ARC • LNR

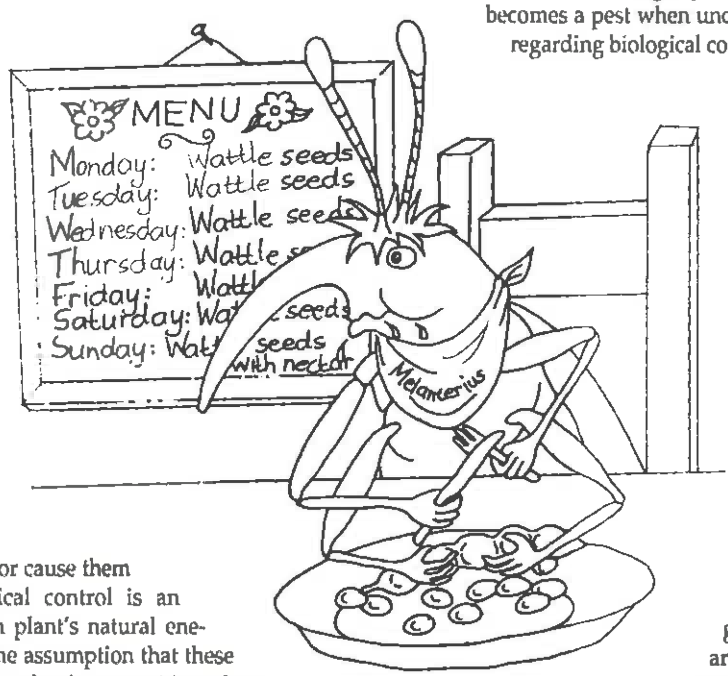
Compiled by Hildegard Klein
ARC-Plant Protection Research Institute

1. BIOLOGICAL CONTROL OF ALIEN INVASIVE PLANTS

1.3 Principles of biological control

WHAT IS BIOLOGICAL CONTROL?

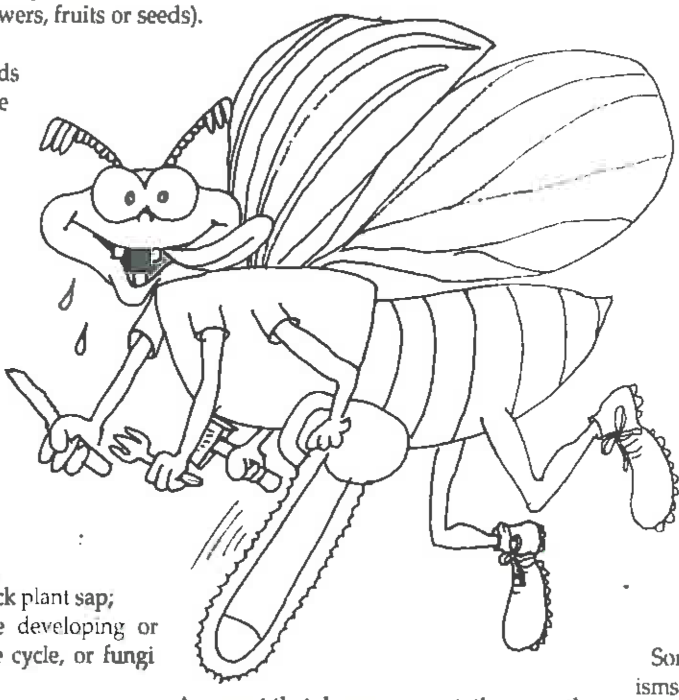
Biological weed control consists in the use of natural enemies to reduce the vigour or reproductive potential of an alien, invasive plant. The principle is that plants often become invasive when they are introduced to a new region without any of the natural enemies of the plant. The alien plants therefore gain a competitive advantage over the indigenous vegetation, because all indigenous plants have their own natural enemies that feed on them or cause them to develop diseases. Biological control is an attempt to introduce the alien plant's natural enemies to its new habitat, with the assumption that these natural enemies will remove the plant's competitive advantage until its vigour is reduced to that of the natural vegetation. Natural enemies that are used for biological control are called biocontrol agents.



