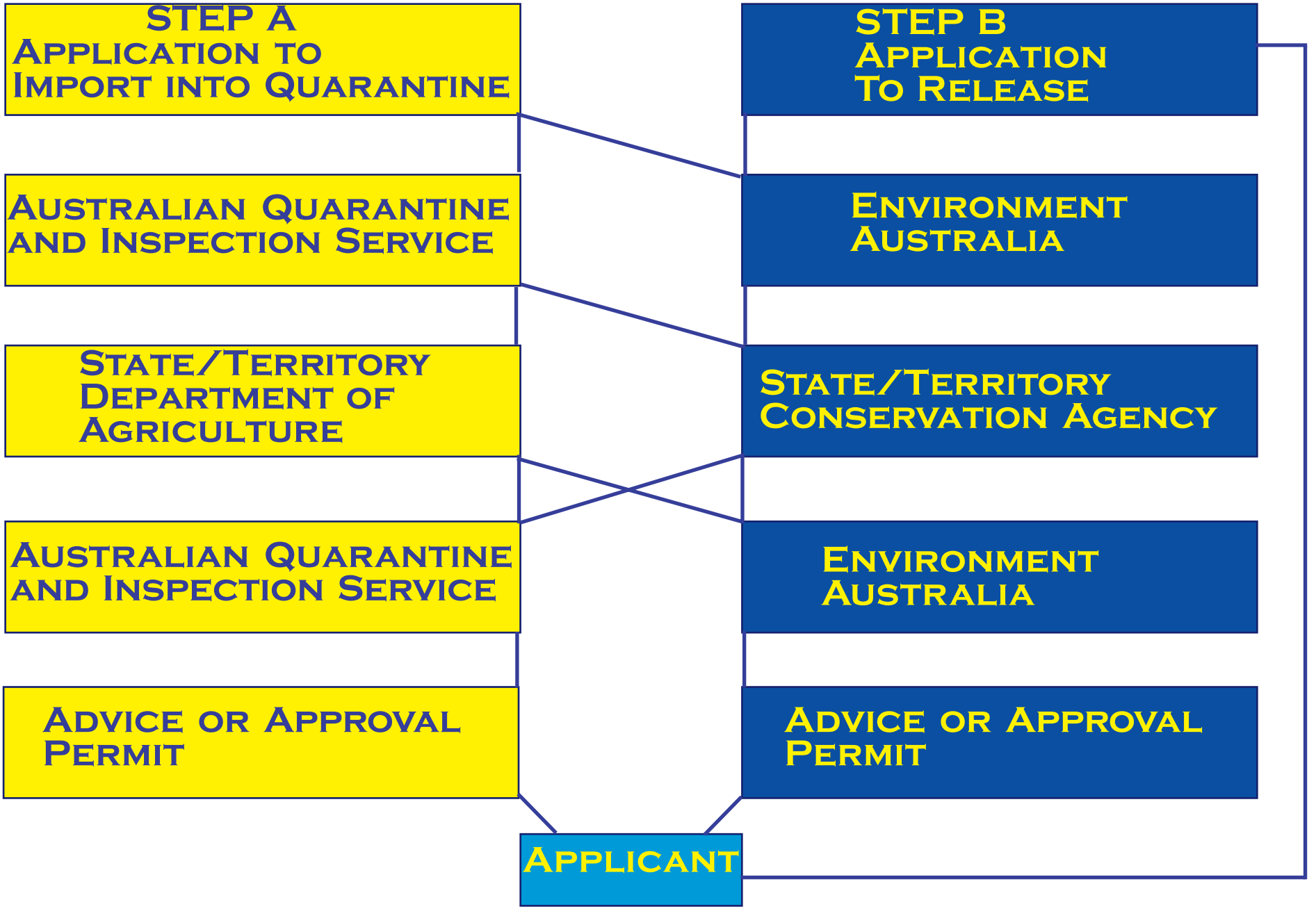
Return to:

Main menu
Current protocols and procedures

Related topics:

Legal background to biological control
Biological Control Act
Wildlife Protection Act
Flowchart of protocols and procedures
Administrative procedures

Flowchart of protocols and procedures for obtaining approval to import and release biological control agents.



Flowchart of protocols and procedures for obtaining approval to import and release biological control agents.

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Current Ptotocols and Procedures

Related topics:

Legal Background

Biological Control Act

Wildlife Protection Act

Flowchart of protocols and procedures

Administrative procedures

Formal approvals under current procedures

Basic Concepts and Methods in Biological Control

Naturally occurring organisms, such as parasites and parasitoids, predators, pathogens and competitors, usually play a major role in regulation of the abundance and distribution of a species. Existing levels of regulation of some species may not prevent their having a significant detrimental economic or environmental impact - i.e. the species are pests. Biological control involves manipulation of parasites, parasitoids, predators or pathogens to reduce the impact of pests to insignificant levels.

Biological control may be achieved by:

i. classical biological control - involving introduction of exotic organisms in the hope that they will establish in sufficient numbers to permanently reduce the impact of the target pest. This method is particularly appropriate when the pest species is exotic and has been introduced to Australia without the parasites, predators and pathogens that regulate it in the country of origin. The method may also be effective against native pest species if regulating organisms from closely related exotic species can be imported.

ii. augmentative biological control - involving mass rearing and periodic release of organisms that would normally be present in insufficient numbers to reduce pest impact to acceptable levels.

iii. innundative biological control - a form of augmentation involving release of large numbers to obtain rapid but short-term control through effects of the individuals released rather than their progeny. Classical biological control and initiation of augmentative or innundative control using exotic organisms require **approval of the import and release** of exotic organisms.

Classical biological control offers the promise of environmentally friendly, relatively cheap, self-sustaining pest management. However, the up-front costs are high and not always recoverable commercially, and successful control takes a minimum of 5 to 10 years.

Return to

Main Menu

Related topics

Procedures in a biological control program

Practical limitations on the biological control process

Procedures in a biological control program

Based on a paper by: Wendy Forno, CSIRO Entomology, PMB 3, Indooroopilly Q 4068, Australia

Practitioners in biological control agree that there are a number of steps which should be followed in a biological control program. A crucial step in any biological control program is to identify the target pest and to research all that is known about the pest, its biosystematics, distribution, economic importance and conflicts of interest before the program commences in earnest.

Following is a summary of the steps in an ideal classical biological control program, an ideal that can only be followed without any of the usual **practical limitations** on the biological control process.

1. **Initiation**
   - review literature on target pest;
   - review literature on natural enemies;
   - compile data;
   - identify and if possible, resolve, any conflicts of interest;
   - determine whether any other institution worldwide is working or has worked on biological control of the target pest.
2. **Approval to work on the pest**
   - prepare application using data assembled to seek approval/ funds to work on the pest.
3. **Foreign exploration**
   - if an exploratory phase is necessary, find out the procedures for working in the country/s of the native range of the pest and establish connections with appropriate institutions; also the procedures for exporting insects/pathogens from these countries;
   - establish a base within the native range which is close to an international airport or which has good connections to international services and if possible close to institutions which may be of assistance;
   - search for potential control agents through well planned surveys;

Continued next page

3. **Foreign exploration (continued)**
   - have specimens determined by specialist taxonomists;
   - prepare inventory of insects/mites/pathogens attacking the pest;
   - assess those which have potential as biocontrol agents.
4. **Surveys in introduced range**
   - survey the pest in the introduced range to determine the organisms using the pest as a host;
   - establish whether the organisms are native to the country, whether there are species apparently not native attacking the pest and in particular, compare the identified organisms with those found in the native range;
   - compile data.
5. **Ecology of the pest and its natural enemies**
   - study and if possible, compare the ecology of the pest species in its introduced and native ranges;
   - study the ecology of the natural enemies in the native range including their use of related hosts.
6. **Host specificity studies**
   - seek approval of the list of species to be screened to determine the host range of an agent by submitting the list to the regulatory authorities;
   - if possible carry out some preliminary host testing in the native range;
   - either complete the host testing outside the target country or seek approval to import the agent into an approved quarantine facility for completion of the host screening trials.

