Session 4
Biological Control

BIOLOGICAL CONTROL OF WEEDS: THE WAY FORWARD, A SOUTH AFRICAN PERSPECTIVE

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ABSTRACT

South Africa currently ranks in the top three of the most active countries involved in biological weed control. A synthesis of biological weed control in South Africa provides a portrayal of the worldwide situation. Many of the 76 agent species, mostly herbivorous insects, that have been released in South Africa since 1913 are substantially damaging the 40 species of weeds that have been targeted for biological control. However, the degree of control that has been achieved is variable and, with few exceptions, the weeds have not declined to acceptable levels. In general, expectations for biological control are set at unrealistically high levels so that biological control programmes often are construed as failures unless the target weed is brought under complete control. However, much can be achieved with biological control agents that cause even moderate levels of damage on the target weed. The way forward is to thoroughly evaluate each programme so that appropriate management strategies, including integrated control, can be implemented to maximize the performance of the biological control agents. Examples from South Africa that illustrate this approach are discussed, including the biological control of (i) *Opuntia stricta* (Cactaceae), a succulent shrub of conservation areas; (ii) *Solanum elaeagnifolium* (Solanaceae) a herbaceous shrub of arable lands; (iii) *Prosopis* species (Mimosoideae, Leguminosae), a perennial tree of range-lands; and (iv) *Sesbania punicea* (Papilionoideae, Leguminosae), a riverine, perennial tree.

INTRODUCTION

The earliest intentional attempts at biological control of a weed were made with a cochineal insect species, *Dactylopius ceylonicus*, which was successfully used against a troublesome cactus, *Opuntia vulgaris*, in southern India during 1863 and in Sri Lanka during 1865 (Tyron, 1910). For almost forty years no further biological control programmes were initiated until 1902 when 14 species of agents were released onto *Lantana camara* in Hawaii (Julien, 1992). These releases were followed some ten years later by others on other weeds elsewhere and biological control became a commonly accepted and regularly utilized method of weed control (Julien, 1992). The rate at which agents were released escalated during the ensuing decades, with a decline during the 1940s and a slowing during the 1980s (Table 1.). List A of Julien (1992) shows that up to the end of 1990 there had been a total of at least 780 deliberate releases of 274 species of agents onto 122 weed species in 59 countries.

Table 1. The number of deliberate releases of biological control agents onto weeds during the first eight decades of the twentieth century, worldwide and in South Africa only.

	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s
Worldwide	14	13	45	47	21	74	119	207	212
South Africa	0	1	0	11	2	1	6	21	27

In 1913, the first biological weed control agent was released in South Africa. Since then the rate of introduction of additional agents has been variable but, in keeping with global trends, the number of releases has increased steadily over the last four decades (Table 1). If the number of agents released and the number of weed species tackled up to 1990 is used as a measure of how active each country has been in biological weed control, then South Africa ranks third (Table 2).

Table 2. The number of species of biological control agents released and the number of weed species tackled with biological control by 1990 in the five countries that are most active in biological weed control.

	Number of	
Country	Species of agent released	Weed species
United States of America (including Hawaii)	130	54
Australia	123	45
South Africa	61	28
Canada	53	18
New Zealand	24	15

Although meaningful syntheses are possible (e.g Sheppard, 1992), considerable difficulties are encountered when attempts are made to assess the success of biological weed control on a global scale. Problems arise, for among other reasons, because the performance of an agent species often varies from country to country, either through ecological effects, intra-taxonomic variation or in the way the agent is manipulated in different regions. Additionally, the rating of the performance of biological control agents is usually subjective and therefore highly variable and difficult to compare between one region or country and another. Reviews on a national or regional scale are more instructive because assessments of agents can be standardized through first-hand knowledge of all the biological control programmes.

For these reasons, the biological control of weeds in South Africa is reviewed. Examples are presented which demonstrate that thorough evaluation studies are needed, firstly to assess the effectiveness and deficiencies of each biological control programme and secondly for the design and implementation of procedures to maximize the performance of partially successful agents. Although the examples are restricted to South African weed control programmes, the lessons that have been learnt apply universally.

