Recent advances in the biological control of weeds

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INTRODUCTION

I have strayed slightly from the originally suggested title for this talk, though perhaps only by a matter of degree. I find it difficult to apply the term "new advances" to the results, often gradually achieved, of what are in fact carefully planned long term programs whose basic rationale has not changed for some time. Such traditional biological control programs still form the bulk of activity in the field and will continue to do so. It is therefore appropriate and of value to this meeting that recent achievements should be summarized here. This I shall do by briefly reviewing the current range of programmes in Australia and also overseas, particularly where relevant to Australian problems. In addition, it would not be doing justice to the field if I did not examine recent developments in theory and principles, where modifications to the traditional system have been made and perhaps where the term "new advances" might be more relevant. Finally I would like to add a note on how biological control is coming to be, and should in the future be, considered as part of programs of weed management.

However, first let me consider some of the more recent practical results.

Current projects in Australia

Table 1 lists those weeds currently under investigation in Australia together with the stage which studies have reached.

Two other species, nodding thistle (*Carduus nutans* L.) and silver-leaf nightshade (*Solanum elaeagnifolium* Cav.), might also be mentioned. These are also very much under consideration, largely because of their significance and because promising natural enemies are known from overseas work (see later).

Apart from the high level of success attending the skeleton weed (*Chondrilla juncea* L.) program in particular (Cullen, 1977), perhaps the most significant point is that 10 years ago such a table would have been much smaller, the increase reflecting the increased interest in the field in recent years. The reasons are probably threefold. There is no doubt that there has been increased concern about the hazards of chemicals in the environment and consequent pressure to find other means of weed control. This has been aggravated by simple economic considerations, - a straightforward consequence of reduced profit margins in the rural sector and increased herbicide costs. Thirdly, and rather importantly, there have been some successes, both here and overseas, sufficient to make it clear that the chances of obtaining a worthwhile measure of control are not remote - in fact are quite high, provided a program is properly managed. This is a point appreciated by farmer and scientist alike, the former, increasingly realizing the

Table 1. Status of current programs in Australia

Weed	Stage of program[1]	Reference[2]
Alternanthera philoxeroides (Mart.) Griseb	4	Harley, Forno and Julien, 1978
Baccharis halimifolia L.	4	McFadyen, 1973
Chondrilla juncea L.	5	Cullen, 1977
Echium plantagineum L.	2	Wapshere, 1977
Eichhornia crassipes (Mart.) Solms.	4	Harley, Forno and Julien, 1978
Emex australis Steinh. and *E. spinosa* Campd.	4	
Eriocereus martinii Lab.	4	
Heliotropium europaeum L.	2	
Lantana camara L.	5	
Parthenium hysterophorus L.	1	
Senecio jacobaea L.	2	
Rubus fruticosus L. agg.	1	

[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] Only references relevant to the current stage of the program are given. In several cases this is only known through unpublished reports and personal communication.

possibilities, so pushing for further investigation, while the latter recognizes that procedures can be and have been improved as a consequence of considerably increased scientific input. The chances of success have been increased, and at the same time become more predictable.

Overseas programs

Turning to the overseas situation, Table 2 lists those projects whose targets are also of interest to Australia, in which there has been significant recent development, or which are otherwise important. Sixteen species or groups of species are included out of a possible 47, so I have been quite selective. The remaining programmes are either at an early stage or have shown no major changes recently. The table includes most of the major overseas successes of recent years, i.e. ragwort (*Senecio jacobaea* L.), nodding thistle and alligator weed (*Alternanthera philoxeroides* (Mart.) Griseb), together with the potential or partial successes of *Rubus constrictus* Lef. and M. and *R. ulmifolius* Schott, caltrop (*Tribulus terrestris* L.) and possibly water hyacinth (*Eichhornia crassipes* (Mart.) Solms.).