Continued next page

7. **Approval of agents**

• results of host specificity studies are considered by the appropriate regulatory authorities;

• if host screening has been completed outside the target country, approval may be given for importation for release, often with the requirement that the agent be taken through one generation in quarantine to overcome the risk of importation of unwanted organisms;

• if host screening has been partially completed outside the target country, then approval may be given to import the agent into a quarantine facility for completion of the host screening tests; further approval must be sought for field release of the agent;

• if host testing cannot be done outside the target country then approval may be given to import the agent into an approved quarantine facility for host screening. Again approval must be sought for field release;

• sometimes an agent has been screened by another country and then approval may be granted to import the organism either without further testing or with further testing of a much reduced list.

8. **Importation**

• upon importation each agent is usually reared through at least one generation to eliminate parasitoids, pathogens and other unwanted organisms;

• where the agent is certified as being disease and parasitoid free by the supplier it may be released in the field but only after transfer from any packaging or plant material which has been imported;

• all imported plant and packaging material must be destroyed, preferably by autoclaving or incineration.

9. **Rearing and release**

• upon the completion of quarantine procedures and receipt of approval for release, the agent is mass-reared and released in the field.

Continued next page

Procedures in a biological control program (continued)

10. Evaluation

• field studies are undertaken to determine establishment, spread and effect of the agent on the weed. Complementary studies may be undertaken to assist in the interpretation of field data.

11. Distribution

• collaboration with other institutions is often essential to ensure rapid and widespread distribution of agents. Distribution may be from laboratory colonies or from field sites where the agents are abundant.

Return to: Main menu
Basic concepts and methods in biological control

Related topics: Practical limitations on the biological control process

Practical limitations on the biological control process

Technical, logistic and/or economic factors may limit the extent to which the procedures in a biological control program can be pursued.

In regions other than Europe and North America, information about the pest and its natural enemies may be limited or non-existent. Literature searches will be of limited use in assessing whether potential biological control agents are present, or in determining the likely host range of potential agents.

Limited funding for a project or logistical or political problems in the country of origin (e.g. civil war, strained diplomatic relations with Australia, lack of transport or communication networks, lack of scientific support) may limit exploratory work in the country of origin to one or several brief visits. In these cases information available on any agents collected will be minimal.

Return to: Main menu
Basic concepts and methods in biological control

Related topics: Procedures in a biological control program

Positive and negative impacts of biological control

Any approach to pest control, even doing nothing, has positive and negative impacts.

The primary intended positive impact of biological control is reducing the impact of pests to insignificant levels. The target pests may be problems in highly modified and managed ecosystems, including insect and weed pests of agriculture or horticulture, or in ecosystems with minor modification and management, such as weeds of native pastures, or in relatively unmodified, conserved ecosystems, such as weeds of national parks or wilderness areas. Over 50 native plant species are considered endangered in Australia because of competition from introduced weeds (Bell, 1983). If successful, biological control reduces the damage caused by the pest, and the costs of, and damage caused by, alternative chemical and cultural control.

Significant costs of pesticide-based pest control are the environmental and health impacts of pesticide drift and residues. Major reductions in pesticide use have followed successful biological control of insect pests and weeds. Thus, although the primary beneficiaries of biological control may be farmers or graziers whose pest control costs and direct exposure to pesticides are reduced, benefits to the wider community come from reduced possible effects of pesticides in the environment.

Continued next page

Positive and negative impacts of biological control (continued)

There has been discussion in the literature of the possibility of negative environmental impacts of biological control agents through their effects on non-target native species. An often quoted example of an introduction to Australia that has had deleterious effects on native species is the cane toad, although it would not be considered for release today. Howarth (1991) highlighted possible negative environmental impacts, using largely circumstantial evidence to claim that extinctions of several target and non-target native insects, other arthropods and snails in Hawaii were due to biological control introductions.

His conclusions have been questioned by Funasaki et al (1988) who found only one of 30 recent biological control introductions into Hawaii attacked any native species. Turner (1985) reported that 7 of 33 weed biocontrol agents introduced into North America had developed on natural populations of non-target native plantsclosely related to the target weeds, but significant negative impact had not been demonstrated. There are no records of significant deleterious effects on native species by biological control agents introduced in the last 70 years in Australia.

An aim of the review process is to evaluate the risks of deleterious effects on native species for agents proposed for release in Australia. Investigation of **host specificity**, experimentally and by field observation, provides the key data for defining the **risks**.

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Positive and negative impacts of biological control: Rubbervine

Excerpt from : **McFadyen & Heard 1997**

Rubbervine, *Cryptostegia grandiflora*, is very serious weed of pasture and riverine ecosystems in north Queenslnd which is continuing to spread west towards the Northern Territory and Western Australia. In the open, it forms bushes up to 3 m tall, but also grows as a vine up trees, completely covering them up to 30 m height. Because of its dense foliage, only shed during the dry season, no light reaches the understorey plants which also die. All native vegetation dies in affected riverine ecosystems, and the native animals may also disappear as a consequence. In 1989, rubbervine affected 350 000 km^2 in north Queensland and was rated as Australia's worst environmental weed (Humphreys *et al.* 1991).

Host range of *Euclasta whalleyi*

Rubbervine is in the family Asclepiadaceae, subfamily Periploicoidea, closely related to the family Apocynaceae. Australia has many native plants in these two families, some of which (*Hoya, Stephanotis*) are also important ornamentals. A biological control program started in 1985, with searches in Madagascar where the plant is native. Unfortunately, few potential agents were found, and none was host specific to the genus *Cryptostegia*. In tests, two of the species also damaged other native and ornamental plants in the families Apocynaceae or Asclepiadaceae, and were rejected for this reason.

Continued next page

Positive and negative impacts of biological control: Rubbervine (continued)

The leaf-feeding moth *E. whalleyi* was the most host specific of the insects found. In both laboratory tests and the field, it fed and developed on plants in several genera of the subfamily Periplocoidea, but on none outside this family. There are only five species in this subfamily in Australia, only one of which is common and found in the same areas as rubbervine. This plant is also a vine, and grows in the same riverine habitats of northern Australia as rubbervine. Where rubbervine invades an area, the native vine is displaced and becomes locally extinct.

Decisions based on host specificity testing

Because of the enormous environmental damage being caused by rubbervine, the lack of other practical control methods or other potential agents, and in view of the fact that the survival of the native vine was severely threatened by the spread of rubbervine, the decision was taken to release the moth. The decision process for release of a biological control agent in Australia involves conservation authorities in each state, and in this case the application included letters from the Queensland Department of the Environment strongly supporting the application.

Impact of the decision

Releases were made between 1988 and 1992, and the moth was widespread and causing severe damage to rubbervine by 1995. Larvae have been found feeding on the native vine where this is close to rubbervine, but the moth has not been found on the native vine in the absence of rubbervine. It is still too early to judge the final impact of the moth on either rubbervine or the native vine, or whether successful control of rubbervine will allow the native vine to regenerate in the areas where it was displaced.

Continued next page

Positive and negative impacts of biological control: Rubbervine (continued)

Discussion

This example demonstrates some of the issues that have to be considered when deciding whether a potential biological control agent should be released or not. The results from host-testing should determine the risk if any to non-target plants, but the decision as to whether the possible damage outweighs the benefits depends on the importance of the various factors involved. The decision reached will vary in different situations and may not be the same for different countries.

It is important to remember that weed biological control has an excellent safety record, with only eight instances of damage to non-target plants recorded in 100 years of agent introductions (McFadyen 1998). Of these, in five the damage was anticipated but considered not to be important. Two were the result of inadequate host-testing and in the remaining instance, *Zygogramma bicolorata* on sunflower, the impact of very high populations was underestimated. However, in not one case were there significant economic or environmental losses, and these were far outweighed by the benefits gained from the introductions.

Reductions in pesticide use: example of positive impact

- Highly residual and broad spectrum arsenical herbicides were used tocontrol prickly pear and harrisia cactus before successful biological control agents were established.