BIOLOGICAL CONTROL OF WEEDS IN SOUTH AFRICA

The ecology and management of biological invasions in southern Africa is reviewed in Macdonald *et al*. (1986), which includes the potential of insect herbivores for biological control of invasive plants in South Africa (Moran *et al*., 1986). More specifically, the biological control of weeds in South Africa has been thoroughly reviewed in a special issue of Agriculture Ecosystems and Environment, volume 37, numbers 1-3, 1991. The Plant Protection Research Institute of the Agricultural Research Council is responsible for biological weed control in South Africa.

To date, 76 agents have been released in South Africa for biological control of weeds. Of these, 69 species (91%) are herbivorous insects while the rest include four fungal species, two mite species and one fish species. Eighteen of the agent species (24%) primarily damage the reproductive parts (buds, flowers and seeds) of the weeds while the rest mainly damage the vegetative growth. The four principal feeding methods of herbivorous insects (i.e. chewers, suckers, borers and gallers) are utilized by the range of agent species, even though two methods (galling and sucking) have been considered conventionally to be of little value in biological control (Harris, 1973, Goeden, 1983, Hokkanen, 1985).

The 40 weed species that have been the target of biological control in South Africa include taxa in 14 families, mainly the Cactaceae (15 species), Leguminosae (8 species) and Compositae (5 species). A wide range of growth forms are represented including perennial woody trees and shrubs (12 species), herbaceous shrubs (4 species), succulent shrubs (14 species), herbs (5 species) and aquatic macrophytes (5 species of which three are free-floating and two are attached).

Criteria to evaluate the success of the biological weed control programmes in South Africa were defined during April 1994 at a 'work-shop' attended by most of the personnel involved in the biological control of weeds in South Africa. Three categories of control were recognized, based on the amount that alternative control methods (chemical or mechanical) have been reduced since the introduction of biological control agents onto the weed. The degree of control is classified as: (i) complete, when no other control measures are needed to reduce the weed to acceptable levels, at least in areas where the agents are established; (ii) substantial, when other methods are still needed to reduce the weed to acceptable levels, but less effort is required (e.g. less frequent herbicide applications or less herbicide needed per unit area) because the extent or density of the weed infestations has declined or because there has been a reduction in the rate at which the weed disperses or reinvades cleared areas; and (iii) negligible, when control of the weed remains almost entirely reliant on other control measures in spite of damage inflicted by the agents.

At least 23 out of the 40 biological weed control programmes that have been undertaken in South Africa have been of sufficient duration for meaningful evaluation using the above classification. The analysis shows that 6 species (26%) are under complete control while 13 species (57%) are considered to be under substantial control and 4 species (17%) are under negligible control.

For two reasons, the proportion of species considered to be under complete control in South Africa (i.e. 26%) is misrepresentative. Firstly, three of the species, *Harrisia martinii*, *Hypericum perforatum* and *Opuntia leptocaulis*, were only minor problems in South Africa but were subject to biological control because of the notorious problems they, or closely related taxa, have caused elsewhere and because there were effective biological control agents readily available (Gordon & Kluge, 1991, Moran & Zimmermann, 1991). Secondly, biological control of the other three weed species, *Opuntia vulgaris*, *Pistia stratiotes* and *Salvinia molesta*, in South Africa also relied on the use of agents that had been used successfully elsewhere in the world (Room *et al.*, 1981, Harley *et al.* 1984, Moran & Zimmermann, 1984). Therefore, complete control is not easily or often achieved using biological methods alone.

Expectations for biological control are routinely set at extremely high levels (cf. Julien *et al.*, 1984, Dennill & Donnelly, 1991). Each biological control introduction aspires to repeat the "miracle" that was achieved with the biological control of *Opuntia stricta* in Australia during the 1930s (Dodd, 1940) or the resounding successes of a few other highly successful programmes since then (e.g. *Hypericum perforatum* in the United States of America) (Holloway & Huffaker, 1953). As a result, in most cases, biological control programmes are construed as only partial successes, or sometimes as failures, unless the target weeds are brought under complete control. This attitude engenders negative perceptions about biological control and discourages further exploitation of potentially useful biological control agents.

