BIOLOGICAL CONTROL OF WEEDS - A REVIEW

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Summary. The current state of progress in Australian biological control programmes for weeds is reviewed and other potential programmes considered. Studies elsewhere relevant to Australian problems and current emphases and concerns in methodology are briefly described. The increasing problems presented by conflicts of interest are discussed and the role of adequate post-introduction studies in aiding predictability and integration with management systems is emphasised.

INTRODUCTION

Ten years ago there were only four projects on biological control of weeds; on lantana (*Lantana camara*), groundsel bush (*Baccharis halimifolia*), Noogoora burr (*Xanthium pungens*) and skeleton weed (*Chondrilla juncea*). There are now 18 projects. In the face of this increased activity the limited number of contributions in this session might seem surprising, but I would direct attention to the fact that the V International Symposium on Biological Control of Weeds held in Brisbane in 1980 included 25 papers by Australian workers in this field. In attempting to give an up-to-date account of activities in biological control in both Australia and overseas I shall be referring extensively to work presented at that meeting.

In this review I will discuss the stage of development of programmes and potential programmes in Australia, and then make some comment on relevant overseas development. Improvements and emphases in methodology will then be discussed with reference to some of the problems which are receiving attention from workers in this field both here and elsewhere. Finally, I want to dwell a little on one of the problems emerging in this field and what is necessary, not only to help overcome it, but to advance our expertise in the whole field and its utility to weed science in general.

THE AUSTRALIAN SCENE

The current state of progress in the 18 Australian programmes is shown in Table 1. There are six more programmes and several others have made significant advances compared with a similar list published in 1978 (Cullen 1978).

Following its success in the U.S.A., the flea bettle *Agasicles hygrophila* was introduced into Australia and has devastated floating alligator weed (*Alternanthera philoxeroides*) and this form of the weed must be considered under control. Success is not complete however, as the weed is not controlled in terrestrial habitats (Julien 1981b). The problem the weed presents in such situations is less direct, threatening to give rise to further aquatic infestations and to increase the weed's range, perhaps to areas where *A. hygrophila* might be less effective.

McFadyen and Tomley in their paper review the dramatic success of the Harrisia cactus (*Eriocereus martinii*) programme in Queensland. Three insect

Table 1. Status of current programmes in Australia.

Weed	Stage of programme[1]	References
Acacia nilotica	2	Mohyuddin 1981
Alternanthera philoxeroides	5	Julien 1981
Baccharis halimifolia	4	this conference
Chondrilla juncea	5	Cullen 1979
Echium plantagineum	3	Delfosse and Cullen 1981b; Wapshere 1981
Eichhornia crassipes	5	Wright 1981
Emex australis and *E. spinosa*	4	Julien 1981
Eriocereus martinii	5	this conference
Heliotropium europaeum	3	Delfosse and Cullen 1981a
Hypericum perforatum	3[2]	Delfosse and Cullen 1981c
Hyptis suaveolens	2	
Lantana camara	5	Willson 1979
Mimosa pigra	2	
Parthenium hysterophorus	3	this conference
Rubus fruticosus agg.	2	Amor 1981; Hasan 1981
Rumex spp.	1	
Salvinia molesta	5	
Senecio jacobaea	4	Cullen and Moore 1981; Schmidl 1981

[1] Key to stages
1 Exploration
2 Study of one or more potential control agents
3 Release of one or more potential control agents
4 Establishment of at least one control agent
5 Some control achieved

[2] Current programme only.

species have been established in the field; a mealybug (*Hypogeococcus festerianus*), a stem-boring beetle (*Alcidion cereicola*) and a stem-boring weevil (*Eriocereophaga humeridens*). The effect of the mealybug in particular has been spectacular, with plants dying in large numbers after two years' heavy infestation by the insect. All chemical control operations against this weed have ceased.

There has been extensive collapse of water hyacinth (*Eichhornia crassipes*) at Rockhampton principally due to the activity of the introduced weevil *Neochetina eichhorniae*, with a steady reduction in the area of water hyacinth since late 1978 (Wright 1981).

The most recent success in this field is the dramatic effect of the weevil *Cyrtobagous singularis* on salvina (*Salvinia molesta*) on Lake Moondarra in Queensland. Large areas of weed have been destroyed (P.M. Room, personal communication, 1981).