- Successful biological control of the major pestsof citrus has greatly reduced the number of insecticide sprays applied to orchards.

- Control of salvinia was achieved by addition of herbicides to municipal water supplies, recreational waterways and natural river systems before successful biological control agents were introduced.

Cane toad: example of negative impact

Undoubtedly, the introduction of the cane toad to control pests of sugar cane has had negative environmental impacts in Australia.

The relevance of the cane toad example to the review process is worth discussing. Introduction of the cane toad preceded any formal, legal controls over biological control introductions. The current review process, if presented with an application to introduce a cane-toad-like agent should request information from the native range, from other countries which had introduced the agent, or from cage tests on the likely host range of the agent and its effect on the target pest. This information would clearly show that the cane toad feeds on a wide range of organisms, a range that would include many native species, probably with no preference for the proposed target pest. The decision to reject such an application would be easily made now, but when the toad was introduced early this century little value was attached to non-target native species and the sugar industry was of great economic and social significance. A review at that time may well have decided that the high probability of risk to non-target species may have been worth taking when balanced against the possibility of achieving biological control of a pest of sugar cane.

However, scientists are now more environmentally aware and understand community ecology in native habitats. Adding a generalist predator could unbalance the predator-prey interactions/relationships which have naturally evolved in this country.

Host Specificity: overview

Determination of host specificity or host range (i.e. determining the **range** of non-target organisms likely to be damaged in the field, and the **severity** of any damage if the agent is released and establishes in Australia) is the central issue in satisfying the aim of the review process.

Factors that determine whether an organism will be a host for an agent in the field are:

A. the organism must be biochemically and physiologically suitable for the agent to complete development;

B. sensory cues given off by the organism must be accepted within the host finding and acceptance behaviour of the agent;

C. the organism must be temporally and spatially available to the agent in the field;

D. the agent and organism densities and probabilities for the three preceding conditions (suitability, acceptance, availability) must allow population increase of the agent using the organism as the host, otherwise another host will be necessary to support the agent population.

Sources of information on factors determining host specificity of agents to be released in Australia are:

a. general knowledge of biology, ecology, behaviour, evolution (factors A,B,C,D)

b. field observations in the country of origin (factors A,B,C,D)

c. host specificity testing in cages under quarantine (factors A,B)

d. host specificity of closely related organisms (factors A,B)

e. field observations on the target pest and similar organisms in Australia (factors C,D)

All information sources have some limitations, and factors such as the population density of the agent in the field in Australia after establishment are virtually unpredictable. The best prediction of likely host range is based on an integration of information from all sources.

Despite difficulties in predicting host ranges of agents in the field, all damage to non-target organisms in the field by agents whose host ranges have been investigated prior to release in Australia has been predicted. Biological control practitioners have been conservative in their judgement, so agents with questionable host ranges have been destroyed and no applications have been made for release of those agents.

Continued next page

Host specificity - overview (continued)

Most insects are very restricted in their range of accepted hosts, particularly the plant feeders and endoparasitoids (internal parasites). Each species has a set of sensory receptors, sensory and neuro-motor pathways, and behavioural steps that contribute to selection or rejection of potential hosts. Results of the host selection process will be influenced by presence and absence of sensory cues and the maturity and physiological state of the insect.

Obviously sensory cues and behaviour are not relevant to host specificity of pathogens that may be considered for biological control. The host range of many pathogens is limited, as for most insects, and is determined by host availability, physiology and chemistry, and climatic variables. These may be tested in the laboratory more readily than for insects.

The evolutionary stability of host range is of concern to some who expect genetically related host shifts to threaten non-target species after release in the field. "However, despite the introduction of over 600 insect species from one geographic region to another for biological weed control during this century, there are relatively few documented cases of changes in host plant range... [and all can] be explained in terms of established behavioural concepts of preadaptation, threshold change resulting from host deprivation, and effects of experience" (Marohasy 1996). The risk of host shifts is very slight (Lawton 1985).

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Host test list
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Host specificity testing - methodology for pathogens for weeds

Observations in the country of origin

The first steps in **determining host range and specificity** involve information gathering in the country of origin and other countries where the agent is endemic. Literature searches for named agents may provide information on host range of the agent. Locally published lists of pests will indicate whether the potential agent is known to damage commercial plants; pests of commercial plants will usually have been identified by local entomologists, except in countries where little entomological research has been done.

Thorough field observations in the country of origin are a good indicator of specificity because all aspects of host finding, selection behaviour and environmental interactions are tested, rather than in more artificial **cage or laboratory tests**.

However the potential agent is likely to be present at low density in the country of origin, so behaviour of the agent at high density when availability of the preferred host is limited (the outcome of successful biological control), may not be tested by these observations. Also, the agents may not be exposed in the country of origin to groups of organisms closely related to the target that are present in Australia. Host specificity tests are needed to a greater or lesser extent, depending on available field data, to define the possible host range of the agent in Australia.

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Host specificity - overview

Related topics: Host specificity testing

Background to host specificity testing

Despite a belief by scientists involved that host range may be judged from field observations in the country of origin, cage testing against a **range of economically important plants** was implemented early this century to "satisfy the man on the land" that potential weed biocontrol agents would not attack his crops (Dodd 1940). Host specificity testing in cages continues to be used as a "reassurance factor" to supplement other host specificity information.

Host specificity testing in cages in quarantine has been required under the **Quarantine Act** and **current protocols and procedures** under the **Biological Control Act** for all potential agents imported in recent decades. The **host test list** to be used in the cage testing must be **approved** prior to testing.

Prediction of the field host range based on results of cage tests is imperfect, and prediction of the severity of damage to hosts in the field based on results of cage tests is virtually impossible (Turner 1985). Cage testing may disrupt or restrict both sensory cues and insect behaviour. Non-target species accepted as hosts in cage testing are often not used as hosts in the field, by both insect biocontrol agents (Goldson and Phillips 1990, Sands 1993) and weed biocontrol agents (Cullen 1989, Shepherd 1989). Cage testing thus tends to be a conservative indicator of host range; decision making based on cage test results will usually lead to rejection of "safe" agents rather than acceptance of "unsafe" agents. Test plants or insects in an inappropriate developmental or physiological state will not be accepted as hosts in cage tests, and the age, size and state of test and target plants or insects should be stated. Conversely, an agent in an inappropriate developmental or physiological state may not accept a test plant or insect, even though they may be used as hosts in the field. Controls, in which individuals in the same developmental and physiological state as the test individuals are confined with the target, are necessary to avoid this possibility. It is therefore vital that the appropriate testing procedures are followed.

Continued next page

Background to host specificity testing (continued)

Because sensory cues and behaviour are not relevant to host specificity of pathogens that may be considered for biological control, pathogens may be tested in the laboratory more readily than for insects.

The reviewer mus be confident that the methodology used in host tests has been sufficiently rigorous.

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Host specificity testing: methodology for insects

Based on a paper by Tim Heard, CSIRO Entomology, Long Pocket Labs

The host range of an insect is the group of species on which oviposition by adult females and development of larvae occurs. In most phytophagous and parasitic insects the larval food is determined by the ovipositing adult female not by the larva. This is because many larvae are fairly immobile and can only feed on the plants/insects on which they have been laid. Hence, the process of host selection by ovipositing females is used by most biological control workers as the most important indicator of host range. To test this host selection, insects are given access to a range of species including the target pest. The adults are later removed and the number of eggs laid on each specimen or the number of emerging progeny is counted.

For efficiency, test species should be tested in a rational order with the species most at risk tested first. Wapshere (1989) proposed a strategy in which the first step is to test a small group of species that are very closely related and with morphological and biochemical similarities to the target species.

Oviposition and feeding preferences need to be understood and incorporated into designs of host range testing. The greatest errors are made when the incorrect material of stage, foliar form, nutritional quality, etc. is provided.

Oviposition trials may be designed as choice or no-choice tests. In a choice test, a group of insects is allowed access to several species simultaneously. In a no-choice situation, the insects are allowed access to only one species at any one time.