A host-specific seed feeder

In the control of alien, invasive plants, the biocontrol agents used most frequently are insects, mites and pathogens (disease-causing organisms such as fungi). Biocontrol agents attack specific plant organs, such as the vegetative parts of the plant (its leaves, stems or roots) or the reproductive parts (flowers, fruits or seeds).

The choice of biocontrol agents depends on the aim of the control project. If the aim is to get rid of the invasive plant species, scientists select the biocontrol agents causing the most damage. In such projects, scientists may use agents that damage the vegetative parts of the plant as well as agents that reduce seed production. Examples of suitable biocontrol agents for such situations are beetles or moths with stem-boring or root-boring larvae; moths, beetles or flies with leaf-mining larvae; midges, flies, wasps, mites or fungi that cause plant galls; beetles, wasps or moths that feed on leaves as larvae and/or adults; bugs, cochineal insects or mealybugs that suck plant sap; moths, beetles or bugs that damage developing or mature seeds during part of their life cycle, or fungi that cause plant diseases.



An agent that damages vegetative growth

However, if the target plant is useful in certain situations but becomes a pest when uncontrolled, **conflict of interests arises** regarding biological control. In such cases it is unwise to use biocontrol agents that could kill the plant or make it unfit for utilisation, because the distribution of biocontrol agents cannot be limited to those areas in which the target plant is regarded as harmful. This conflict is usually resolved by avoiding biocontrol agents that have the ability of causing damage to the useful part of the plant, and instead using only seed-reducing agents. These reduce the reproductive potential of the plants, curb their dispersal and reduce the amount of follow-up work needed after clearing, while still allowing for the continued utilisation of the plant. For instance, trees are normally grown for their wood, but the seeds are seldom utilised. Suitable biocontrol agents for such tree species would be insects, mites or fungi that attack flower buds, flowers, fruits or seeds. If seeds of these trees are needed to replant a plantation, a seed orchard can be specially protected against the biocontrol agents in the same way as other crops are protected against insect pests. If, on the other hand, the pods are the most valuable part of the tree, as in the case of mesquite (*Prosopis* spp.), no biocontrol agents can be selected that will affect the flower buds, flowers or pods. The seed-feeding beetles that were introduced against mesquite prevent only the germination of seeds from the animal droppings, without significantly reducing the nutritional value of the pods. They do not prevent pod or seed production.

Biocontrol agents are mostly introduced from the country of origin of the plant. Most of the invaders of the arid regions of South Africa are indigenous to the Americas and those invading the Fynbos are mostly native to Australia. Therefore, their natural enemies were collected in those countries.