In 1978, two programmes (on lantana and skeleton weed) were listed as already giving some control(Cullen 1978). Control of lantana is slowly and steadily increasing as other vegetation replaces it following injury by introduced insects, and it is hoped that the increasing complex of insects will steadily extend the range over which lantana is effectively damaged (Willson 1979).

Control of the narrow leaf form of skeleton weed remains good, and a new rust strain has been introduced for the intermediate leaf form, but the search continues in Europe for strains virulent against the broad leaf form (Cullen 1979).

McFadyen reviews the groundsel bush programme in this conference, and the considerable amount of work which has resulted in the introduction of 20 species of insects into quarantine at Sherwood. At this stage, only four have established in the field: the leaf-feeding beetle *Trirhabda baccharidis*, the leaf-webbing moth *Aristotelia* sp., the stem-boring beetle *Megacyllene mellyi* and the leaf-feeding beetle *Anacassis fuscata*. Preliminary results from *M. mellyi* look promising but as control has not yet been achieved, work is proceeding on other insects.

The current status of the parthenium weed (*Parthenium hysterophorus*) programme is also reviewed in this conference. This relatively recent programme commenced with exploratory work in Mexico in 1976 and has led to the introduction of a leaf-feeding beetle *Zygogramma bicolorata* and a seed-feeding weevil *Smicronyx lutulentus*. McFadyen and McClay describe the biology and specificity of these species, both of which have been released in the field.

While this brief summary points to a picture of considerable activity and a substantial increase over the situation even three years ago, it should also be pointed out that there are several potential targets on which some preliminary work has already been carried out. These include thistles (*Carduus* spp.) onion weed (*Asphodelus fistulosus*) and silverleaf nightshade (*Solanum elaeagnifolium*). The only real reason why these are held in abeyance is the perennial problem of shortage of resources, including trained personnel. There is also the possibility that work could be renewed on Noogoora burr (W.H. Haseler, personal communication, 1981).

RELEVANT OVERSEAS PROGRAMMES

A list of overseas programmes of potential relevance to Australia was published in 1978 (Cullen 1978). This still stands, though much of the work carried out on these has now been taken up or even overtaken by work in equivalent Australian programmes. However, to that list one could now add the U.S.D.A. programme on curled dock (*Rumex crispus*) (Spencer 1981), some of which is relevant to the new programme on *Rumex* spp. initiated by the Western Australian Department of Agriculture. There is fresh information available as a result of further work on caltrop (*Tribulus terrestris*) (Sankaran and Ramaseshiah 1981), perennial thistle (*Cirsium arvense*) (Watson and Keogh 1981), field bindweed (*Convolvulus arvensis*) (Rosenthal 1981), silverleaf nightshade (Orr 1981) and mistflower (*Eupatorium riparium*) (Trujillo 1976). There has also been initiated in the southeastern states of the U.S.A. a cooperative project entitled "Biological control of weeds with fungal plant pathogens" amongst whose projected targets are spiny sida (*Sida spinosa*), Johnson grass (*Sorghum halepense*), nutgrass (*Cyperus rotundus*) and yellow nutgrass (*C. esculentus*) (Freeman and Charudattan 1981).

THE PRACTICE OF BIOLOGICAL CONTROL

In looking briefly at progress in the practices and techniques employed in biological control programmes, the principal impression is that while the more important problems and considerations are becoming clearer, the same cannot always be said about their solutions. Thus in considering the likely source of effective natural enemies, Wapshere (1981a) has discussed the importance of the weed's origin, the centre of speciation of the genus and climatic homologues, while Room (1981) has suggested the possible utility of studying the weed's exotic range and Sands and Harley (1981) have emphasised the importance of within-species variation in collecting potential control agents. Myers and Sabath (1981) and Marshall *et al.* (1981) have suggested different considerations in selecting the type of population and method of sampling which might be most useful. The importance of avoiding deleterious genetic effects is recognised in the laboratory rearing phase, but the manner of so doing is not always clear. Mackauer (1981) has suggested some general guidelines and it will be interesting to see how readily they can be followed in practice. In looking at the importance of diseases imported with control agents in limiting their potential, it can be argued that the time and effort necessary to detect and remove a disease is unwarranted. Examples are known of insects carrying a disease and being successful control agents (e.g. *Longitarsus jacobaeae* which has a cephalogregarine parasite in North American stocks (Dunn and Andres 1981)), and clean insects are likely to acquire similar diseases from their new environment. However, there are examples of diseases being significant (e.g. a polyhedrosis virus in *Tyria jacobaeae* (Schmidl 1972)) and recent accounts have argued strongly for inspection and disease removal (Allen 1981; Dunn and Andres 1981). There is a uniformity of purpose in evaluation studies, but considerable differences in commitment and the techniques in use; the former often reflects different philosophies and the latter reflects different target species and environments.