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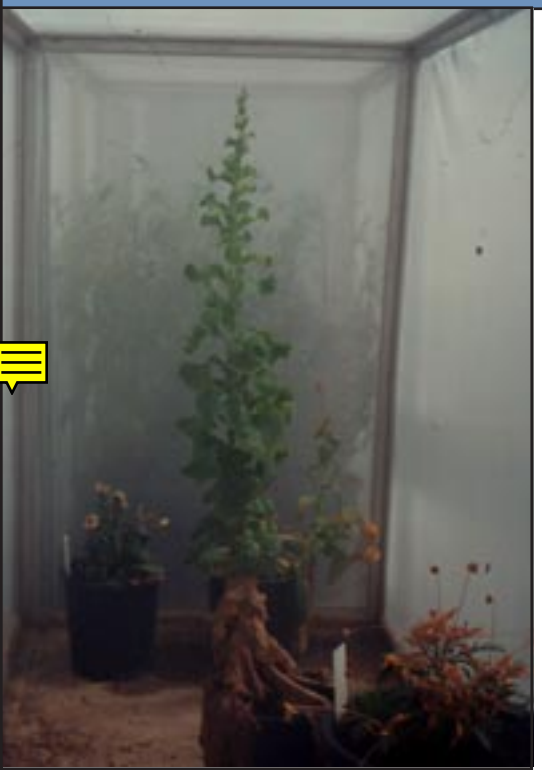
Host specificity testing: methodology for insects (continued)



Cullen (1989) gives an overview of no-choice and choice testing. Whether one commences with a choice test in which the agent is given the choice between feeding/ ovipositing/ developing on the host or on one or more test species, or commences with a no-choice or starvation test, does not matter as the final conclusions will be the same. To get sufficient information on feeding, oviposition and development, several different types of trials may need to be conducted and replicated. In both designs, a control consisting of the target pest must be included, either in the same cage or in a separate cage using a cohort of the same insects. This ensures that the insects used were in a suitable condition for oviposition and feeding. It also provides 'baseline' data, or estimates of normal numbers of eggs and feeds inflicted by a given number of insects in a given period. Damage to other species can then be compared with these baselines.

All tests should be conducted under conditions optimum for insect development and with sufficient light and nutrients to maintain host quality. Many insects utilise visual cues emanating from the host plant during host-finding and selection. Therefore, if tests are carried out in a closed laboratory, not in a naturally lit greenhouse, high quality lights which mimic natural sunlight should be used.

Tests must be replicated. For choice tests, use a different combination of plant species in each trial. The exposure period should consist of a minimum of one day as there may be diel rhythms of activity. In addition, some insects feed or oviposit in bouts, and many days may be required for a number of these bouts to occur.

Continued next page

Host specificity testing: methodology for insects (continued)

Where both larval and adult feeding seriously damage the host, the feeding range of the adults also needs to be determined. Usually this can be done concurrently with oviposition trials. In this case, the extent of feeding is also evaluated at the end of the trial. If feeding damage is quantified it may be compared to damage on other hosts more conclusively and is amenable to statistical analysis. Feeding damage may be measured by counting feeding scars, counting structures destroyed, measuring leaf area destroyed, etc.

Choice tests: The advantages of choice tests are that they are more natural (in nature, insects are constantly faced with making choices), and they are more efficient as several species can be processed simultaneously. The numbers of insects used will also depend on whether the insect is being tested for its preference for feeding/ovipositing on a species in conditions of free choice, or whether it is being forced to select less-preferred hosts by putting more insects in the test than can be accommodated by the target pest.

No-choice tests: No-choice tests must follow choice tests for those species which supported feeding or development of any life stage. These trials are essential to determine if a species can be self sustaining for successive generations on the test species alone.

Oviposition trials are not possible for many insects which do not express natural host selection behaviour under cage conditions. This may be due to sensitisation, where some attribute of the host, e.g. volatiles, has excited and increased the responsiveness of the insect resulting in it ovipositing on non-hosts or even on cage walls.

Continued next page

Host specificity testing: methodology for insects (continued)

In nature these two species may not co-occur and hence the situation wouldnot arise. Sometimes it is possible to evoke natural behaviour by enlarging the cage, adding a natural substrate or otherwise making the conditions more natural. If these are unsuccessful, larval development trials are required.

Larval development trials

When oviposition is observed on a test species, further trials are required. In particular, it is necessary to determine the viability of the eggs, the ability of the host to support larval development, the mortality of the pupal stage, and the size and fecundity of the resulting adults. Thus the determination of host specificity also includes the determination of the physiological host range, that is, the range of species on which larval development can occur.

In certain circumstances, it may be necessary to transfer larvae to the point of feeding. E.g. for some Lepidoptera that lay eggs randomly, the method for host testing is to transfer these eggs onto plants and monitor the development of the eggs into adults. It is essential that the larvae are only able to feed on the species being tested. It is not acceptable that the larvae begin feeding on the normal host, for example, and then get transferred to the test species. This is because of the principle of induced food preference, a phenomenon by which larvae that have feed on one plant species will often subsequently reject other host species.

Continued next page

Host specificity testing: methodology for insects (continued)

The insects used for testing

The health and age of the insect culture used for specificity testing must be constantly monitored. The numbers of insects used in each trial and the number of trials will vary according to the biology of the insect and the holding capacity of the host or part of the host supporting development, e.g. stems, flowers, or leaves. Ideally a different insect culture should be used in each replicate. These cultures may represent insects that are from different localities (as geographic variation in host preference within a species may occur), different ages, different collection dates, etc. The idea is to test insect material that varies genetically, phenologically, and physiologically.

The plant material being tested for weed biocontrol agents

The plant material may be a cut piece or whole plants depending on the plant structure being tested, the size of the plant, the biology of the insect, the duration of the trial, etc. Whole plants grown under natural conditions are preferable as cutting can significantly affect the chemical cues emanating from the foliage.

Plant material from a different individual plant should be used for each replicate of the host testing trial. This gives more confidence to the results as a broader genetic range within the plant species is being tested.

The material provided from different plant species must be of equal suitability in terms of structure and phenological development and a similar quantity of material must be provided.

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Host specificity testing: methodology for pathogens for weeds

Based on a paper by Allan Tomley
Queensland Department of Natural Resources, Alan Fletcher Research Station, Brisbane.

Host testing trials for pathogens differ from those used for insects in that there is no need for choice testing. Replicates of the target weed and test species are inoculated. In each inoculation, infection of the target weed control plant must be normal. The life-cycle of the pathogen under test must be well known. The plants are inoculated and incubated under ideal conditions for the development of the particular pathogen, and are maintained for a period which allows its development, e.g. production of urediniospores. Test plants are usually kept for twice the length of the latent period for the pathogen on its natural host and examined both macroscopically and microscopically. In the latter case, sample sections of the leaves are taken and examined; scanning electromicrographs are also used. Examinations are made of: the fate of the spores on the leaf surface, development of infection hyphae, appressoria, penetrant hyphae, haustoria and reaction of the test plant at both organ and cell level, e.g. deposition of callose tissue, necrosis of cells to form a barrier, presence of polyphenols, chlorosis and leaf abnormalities (tumefactions).

As an example of **assessment categories** and a **susceptibility rating system** that may be used to rank observed macro/micro symptoms, those developed for Rubber vine rust are presented.

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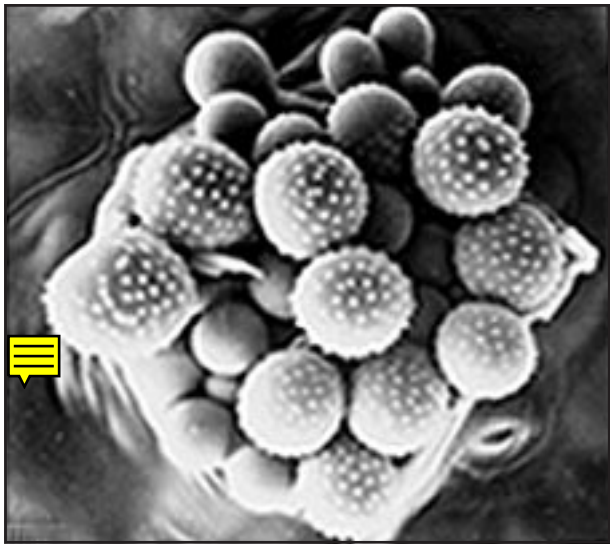
Assessment categories: macro-/microsymptoms

Based on a paper by Allan Tomley. Queensland Department of Natural Resources, Alan Fletcher Research Station, Brisbane.