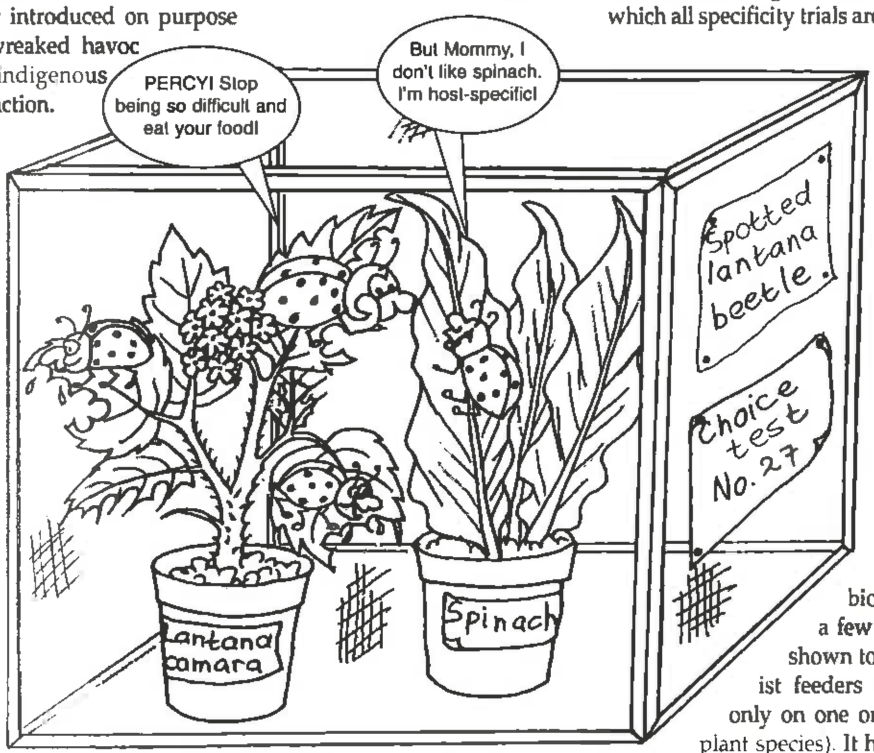
Sometimes, locally occurring organisms may be used, e.g. the stump fungus on black and golden wattle and the gummosis fungus on hakea.

1.3 Principles of biological control

Research is being undertaken to develop a similar mycoherbicide against prosopis. Such locally-occurring organisms are usually not lethal to their host plants, but have to be assisted in some way to cause greater damage. This could be done by applying the fungal spores onto a fresh wound, e.g. by painting a mixture of the myco-herbicide Stumpout® direct onto the cut stumps of black or golden wattle.

IS BIOLOGICAL CONTROL SAFE?

The introduction of living organisms from one country to another is always extremely hazardous, and numerous cases are known where alien organisms (whether introduced on purpose or inadvertently) have wreaked havoc and driven countless indigenous plants or animals to extinction. Therefore, biological control of alien, invasive plants has developed into a highly specialised science that is practised with the utmost care. Every conceivable precaution is taken to prevent the introduction and release of alien organisms that could become harmful.



Host specificity testing

The introduction and release of weed biocontrol agents may be undertaken only by scientists who have the necessary knowledge and experience of insects, mites and/or fungi and their interaction with plants, who have access to approved quarantine facilities in which the introduced organisms can be studied and reared without the danger of escape, and who are subject to the safety regulations imposed by their own government as well as regular scrutiny and discussion of their projects by fellow scientists from other countries. In South Africa, research on the biological control of weeds is undertaken by the ARC-Plant Protection Research Institute, in co-operation with the Departments of Zoology and/or Entomology of several universities.

No biological control agents may be released against weeds in South Africa without the permission of two Government Departments: the National Department of Agriculture and the Department of Environmental Affairs and Tourism. Before granting permission, these Departments require a whole series of scoping reports and environmental risk assessments, which are also submitted to an independent panel of experts to ensure that the candidate biocontrol agents will pose no threat to crops or indigenous plants of South Africa or its surrounding countries.

The potential risk posed by a candidate biocontrol agent is determined by biocontrol researchers through extensive host range studies (specificity tests) that are carried out in a quarantine facility. These trials determine the range of plants that a potential biocontrol agent is able to use as host plants throughout its life cycle, as well as its host plant preferences. Permission to release a biocontrol agent will be sought only if the host-specificity tests prove without doubt that the potential agent is sufficiently host-specific for release in this country. To be regarded as sufficiently host-specific, the candidate agent must be either monophagous (i.e. the insect feeds on only one plant species, the target weed in this case) or it could have a slightly wider host range, provided that none of the additional host plants occur in South Africa or surrounding countries, either as indigenous or introduced crop plants.