In addition to insects, mites, plant pathogens and nematodes which can be used in classical biological control programmes, there is an increasing exploitation of other herbivores of less specialized habits and which can be managed. The best example is probably the grass carp (*Ctenopharynogodon idella*) for aquatic weeds (van Zon 1981), but *Tilapia* spp. and dugongs also for aquatic weeds, and goats for several less palatable terrestrial weeds, deserve mention. Kemp *et al.* in their paper discuss the possible potential of the Australian lungfish (*Neoceratodus forsteri*) for the control of submerged aquatic weeds in Australia, and point to some of the information which would be necessary to properly evaluate this species. In particular they mention the likely utilization of weed material in the presence of varying amounts of alternative food, and the possible effects of a large omnivorous fish in areas not previously exposed to such animals.

CONFLICTS OF INTEREST

At this tage I shall turn from problems of execution to what is emerging as a major problem of principle, that of conflicts of interest; this was heightened in Australia recently by the Paterson's curse/Salvation Jane (*Echium plantagineum*) controversy. Not surprisingly, Australia is not alone in having to face this type of problem and Andres (1981) has recently reviewed differenct facets of this area using some North American examples.

The basis of the problem is what is often considered as the irreversible nature of a successful introduction and the general effect it will have throughout a plant's distribution. In the classic situation, as exemplified by Paterson's curse, the weed itself has beneficial as well as deleterious properties and the balance must be determined by those responsible for agricultural policy. Such policy will usually be based on economic grounds though ecological and sociological considerations may also apply. This is not the responsibility of the biological control worker, but of those concerned about control to ensure that the appropriate data are available to justify control of a plant with some beneficial properties. What can also be relevant to the resolution of such conflicts is prediction of the degree of control or its variation under different conditions, which clearly *is* the responsibility of the biological control worker.

Where non-target plants are concerned, the situation becomes more complex and the role of the biological control worker and his predictions more important. It is this area which is becoming of increasing concern in North America (Andres 1981) and could well become so here. Where biological control agents are completely specific to the weed and no damage at all is expected to other plants, the situation is simple. Where some damage is obtained under experimental conditions however, judgements must be made of its likely significance under field conditions. More information is required about plants possibly at risk, and the prediction of the likely outcome in the field becomes extremely important. So far the record is good, but this aspect is likely to become of increasing importance as science becomes more and more accountable to the community; the ability of the scientist to predict the outcome could then become quite crucial.

CONCLUSION

Predicting the outcome of biological control programmes has not only always been extremely difficult but also extremely important in policy making and is likely to become more so, bearing the previous comments in mind.

The elucidation and validation of general principles in biological control are also extremely difficult areas. Are there any general principles? Generalisations with exceptions are not a great deal of use in a field where every case is different. Does current research in herbivory and chemical defences of plants have relevance for biological control? Are annual weeds, crop weeds, sexually reproducing weeds, unstressed weeds and native weeds, all poor targets for biological control? At present the answer is that we are not sure because we do not have the right information.

Finally a word concerning weed management. If weeds are to be managed in systems which include a biological control input, and there is little doubt that an increasing number are going to be so managed, then we must have adequate information about that system.

The same information will also help test the hypotheses put into practice during the course of a programme.

The overall conclusion from this review should be clear. Biological control activity is increasing and is often being successful, but we must ensure that adequate effort is put into finding out exactly what we are doing when we introduce a new organism into a new environment. Otherwise the potential of biological control to contribute more and and more to solving our weed problems will not be realised because we are unable to predict and manage the outcome.

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