The following assessment categories for macro-/microsymptoms were developed for host specificity testing of a rust agent for rubber vine.

0	=	spore lysis, low (<10%) or no germination
1	=	spore germination (>20%)
2	=	abnormal germ-tubes
3	=	abnormal appressorial development, invariably non-stomatal
4	=	normal appressional development, invariably over stomata
5	=	collapsed appressoria, no penetration
6	=	penetrant hypha with or without evident substomatal vesicle
7	=	necrosis of penetrant hypha, heavy staining (polyphenol) around and beneath stomata
8	=	short internal hyphae only, no haustorial mother cells/haustoria
9	=	collapsed or necrosed internal hyphae, callose or polyphenols present
10	=	longer internal hyphae, haustorial mother cells and haustoria
11	=	hyphal collapse, host cell plasmolysis and/or callosed haustoria
12	=	extensive internal hyphal network, initiation of sorus formation
13	=	external symptoms; chlorosis or reddening; leaf abnormalities (tumefactions)
14	=	restricted sporulation (<1 pustule/cm2)
15	=	abundant sporulation (>15 pustules/cm2)

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Specificity testing for pathogens

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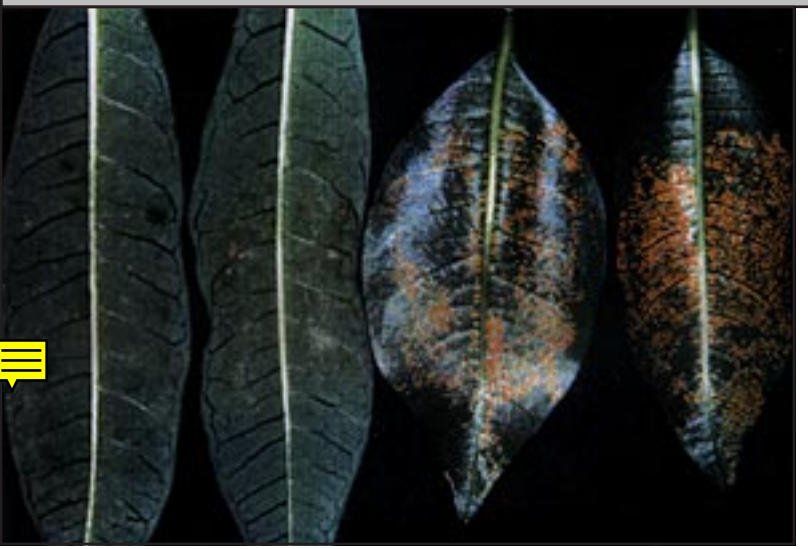
Susceptibility rating system



Based on a paper by Allan Tomley,
Queensland Department of Natural Resources,
Alan Fletcher Research Station, Brisbane.

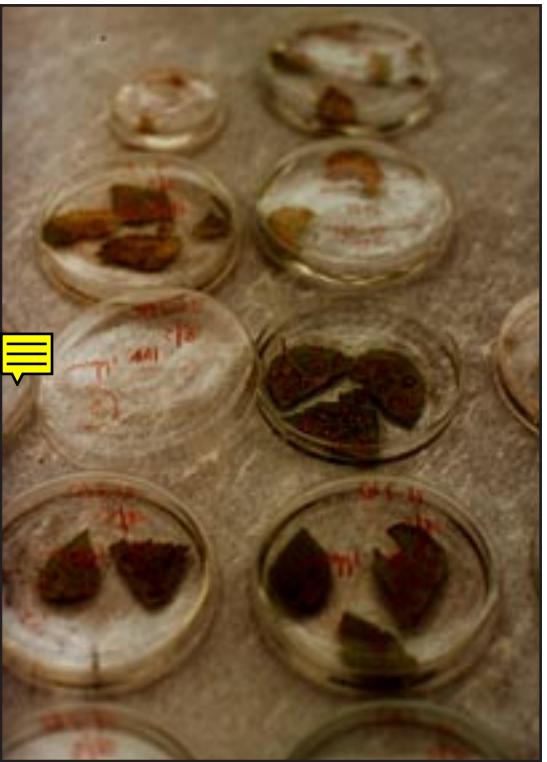
The following susceptibility rating system based on observed macro-/microsymptoms was developed for host specificity testing of a rust agent for rubber vine.

Score	Rating	Macro/microsymptoms
0	Immune (I)	No visible symptoms; no stomatal penetration
1	Highly resistant (HR)	Visible symptoms: chlorosis, flecking or general discolouration; hypersensitive reaction at the stomatal or substomatal level
2	Highly resistant	Development of internal hyphae but restricted by production of callose or polyphenols
3	Highly resistant	Internal hyphae with more extensive branching producing haustorial mother cells but aborted at cellular level
4	Highly resistant	Development of hyphal network; haustoria abundant but invariably non-functional (collapsed or callose ring), with or without host cell plasmolysis No visible symptoms
5	Resistant (R)	Hyphal network extensive; initiation of sori, non-eruptive or eruptive and appearing as swellings or blisters on leaf surface, abortive, no sporulation. Host cell plasmolysis and/or haustorial collapse. Macrosymptoms generally present: chlorotic spots
6	Resistant	Eruptive sori, usually small in size; sporulation restricted (few pustules/leaf) and delayed; evidence of mainly collapsed-callosed haustoria. Macrosymptoms generallypresent: widespread chlorosis, leaf distortion

Continued next page

Susceptibility rating system (continued)

Score	Rating	Macro/microsymptoms
7	Partially resistant (PR)	As above, but pustules larger and more abundant but still less than 1/cm2 (moderately susceptible)
8	Highly susceptible (HS)	Numerous pustules (>15/cm2), abundant sporulation; majority of haustoria healthy. Typically chlorotic then necrotic leaves; but premature leaf fall not evident
9	Highly susceptible	As above, but premature leaf fall common; with or without chlorosis or reddening (anthocyanin production)



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Specificity testing for pathogens

Related topics:

Symptom categories for pathogens

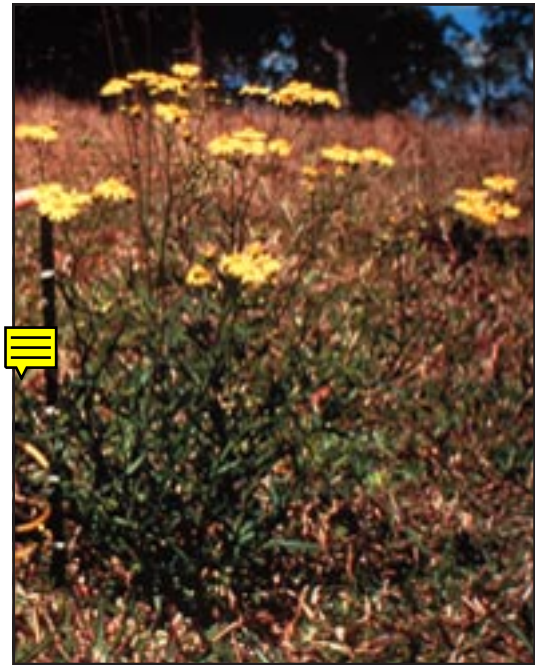
Host test list

The original purpose of host specificity testing was to demonstrate that crop plants would not be attacked by weed biocontrol agents. Host test lists consisted of a standard list of major crop plants, irrespective of the agent. Two significant changes have since been adopted for host test lists for weed biocontrol agents.