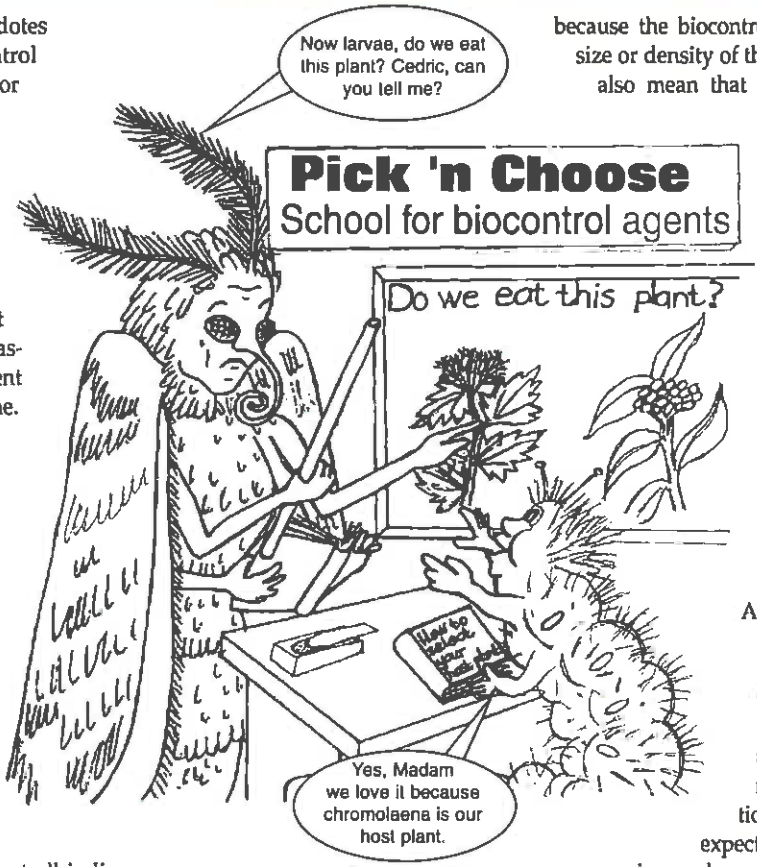
Although specificity tests have to be adapted and slightly modified for each candidate biocontrol agent, there are certain principles on which all specificity trials are based. By studying thousands of insect species with their host plants, entomologists have developed a very good understanding of the factors that determine the principle of host-specificity in insects. Certain insect families are known to consist of general feeders (insects that feed on a very wide variety of plant species), and scientists would never consider members of these families as potential biocontrol agents. However, a few insect families have been shown to consist mainly of specialist feeders (insects that can survive only on one or a very small number of plant species). It has also been found that if such specialist feeders can survive on more than one plant species, these plant species are usually very closely related, i.e. they would belong to the same genus or at least to the same plant family as the primary host. The implication of this principle to biological weed control is that when selecting test plants for specificity trials, researchers start with those plant species that are most closely related to the target weed, and work in ever-widening circles of relationship around the target weed. Relationship is not the only factor that determines an insect's host choice, and researchers always try and find the reason for the potential biocontrol agent's choice of host plants. This could necessitate novel techniques that are too complicated to explain here. Mostly it is also considered important to include representatives of plant families containing economically important plants or threatened species in the list of test plants.

The future of biological weed control as a career depends on its track record, and therefore it is in the interest of each biocontrol researcher to ensure that no biocontrol agents are released unless they are really host-specific. No short cuts or slip-ups can be tolerated, and it could take between two and ten years before the specificity tests for a single biocontrol agent have been completed.

Tested and approved biocontrol agents therefore do not pose a threat to our crops or indigenous vegetation in South Africa, or to those of neighbouring countries. No cases have ever occurred of properly tested weed biocontrol agents changing their host plant affinities after their release in a new country, to include plants other than those

1.3 Principles of biological control

known to be acceptable hosts. Anecdotes are sometimes quoted of biocontrol agents causing damage to crops or indigenous plants. These non-target effects can all be explained by the fact that the agents were released before the second half of the 20th century, when specificity testing became customary, or that the scientists had correctly predicted the wider host range but had taken the calculated risk of releasing the agent, based on an argument that was considered valid at that time.