Ragwort has been a problem in some of the eastern and western coastal provinces of Canada and in Washington state, Oregon and California in the U.S.A. The cinnabar moth (*Tyria jacobaeae* (L.)) was first established in California from releases made in 1959, in eastern Canada from releases in 1963, and in British Columbia from releases in 1964. It increased slowly at first in all sites but began producing severe defoliation 4 to 6 years later. Ragwort's ability to regenerate from the rootstock is well known, but in Nova Scotia the growing season is apparently too short for the plants to recover sufficiently before the severe winter, and large numbers of those defoliated died. The weed is completely controlled by the cinnabar moth alone in this region. In 1973 the density on the release site was approximately one thousandth of the original level. Results were similar in Prince Edward Island (Harris, 1973). By contrast, in the warmer areas of the Pacific states the plant was able to recover and while flowering stems were greatly decreased, plant numbers were not greatly affected. In one site in California, for instance, all flowering stems were removed (originally $18/m^2$) but rosette numbers varied from $15/m^2$ where the vegetation was dense, to $70/m^2$ in bare ground, - an increase in density in the latter situation. In 1972, the flea beetle (*Longitarsus jacobaeae* Waterhouse) was established in this area and steadily increased. By 1976, the ragwort density in this same area varied from zero to 0.6 plants per m^2 according to the amount of other vegetation, while in a second site where the flea beetle was released in 1969, ragwort had virtually disappeared (Hawkes, personal communication). This beetle is now established in Oregon, Washington and British Columbia but it is too early to expect the full effect yet.

Nodding thistle has been dramatically decreased in Virginia by the action of the seed weevil (*Rhinocyllus conicus* (Froel.)) (Kok, 1977) and is decreasing in Oregon and Montana (Dunn, personal communication) and in Saskatchewan, Canada (Harris, personal communication). Alligator weed has been virtually removed as a menace in large areas of the waterways of south eastern U.S.A. due to the activity of the beetle *Agasicles hygrophila* Selman and Vogt (Spencer, 1977).

established and effective in the same environment in the native range of the weed (Wapshere, 1970). Finally and rather less well defined is the problem of obtaining sufficient genetic diversity and adaptability from the source population. The founder colony of a natural enemy released in a new environment is invariably derived from an extremely small sample of the original field population of the species. Thus there is always the danger of artificial selection and decreased adaptability. Environmental matching may minimize the deleterious effects this might have in that it involves endeavouring to include the most useful genotypes in the sample population, but there are other considerations, derived from population genetics, which even if difficult to implement should be borne in mind (Mackauer, 1974; Messenger, Wilson and Whitten, 1976).

2. Types of organism considered for importation

Biological control of weeds has traditionally been the field of the entomologist and insects have been given prominence when considering possible natural enemies e.g. *Cactoblastis cactorum* (Berg), *Chrysolina quadrigemina* (Suffrain). Recently, however, there has been a dramatic increase in interest in pathogens, encouraged in part by the success of *Puccinia chondrillina* Bubak and Syd. on skeleton weed. Recent years have seen the importation of *Phragmidium violaceum* to Chile for control of *Rubus ulmifolius* and *R. constrictus* (Oehrens and Gonzalez, 1977), *Uredo eichhorniae* to the U.S.A. for possible control of water hyacinth (Charudattan et al, 1977a), *Aecidium asclepiadinum* and *Puccinia araujae* to the U.S.A. for possible control of milkweed vine (*Morrenia odorata* (Hook. and Arn.) Lindley) (Charudattan et al, 1977b) and consideration given to the importation of *Uromyces rumicis* (Schum.) Wint. for control of curled dock (*Rumex crispus* L.) in the U.S.A. (Frank, 1973). There is also a considerable amount of study of endemic fungi and locally evolved pathogens e.g. *Cercospora rodmanii* Conway on water hycainth (Conway and Freeman, 1977), *Phytophthora citriophthora* on milkweed vine (Ridings, Mitchell and Schoulties, 1977). Apart from fungi, there have been two examples recently of the use of nematodes. Watson (1977) has demonstrated the potential and specificity of *Paranguina picridis* Kirjanova and Ivanova from the U.S.S.R. for the control of creeping knapweed (*Acroptilon repens* (L.) DC.), while in Texas, the potential of *Nothanguina phyllobia* (Thorne) Thorne for the control of silver-leaf nightshade is under study (Orr, Abernethy and Hudspeth, 1975).