Firstly, Wapshere (1974, 1989) suggested that, because stenophagous insects (i.e. those with a limited host-range) use as hosts closely related plant species with morphological and biochemical similarities, host testing should concentrate on plants closely related to the target. The aim was to define the host-range rather than to demonstrate which plants were not used as hosts.

Secondly, with increasing value placed on the natural environment, damage to native plant species must be considered (See **Wildlife Protection Act**).

The host test list for weed biocontrol agents should focus on the species most "at-risk" i.e. species closely related to the target and/or with morphological and biochemical similarities and present in the same areas as the target, beginning with plants in the same genus, then selecting species from genera in the same and related tribes, then from the same and closely related families.



Other criteria which may be used to select plants for testing include:

- plants on which the agent has been found, although they are not recorded as hosts;
- species attacked by close relatives of the agent;
- important economic or native species which occur in the same area as the target and will therefore be exposed if the agent establishes in the field.

Continued next page

Host test list (continued)

Host specificity trials for arthropod agents have only been required since effects on native fauna have been considered, so the history of testing these agents is relatively short. Even so, the conservation value of insects (except for lepidoptera) is still considerably less than values usually attached to plants. Testing of arthropod agents is much more difficult than testing for weeds because organisms to be tested may be difficult to find and even more difficult to culture; there is often no information available on the biology and hosts of native insects, so culturing them is impossible without extensive research. Host test lists approved for arthropod agents have been much shorter than those for weed agents because of practical difficulties, precedence, and perhaps the perception of insects as having less conservation value than plants.

As for phytophagous insects, insect endoparasitoids tend to use closely related species as hosts. Thus the phylogenetic basis for selection of a host test list is usually adopted. However some parasitoids use a variety of hosts present in a selected habitat; the habitat is usually a host plant. Beneficial and native species which occur in the same area and use the same host plant as the target should be included in the test list for arthropod agents.

Given the focus on closely related species, consultation with a taxonomist familiar with the taxonomic group in which the target species belongs is necessary (both for the applicant and reviewer).

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Host specificity testing - methodology for pathogens for weeds

Specificity of closely related organisms

The host ranges of an agent's relatives may be a useful indicator of the agent's host range. However, there are no certainties. Taxonomic "lumpers" have been known to synonomise as one species taxa with different host ranges and specificities. The whole range of relationships between organisms and their hosts and their relatives are possible: some groups of closely related species use taxonomically unrelated hosts ("disjunct oligophagy"); many unrelated species use the same host species; some groups of related species are all monophagous on the same or closely related hosts, but others include polyphagous and monophagous species. In terms of evolution, monophagy is believed to evolve from polyphagy but the reverse is thought not to occur. According to this model, if all the species in a phylogenetic grouping with known host ranges are monophagous then another species in that grouping is also likely to be monophagous.

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Basic concepts and methods in biological control

Host specificity - overview

Risk analysis

Risk analysis may be crucial in meeting the aim of the review process. For example, release of an agent that may damage a non-target organism is more likely to be approved against a pest with major economic, environmental or health effects that can only be controlled by highly persistent or toxic pesticides, rather than a minor pest which could be controlled by cultural measures.

Most cases in which the biological control researcher believes that there is significant risk to economic, beneficial or native organisms do not proceed to formal application for release; the culture of the agent is usually destroyed.

Applications for release of most agents suggest that there is no risk to economic, beneficial or native organisms, and potential significant benefits if control of the target pest can be achieved. The responsibility of reviewers in these cases is to evaluate the **host testing methodology** described in the application and the interpretation of results to ensure that risks to non-target organisms have been adequately defined. If so, the decision to approve release is straightforward.

Some cases have existed where the risk of damage to economic or native organisms has been significant and nevertheless applications to release have been presented and approved. In 1980, an agent for control of the weed parthenium, a major weed in sunflower growing areas, had some potential to damage commercial sunflower crops. Sunflower growers were approached and they decided that, on balance, the sunflower industry was prepared to risk damage to their crop in order to capture the possible benefits of controlling parthenium. In fact, the agent has done no damage to sunflower crops and is causing significant damage to parthenium.

Continued next page

Risk analysis (continued)

In a second case, in 1994, an agent for control of rubber vine, a major pest of conservation and grazing lands, had some potential to damage a native plant growing in the same areas as rubber vine. Conservation agencies decided, because rubber vine poses a major threat to the plant in question and to the ecosystems in which it grows, that the risk of damage to the native plant was worth taking. The agent was released in 1988 and increased to significant numbers in the field by 1995; but there appears to be no damage to the native plant. In each of these cases the risks to be taken and the benefits to be gained were the responsibility of one group of people whose risk analysis was accepted by reviewers.

A case has yet to be presented involving risk of damage to a non-target organism which is the responsibility of an organisation separate from those standing to benefit from control of the target pest. Under the **Biological Control Act**, the benefits of reduced cost of control of the target pest and reduced pesticide application, and subsequent reduced effects of residues on human health and the environment, have to be weighed against risk of damage to non-target organisms of use to other groups or of conservation value. Such a case may be referred to the Minister for DPIE for resolution by formal inquiry.

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Related topics:

Legal background to biological control

Current protocols and procedures

Positive and negative impacts of biological control

Host specificity - overview

Guidelines on Import and/or Release Application

"Guidelines on the information to be provided with an application to import or release biological control agents" specify the information requirements for applications under current protocols and procedures. See the AQIS **web page**. Three qualifications accompany these specifications from AQIS:

i. it is acknowledged that comprehensive information would not be available in each category but an attempt should be made to provide as much as is reasonably available;

ii. it is recognised that in developing a biological control program, particularly for weeds, consideration must be given at an early stage, to the demonstration of host specificity of potential agents. The applicant should provide details of proposed host specificity studies, how and where they will be done, what test species will be used, how the list of test species was derived, and the relationships of the test species to the target pest, to Australian native species and to known beneficial species. Where candidate agents differ appreciably in their relationships with the target, it will be necessary to prepare separate documents specifying the procedures for each type of agent. For example, for weeds it would be necessary to specify different procedures for insect and fungus agents.

iii. this information is required to allow State organisations the opportunity to contribute to proposals for biological control programs in the development stage. This will allow, for example, comprehensive host specificity lists of agriculturally and environmentally significant plants and insects to be finalised before testing is undertaken.

The "Guidelines for importation of fungal pathogens for the biological control of weeds" were apparently drafted with little reference to the more general guidelines. There are many differences where there are no apparent logical reasons. In the following discussion, information requirements for pathogens are grouped with parallel requirements for other agents, but are shown in italics.

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Guidelines on Import and/or Release Applications (continued)

Sections of the general guidelines are summarised as:

Target -

- Scientific name
- Native range
- Distribution
- Australian relatives
- Pest status

Agent -

- Scientific name
- Brief biology
- Native range
- Related species
- Proposed source
- Mode of action
- Control potential
- Non-target organisms at risk
- Interactions with existing biocontrol
- Host specificity testing
- Evaluating establishment
- Biocontrol program procedures

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Target: scientific name

General

1. Scientific name (genus, species, family, order), common name (if any).

Pathogens - taxonomy of target

1. *Scientific name (genus, species and authority) currently accepted by taxonomists, and synonomy*

2. *Common name(s)*

3. *Family to which weed belongs*

5. *Summary of available information on intraspecific variation, especially morphological, in populations both in Australia and in other countries*

This information serves as the basis for deciding which **closely related organisms** are most likely to be at risk of damage by the proposed agent. Point 5 from the pathogen guidelines explores the possibility of varieties, sub-species or sibling species which should be included in host specificity testing, considered as possible sources of agents, and could differ in response to agents. This point has more general significance than just pathogens for weeds.

Taxonomic relationships may also serve as a guide to biology and behaviour.

However, taxonomic relationships for many groups are in a state of flux. If this is so, alternative taxonomic relationships should be considered.

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Related topics: **Host test list**

Related Target: native range

General

2. Native range and, if determinable, probable centre of origin

Pathogens - habitat

1. *Native geographic range and climatic and edaphic variation between sites within the range. Limits to distribution where known*

3. *Probable geographic centre of origin*

This information is helpful in deciding where to look for potential agents, and where the pest may establish in Australia, but is of limited value in terms of the **aim of the review process**.