Indeed, the search for an "ideal" agent has dictated the course of the biological control programme against *Lantana camara* (Fig. 1A) in South Africa. To date 16 species of agents have been released on the weed and the search for additional agents continues (Cilliers & Neser, 1991). Six species of agents have become established on *L. camara* in South Africa and together they cause substantial damage and provide some control of the weed. Overall, however, the effectiveness of the agents is limited because *L. camara* in South Africa, as elsewhere, embraces a large number of different cultivars (Spies & Stirton, 1982a, 1982b, 1982c, Swarbrick, 1986) each of which is effectively a distinct weed species (Cilliers & Neser, 1991). The biological control agents are highly specific and only survive on one or, at the most, a few cultivars of *L. camara* (Cilliers & Neser, 1991). As a result, susceptible cultivars that are suppressed by the biological control agents are readily replaced by herbivore-resistant cultivars and the weed problem persists.

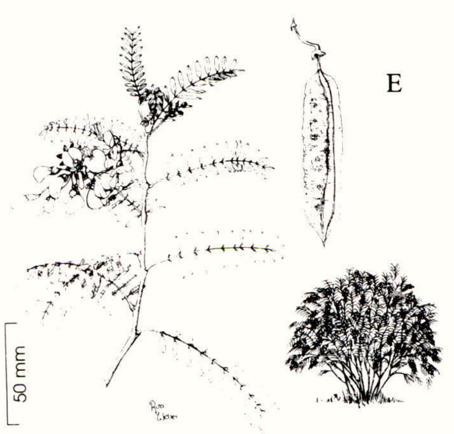

Figure 1. Weed taxa discussed in the text. (A) *Lantana camara*. (B) *Opuntia stricta*. (C) *Solanum elaeagnifolium*. (D) *Prosopis glandulosa*. (E) *Sesbania punicea*. Drawings by: R. Weber (A and E), W. Roux (B), A. Walters (C), G. Condy (D) and M. Steyn (habits A and E). Original drawings are the property of the National Botanical Institute and Plant Protection Research Institute, Pretoria. The drawings have been reproduced from Henderson (1995).

Although an "ideal" agent for control of *L. camara* may be found eventually, it may be more profitable to explore avenues that will enhance the effectiveness of the six species of agents that are currently established on the weed. This approach has been successful with other biological control programmes in South Africa and four examples are presented which show that even moderately effective agents can make a considerable contribution to the control of problematic weeds when appropriate management strategies are adopted. Although the success of some weed control programmes has been enhanced through manipulation of the agents, weeds or habitat (e.g. Room & Thomas, 1985), complementary management strategies need to be incorporated, or at least considered, routinely as part of every biological weed control programme.

Opuntia stricta (Cactaceae)

Opuntia stricta (Fig. 1B) is a succulent, spiny, cactaceous shrub which, when unchecked, forms extensive impenetrable thickets up to 2 m in height. This is the species that was a major pest in eastern Australia before it was very successfully controlled biologically (Dodd, 1940). Until recently *O. stricta* has rated as only a minor pest in South Africa (Moran & Zimmermann, 1991), but during the 1980s it became recognized, along with *Lantana camara*, as the most important invasive terrestrial species in the Kruger National Park (KNP), South Africa's premier nature reserve. The spread of the weed within the KNP was rapid because the fruits of *O. stricta* are a favoured food for baboons and elephants which range over considerable distances and disperse the undigested seeds in their dung.

An extensive herbicide programme was launched in an attempt to "eradicate" *O. stricta* from the KNP. The treatment consisted of injecting Monosodium methanearsonate (MSMA) into the stems of the plants, the dose depending on the size of the plant (Zimmermann, 1989). The stem-injection technique minimizes, but does not eliminate, harmful side-effects of the herbicide on vulnerable indigenous plant species (D A Zeller, personal communication). Practically every *O. stricta* plant that is inoculated with sufficient MSMA is killed, but many small plants are inadvertently overlooked and the growth of these, along with that of seedlings, enables the weed to reinvade cleared areas. Continuous follow-up treatments are needed to keep the weed under control with herbicides and these add to the financial and environmental costs of an already expensive programme.

In an attempt to substitute, or at least supplement, these herbicidal control efforts with biological control, *Cactoblastis cactorum* was introduced into the KNP in March 1988. *Cactoblastis cactorum* has been used successfully in the biological control of several *Opuntia* species around the world, most notably against *O. stricta* in Australia (Moran & Zimmermann, 1984).

Cactoblastis cactorum readily became established and within five years dispersed over the range of *O. stricta* in the KNP. However, populations of the moth seldom reach the levels that are required for the larvae to destroy large plants and dense infestations of the weed persist because the *O. stricta* plants are able to tolerate and compensate for the damage that