Only specialist feeders can be biocontrol agents

Note that these strict specificity tests are only required before the introduction and release of biocontrol agents against weeds, but are not compulsory when parasitoids or predators are introduced to control pest insects or other pest organisms. The number of insect species in any country vastly exceeds the number of plant species, and only a fraction of all living insect species have ever been identified. It would therefore be impossible to carry out host specificity tests against all indigenous insect species that would be at risk before any parasitoid was released to control an insect pest. There are also far fewer insects that are known to be beneficial, than the number of beneficial or crop plants. Biological pest control has been essential in protecting crops and controlling disease-carrying organisms, but it is impossible to determine the effect it has had on the indigenous insect populations. Some catastrophic attempts at biological pest control were perpetrated in the past by careless or ignorant persons in several countries, but these projects would never have been approved by the present authorities in any country practising biological weed control.

HOW EFFECTIVE IS BIOLOGICAL CONTROL?

Probably without exception, biocontrol agents do not completely exterminate populations of their host plants. At best, they can be expected to reduce the weed density to an acceptable level or to reduce the vigour and/or reproductive potential of individual plants. The fact that a few host plants always survive, in spite of the attack by a biocontrol agent, actually ensures that the agent does not die out as a result of a lack of food. The small population of biocontrol agents that persists will disperse onto any regrowth or newly-emerged seedlings of the weed. For this reason, biocontrol can be regarded as a sustainable control method.

A biological control project is considered a complete success if no other control measures are required to keep the weed under control. A few examples of complete successes in South Africa are the biological control of red water fern *(Azolla filiculoides)*, water lettuce *(Pistia stratiotes)*, Port Jackson acacia *(Acacia saligna)*, red sesbania *(Sesbania punicea)* and Australian pest pear *(Opuntia stricta)*. The degree of control is regarded as significant if methods other than biological control are still needed to reduce the weed to acceptable levels, but less effort is required. This could mean that fewer herbicide applications are needed per year or that less herbicide is needed per unit area because the biocontrol agents have reduced the size or density of the weed infestation. It could also mean that less follow-up is necessary because the biocontrol agents have reduced the weed's ability to regrow following mechanical or chemical clearing actions. Examples of such projects are the biological control of jointed cactus *(Opuntia aurantiaca)*, prickly pear *(O. ficus-indica)*, parrot's feather *(Myriophyllum aquaticum)*, water hyacinth *(Eichhornia crassipes)* and silky hakea *(Hakea sericea)* in South Africa.

Biological control works relatively slow. Considering the number of years it has taken invasive plants to reach their present population levels, it is unrealistic to expect an insect species to increase in numbers within one or two years to a level at which it can already significantly reduce the invasive plants. On average, at least five years should be allowed for a biocontrol agent to establish itself successfully before starting to cause significant damage to its host plant.

Unfortunately, biological control is not necessarily effective or possible against every problem species. It could happen that effective biocontrol agents do exist, but cannot be released in South Africa because they are not sufficiently host-specific. Alternatively, the invasive plant might be a man-made hybrid between two or more species, and is no longer an acceptable host to the natural enemies of either of the parent plants. It could also happen that the natural enemies of some plants are not adapted to all the climatic regions in which the plant is a problem in South Africa, or that the habitat already contains predators or parasitoids that attack the biocontrol agents. In such cases, biological control will have to be replaced or supplemented by chemical or other control measures.

ADVANTAGES OF BIOLOGICAL CONTROL

This method:

- is environmentally friendly because it causes no pollution and affects only the target (invasive) plant
- is self-perpetuating or self-sustaining and therefore permanent
- is cost-effective
- does not disturb the soil or create large empty areas where other invaders could establish, because it does not kill all the target plants at once. Instead, it allows the natural vegetation of the area to recover gradually in the shelter of the dying weeds.