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Related topics:

Procedures in a biological control program

Target: distribution

General

3. Distribution in Australia, and in any other countries where it is a pest, or a normal part of the fauna or flora

Pathogens - habitat

2. *Present distribution, both in Australia and elsewhere*

This information will help in deciding which non-target organisms are present in the same regions and habitats as the target pest, and therefore are likely to come into direct contact with any agents released on the pest (See **host specificity - overview).** It also gives an indication of the pest's significance in Australia (See **risk analysis**).

Information on pest status in other countries is of limited value in terms of the aim of the review process.

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Target: Australian relatives

General

4. Relatives native to Australia. (State family names of close relatives if number is large).

Pathogens - taxonomy

4. *Close relatives of economic, or biological importance in the Australian region*

Many agents, particularly plant feeders and endoparasitoids, are restricted in their feeding and development to closely related organisms with similar chemical and other characteristics. The non-target organisms at most risk of damage by the proposed agents will be the close relatives. These must be the focus of host specificity testing.

Given the importance of this information in meeting the **aim of the review process**, the reviewer should be confident of the taxonomic relationships presented in the application or refer the application to a taxonomist who can judge the validity of claimed relationships.

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Related topics:

Host specificity - overview

Host specificity testing - insects

Host specificity testing - pathogens

Host test list

Target: pest status

General

5. Pest status

(a) Host organisms attacked by it (as appropriate)

(b) Nature of damage caused

(c) Extent of losses caused, average and extremes

(d) Estimated value of production loss

6. Other control methods available (if any)

(a) Type of control (chemical, physical, management)

(b) Effectiveness

(c) Costs

(d) Any undesirable side effects

Pathogens - importance of plant

1. *Detrimental aspects - economic, nuisance or environmental*

2. *Beneficial aspects - economic or environmental*

3. *Legislation - whether proclaimed noxious or not, and why*

This information is of most importance during consideration of the proposal to declare the pest as a target for biological control (See **declaration of target organisms**), prior to the applications to import and release agents. The information may also be important in weighing risk of any damage to non-target species against possible benefits of controlling the pest (See **risk analysis**).

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Agent: scientific name

General

1. Name (genus, species, family, order)

Pathogens - taxonomy of agent

1. *Scientific name (genus, species and authority) currently accepted by taxonomists, and synonymy. In the case of an undescribed fungus, the order to which it belongs*

2. *Common name(s)*

3. *Family and order to which the fungus belongs*

5. *Summary of available information on intraspecific variation (including any physiological variation and in particular the existence of other races, one or more of which may be proposed for subsequent introduction)*

Presentation of the name of a described species provides a link to the species description and any other published information on the agent (See **information in the country of origin**).

However, many agents are undescribed species and sometimes of unknown genus. The fact that they have not been described is usually evidence that they are not pests of other commercial or beneficial organisms. For these agents, lodging voucher specimens in a recognised Australian museum provides a reference for future identification of specimens from the field or to ensure that any further importations are of the same apparent species.

Taxonomic relationships, even at the family level, may serve as a guide to biology and behaviour of the agent (See **specificity of closely related organisms**).

Continued next page

Agent: scientific name (continued)

Taxonomic relationships for many groups are in a state of flux. If this is so, the significance of alternative taxonomic relationships should be considered.

Many fungi are pleomorphic. That is one fungus may produce several spore types which may be present at different times. The spores can be the result of sexual or asexual propagation. The state characterised by sexual spores is called the perfect state or teleomorph, the state characterised by the asexual spores is called the imperfect state or anamorph.

Under the International Code of Botanical Nomenclature, it is permissible to treat each of the states as separate species. However, once it has been established that both states are of the one fungus, the name accepted for the perfect state (teleomorph) takes precedence.

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Agent: brief biology

General

2. Brief biology of the agent

Pathogens - reproductive biology

1. *Life cycle including knowledge of spore states (e.g. perfect and imperfect states, various rust spore stages, etc.) and frequency of their production*

2. *Epidemiology in its natural habitat, methods of spread and natural vectors, if any. Indication of type of environmental conditions favouring damage to host*

Pathogens - importance of organism

1. *i. Details of any known toxicity of the organism to animals and humans*

ii. Details of any known or suspected allergic reactions in animals or humans

iii. Is there any information to indicate that the organism may induce toxic substances in the plant(s) it infects, with possible danger to humans or grazing animals ? (Several plant pathogenic fungi are known to cause such effects.)

or

Is there any information to indicate that the candidate organism may combine with other organisms to produce a toxic effect, e.g. as occurs with the nematode and the nacterium causing rye grass toxicity

2. *Other known natural hosts of the pathogen and their taxonomy to varietal or cultivar level*

For many agents little is known of their biology until they are imported under quarantine for testing. Provided quarantine facilities meet AQIS standards, importing an agent into quarantine without knowledge of its biology poses no risk.

Continued next page

Agent: brief biology (continued)

In the application to release the agent, a brief description of the life cycle and relationship of the life cycle to the target or other hosts should be presented as a basis for judging adequacy of host-testing procedures (See **host specificity - overview** and **background to host specificity testing**). Information on host finding and acceptance behaviour, life stages, lengths of life stages, temperature effects, light/dark cycles, feeding, and diapause of the agent or its relatives is also useful.

Given our current understanding of biological systems, predicting the densities that populations of the agent may reach after release in the field is not possible. Nor has it been possible to define sets of biological characteristics that enable prediction of the success of a potential agent (Marohasy 1995). Thus, intensive details on the biology of arthropod agents are not usually helpful in making decisions about their impact on the target after release (**See host specificity - overview**).

The biology and taxonomy of plant pathogenic fungi may appear to be highly variable: many fungi are pleomorphic. That is one fungus may produce several spore types which may be present at different times. The spores can be the result of sexual or asexual propagation. The state characterised by sexual spores is called the perfect state or teleomorph, the state characterised by the asexual spores is called the imperfect state or anamorph.

The full life-cycle of candidate pathogens should be known. Any missing links need to be found, or a sound theory explaining why various stages are not present needs to be formulated.

Continued next page

Agent: brief biology (continued)

As an example, the rusts can have up to 5 different spore stages. An individual life-cycle may have all or only some of these.

While some rusts do have a full life-cycle, all stages may not be present in the field, e.g. *Puccinia abrupta* var. *partheniicola*. In the field in Mexico, only the uredinial and telial stages have been found. While the teliospores are functional, germination has only been observed in the laboratory after dormancy had been broken by chemical treatment. The rust appears to cycle in the field by the urediniospore stage only. These spores have the ability to remain dormant over winter while retaining their viability.

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Agent: native range

General

3. Native range and, if determinable, probable centre of origin

Pathogens - habitat

1. *Native geographic range and climate and edaphic variation between sites within the range*

2. *Present distribution*

3. *Probable geographic centre of origin, if known*

In terms of the **aim of the review**, this information serves as a guide to the possible range of the agent in Australia, and therefore which non-target organisms are likely to be present in the area in which the agent may establish.

(See **host specificity - overview**).

Introductions from different parts of the native range may be considered to select agents adapted to a range of climates in Australia.

Agents need not come from the centre of origin of the target pest. One of the effective agents introduced for control of groundsel bush, *Baccharis halimifolia*, a native of southeastern USA, came from a different species of *Baccharis* in the uplands of southern Brazil, and has established in the coastal lowlands of Queensland.

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Related topics: **Target - native range**

Agent: related species

General

4. Related species and a summary of their host range

Pathogens - taxonomy

4. *Close relatives of economic or biological importance in the Australian region*

The host ranges of an agent's relatives may be a useful indicator of the agent's host range. However, there are no certainties. (See **Host specificity - overview** and **Specificity of closely related organisms**)

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Agent: proposed source

General

5. Proposed source(s) of agent

Specification of source of the agent is important if there are to be multiple introductions of the same agent, to ensure that the same agent is introduced in each shipment. The source is highly important if the applicant proposes release of agents directly into the field without a generation in quarantine. The source of the agent would have to carry an assurance that the agents were free of disease or contamination by other organisms to satisfy quarantine requirements. This matter could easily be evaluated by AQIS.