In addition to pathogens, brief mention should be made of the now well known examples of the use of snails, manatees and fish in aquatic weed control, while not quite so well known is the use of shrimps in paddy fields (Katayama et al, 1974).

3. Testing of host specificity

Present day quarantine provisions are necessarily rigorous, but at the same time host specificity mechanisms are better understood and recent years have seen testing programs everywhere adopt a more logical approach, thus rationalizing the procedure and at the same time enabling more confidence to be placed in the result (Zwölfer and Harris, 1971; Wapshere, 1974).

4. Pre- and post-introduction evaluation of effectiveness

Unfortunately for the efficient use of resources, ecology is not yet sufficiently exact a science to allow accurate predictions of the effectiveness of introductions to be made with certainty. This is particularly true in that field of plant ecology which deals with population survival and the influence of natural enemies in determining abundance. However, the need for development is recognized and the first attempts have been made to analyse weed natural enemy systems - not only to examine the effects of a particular program but to gain some understanding of the way in which such systems operate (e.g. Cullen and Groves, 1977).

Before leaving this discussion mention should also be made of the greater consideration now given to avoiding artifical selection in laboratory rearing and the elimination of disease in imported cultures.

Managed biological control and weed management

In addition to the interest in traditional biological control programs there has also been increased interest in the manipulating or managing of biological control systems e.g. by direct and perhaps regular intervention to improve the level of control. There are several situations where a control system is inadequate because of regular deficiencies in either the timing, distribution or extent of attack. Where these lend themselves to improvement e.g. by supplementary distribution, inoculation and propagation, the possibility exists of still using a biological system but with extra input. There are some good examples of this approach, not always well known, from earlier work, e.g. the inoculation of weedy persimmons with persimmon wilt *Cephalosporium diospyri* Crandall (Wilson, 1965) and of unwanted oak trees by oak wilt fungus *Ceratocystis fagacearum* (Bretz) Hunt. (French and Schroeder, 1969) and in the U.S.S.R., the large scale propagation and use of *Alternaria cuscutacidae* Rud. to control dodders (*Cuscuta* spp.) and *Phytomyza orobanchia* Kalt to control broomrapes (*Orobanche* spp.) (Kovalev, 1973). However, more recently Daniel et al,(1973) have had considerable success using *Colletotrichum gloeosporioides* (Penz.) sacc. f. sp. *aeschynomene* to control northern joint vetch (*Aeschynomene virginica* (L.)) in rice, while a program is developing to use the moth *Bactra verutana* Zeller as an applied control for nutgrass (*Cyperus rotundus* L.) (Frick and Quimby, 1977).

The use and management of biological controls can be expected to develop and increase in sophistication and concomitantly so will the need to know more about the interrelationships involved in the weed - natural enemy system; an area already mentioned as developing in response to a need felt in classical biological control programs. What is required is essentially a better appreciation of the ecology of the weed, with appropriate attention given to the natural enemy component. Whether it be insect or weed pest, this approach is the basis of programs of integrated control or pest management. This concept is certainly not new to weed control but is perhaps developing rather slowly, with the possible exception of aquatic weed control. Here the idea of managing the whole environment of the weed, including the arthropods and pathogens naturally present or imported as part of a biological control program, is being actively pursued (Blackburn, 1977).

In conclusion, biological control of weeds is alive and well, in fact it is developing quite vigorously. As it continues to develop and as weed control tends more to weed ecology, and as the ecology takes into account the influence of the overall environment on survival, death and reproduction, so weeds will become managed. And biological control will increasingly take its rightful place, not as an answer in all circumstances but as an integral part of weed management programs.

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