HOW DOES BIOLOGICAL CONTROL FIT IN WITH WEED MANAGEMENT?

In some instances, biocontrol agents may effectively control a weed on their own. In other cases, the biocontrol agents should be incor-

1.3 Principles of biological control

porated into a more comprehensive weed control programme that might include other methods of control such as chemical and mechanical control as well as utilisation of products of the weed. To make optimal use of the available biocontrol agents, the following points should be considered:

Planning

The possible use of biocontrol agents should already be kept in mind during the planning phase of any weed control programme. The person in charge of planning must find out which agents are available, what they do and how to use them. One then has to consider how best to integrate the use of the biocontrol agents with the other control methods.

Agent reserves or refugia

The mechanical or chemical clearing of large weed infestations may eliminate any biocontrol agents present on the weed in that area. It is therefore essential to establish small reserves of healthy, mature plants on which the agents can survive and reproduce and from which they can spread onto plants that may have escaped the clearing process. Some agents disperse rapidly on their own and can readily colonise extensive areas, while others - such as cochineal insects and mealybugs - have to be collected manually from the reserves and released in the target areas. Persons involved in cactus biocontrol should always remove some insect-infested cactus plant material and distribute it to healthy cactus before the cochineal or mealybugs have destroyed their host plants in a specific area. This will ensure that the biocontrol agents do not become extinct locally, but maintain their presence in the area to colonise regrowth.

Establishment of agents in areas not due for immediate clearing

All the available biocontrol agents should be established in any areas that are not targeted for immediate clearing as well as in areas adjacent to those being cleared, so that seed production and the reinvasion of the cleared areas by the invasive plants could be reduced.

Prioritisation of weeds

Some weed species are at present under effective biological control. Further time and money should not be wasted on other clearing methods. Examples are:

- Silky hakea *(Hakea sericea)* in areas where gummosis disease and the other agents are very active
- Sesbania *(Sesbania punicea)* after the introduction of all three insect agents
- Port Jackson acacia *(Acacia saligna)* when the gall rust fungus is present
- Harrisia cactus *(Harrisia martinii)* after the establishment of the mealybug
- Australian pest pear *(Opuntia stricta)* after the establishment of cochineal.

The chemicals and labour costs saved in this way can rather be used for the control of invasive plants where there are no effective biocontrol agents, or in areas where biological control is less effective.

CONTACT PERSONS

- Inquiries about biocontrol research: Weeds Research Division, ARC-PPRI, Private Bag X134, Pretoria 0001; Tel (012) 329 3269; Fax (012) 329 3278; e-mail weeds@plant2.agric.za
- The supply of biocontrol agents for specific weeds: consult leaflet 1.4 in this series, or contact the Weeds Research Division, ARC-PPRI.

FURTHER READING

On biological weed control in general

HARLEY, K.L.S. & FORNO, I.W. 1992. *Biological Control of Weeds: a handbook for practitioners and students.* Melbourne: Inkata Press: 1-74.

JULIEN, M. & WHITE, G. 1982. *Biological Control of Weeds: theory and practical application. (ACIAR Monograph Series).* Canberra: 1-190.

On specific biological weed control projects in South Africa

HOFFMANN, J.H. (Ed.). 1991. Biological Control of Weeds in South Africa. *Agriculture, Ecosystems and Environment*, 37: 1-255.

OLCKERS, T. & HILL, M.P. (Eds.) 1999. *Biological Control of Weeds in South Africa (1990-1998). African Entomology, Memoir No. 1:* 1-182.

KLEIN, H. 2002. *PPRI Leaflet Series: Weeds biocontrol*, No. 2.1 and all following numbers.

ISBN 1-86849-165-X

Page design: Sanet du Plessis. This leaflet was printed by United Litho, with financial assistance from the *Working for Water* Programme of the Department of Water Affairs and Forestry and the National Department of Agriculture
Copies can be obtained from the librarian, ARC-PPRI at the above address.