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Agent: mode of action

General

6. Mode of action against target organism and extent of action

Pathogens - importance of organism

2. *Damage to weed hosts in the country of origin; to include a detailed description of the disease caused*

This information is necessary:

- to predict the likely effects of the agent on the target in Australia, an element in predicting the benefits in risk analysis.
- to assess the adequacy of **host specificity testing** methodology. If the mode of action is not well understood, host specificity tests are difficult to design and results will be questionable.

Mode of action will be particularly important for arthropod biocontrol agents that are less influenced by taxonomic relationships than by agent and host reproductive biology, lifecycle, behaviour, micro-habitat.

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Agent: control potential

General

7. Potential for control of target

No research organisation, funding body or biocontrol scientist would waste resources on an agent with no potential for control of the target pest. In all cases the hope would be that the agent would become sufficiently abundant to reduce target pest numbers to insignificant levels.

However, unless the agent has been released elsewhere in the world, prediction of the degree of control likely to be exerted by the agent is of limited use. It is not possible, given our current understanding of biological systems, to predict the densities that populations of the agent may reach after release in the field. Nor has it been possible to define sets of biological characteristics that enable prediction of the success of a potential agent (Marohasy 1995).

Thus, although this information is important in **risk analysis**, and the **aim of the review**, only limited weight should be placed on any predictions.

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Agent: non-target organisms at risk

General

8. Non-target organisms at risk from agent (include those closely related biologically and those ecologically similar)

Pathogens - specificity testing, host range

i. *All genera and species of important cultivated plants in the same family as the weed host are to be tested. For each crop species a representative of major genetic groups of cultivars and the major cultivars grown in the region should be tested as a minimum. As many cultivars, hybrids and breeding lines are concerned, along with a considerable amount of parent material from plant breeding programs, the advice of agronomists, plant breeders and botanists from various Departments of Agriculture, Forestry, CSIRO and tertiary training institutions in the region should be sought in choosing the cultivars, hybrids and breeding material to be tested.*

ii. *Genera and species of native plants in the same family as the weed host are to be tested. The advice of botanists in all States and New Zealand regarding testing should be sought so that all relevant species (and ecotypes that have been shown to exist) will be tested*

iii. *In the case of heteroecious fungi any alternate hosts or possible alternative hosts should be tested, e.g. if the rust has as an alternative host certain species of Allium in its country of origin, all species of Allium in the region should be tested*

As a general rule, species closely related to the host from which the agent was collected are most at risk from the agent (See **Host specificity overview**). In particular, as suggested by the guidelines, closely related species which are biologically and ecologically similar and whose habitats overlap those of the target pest are at highest risk. Parasites, parasitoids and predators may use cues from the plant host of their arthropod target to find and accept their target, so other arthropods using that plant host may be at risk.

Continued next page

Agent: non-target organisms at risk (continued)

The list of species most at risk could be better defined if the host finding and acceptance behaviour of the agent was known, especially the environmental and host cues used by the agent. This is usually not the case, but the **behaviour of relatives** of the agent may serve as a guide.

Given the importance of this information in meeting the **aim of the review process**, the reviewer should be confident of the taxonomic relationships presented in the application or refer the application to a taxonomist who can judge the validity of claimed relationships.

Details for selection of commercial cultivars suggested for pathogens could also be applied to other weed biocontrol agents.

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Related topics: Host specificity - overview
Host specificity testing - insects
Host specificity testing - pathogens
Host test list

Agent: interactions within existing biocontrol program

General

9. Possible interactions with existing biological control programs (of same or related targets and other targets)

This question was raised because of the fear that arthropod biocontrol agents could use weed biocontrol agents as hosts and so reduce the efficacy of the weed control agent. Any weed biocontrol agents related to the target for an arthropod biocontrol program should be discussed here.

Negative interactions between agents introduced for control of the same target are theoretically possible, and one instance of this has been documented from the hundreds of introductions of biocontrol agents. However, negative interactions of this type are rare and avoidable if selected agents vary slightly in their particular niche, or host utilisation method.

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Agent - host specificity testing

Agent: host specificity testing

General

10. Host specificity testing program to be proposed to, or which has been accepted by, quarantine and conservation authorities (include list of host/test organisms, methods of testing)

11. Progress of testing program and results of testing program and conclusions

Pathogens - specificity testing, environment

1. *Tests should be carried out under optimum conditions for infection of the susceptible host. For particular hosts other specific requirements may be necessary*

Pathogens - specificity testing, host range

i. *All genera and species of important cultivated plants in the same family as the weed host are to be tested. For each crop species a representative of major genetic groups of cultivars and the major cultivars grown in the region should be tested as a minimum. As many cultivars, hybrids and breeding lines are concerned, along with a considerable amount of parent material from plant breeding programs, the advice of agronomists, plant breeders and botanists from various Departments of Agriculture, Forestry, CSIRO and tertiary training institutions in the region should be sought in choosing the cultivars, hybrids and breeding material to be tested.*

ii. *Genera and species of native plants in the same family as the weed host are to be tested. The advice of botanists in all States and New Zealand regarding testing should be sought so that all relevant species (and ecotypes that have been shown to exist) will be tested*

iii. *In the case of heteroecious fungi any alternate hosts or possible alternate hosts should be tested, e.g. if the rust has as an alternate host certain species of Allium in its country of origin, all species of Allium in the region should be tested*

Determination of host specificity or host range (i.e. determining the range of non-target organisms likely to be damaged in the field, and the severity of any damage if the agent is released and establishes in Australia) (See **host specificity - overview**, **background to host specificity testing**, **host specificity testing - insects**, **host specificity testing - pathogens**) is the **CENTRAL ISSUE** in satisfying the aim of the review process.

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Agent: biocontrol program procedures

General

12. When and where initial releases are proposed

13. Methods to be used for evaluating establishment, dispersal and effect on target and for what period of time

14. See next page

15. Collaborative research with other Departments

16. Assistance to be sought from other Departments, e.g. in making releases, mass rearing, secondary distribution, monitoring of spread and effectiveness

17. Assistance to be offered to other Departments, e.g. in making releases in their areas, provision of bulk stocks for release, provision of starter cultures

These questions address the effectiveness of procedures in, and organisation of, the biological control process proposed by the applicant. This information may be of interest to the reviewer, but is not relevant to the **aim of the review process**.

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Agent: Evaluating Establishment

General

14. Methods to be used for evaluating establishment, dispersal and effect on other species of flora in the vicinity of the target and for what period of time.

Although it would too late to contain an agent if was found to be unexpectedly damaging non-target flora or fauna following establishment, this information is essential as a check on how well the **application and review process** is functioning. Negative results (*i.e.* no expected damage on non-targets) add to confidence in the system, whereas any positive results would require consideration of changes in the decision making process.

The application should also specify the reporting process for circulation of the required information.

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Acknowledgements

Text:

Graham White, Farming Systems Institute, Queensland Department of Primary Industries

Sponsorship:

Cooperative Research Centre for Weed Management Systems
Cooperative Research Centre for Tropical Pest Management

Editing, Compilation and Design:

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AQIS
Geoff Norton, Centre for Pest Integrateion, Technology and Transfer, The University of Queensland
Rachel McFadyen, AFRS, Queensland Department of Natural Resources

Photographs:

Alan Fletcher Research Station, Queensland Department of Natural Resources
Keith Turnbull Research Institute, Frankston, Victoria
Dr. Peter Room CSIRO Entomology
Professor Gordon Grigg, Zoology Department, The University of Queensland

Cartoon pp 2,3.:

Becky Green, Christine Clark Graphic Design, Brisbane

Recommended Texts

Mic Julien and Graham White (Editors) (1997)
Biological Control of Weeds: theory and practical application. ACIAR Monograph No. 49, 192 pages.

Harley K.L.S. and Forno I.W. (1992)
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