Integrated control and management: synthesis of session 6

J.M. CULLEN
CSIRO Division of Entomology, GPO Box 1700, Canberra, ACT 2601, Australia

Introduction

The concept of integrated management of weeds is certainly not new, but it is still fairly loosely defined and if this meeting was dominated by users of herbicides, I would expect to see papers on the integration of the use of one herbicide with the use of another. Alternatively, we might expect the business of this Symposium to be concerned with the integration of insects and pathogens, though there has been virtually no mention of this as an area of interest in its own right. However, to most people, integration refers to the use of very different approaches to control of the same weed. In fact, there are a number of different ways in which biological control can be integrated with other methods of weed management in both space and time (Watson and Wynore 1989). Though these represent a continuum of modes of interaction, understanding and purpose, it is helpful to consider them under three headings: purpose-specific approaches; ecological integration; and physiological integration. (Unless specified by reference to a date, the papers referred to below are all in this Volume).

Purpose-specific approaches

By ‘purpose-specific’ I mean the option to choose the type and level of control according to the requirements. A common situation would be the use of a combination of approaches to tackle a weed that is still spreading, where an important aim would be to remove the outliers that are extending the area of infestation. These may be removed by herbicides or by a combination of other methods that effectively removes the weed, while biological control may be relied on to give long-term control of large, established infestations.

The programme against *Parkinsonia aculeata* L. (Caesalpiniaceae) in northern Australia, described in this session by Flanagan *et al.*, is an example of this combination of techniques, as is the current programme against *Mimosa pigra* L. (Mimosaceae), also in northern Australia. Generally the aim is to use herbicides to effect complete control while biological control is used in established areas where eradication is no longer an option.

A similar, but different example is that given by Hosking and Zimmermann where biological control of *Opuntia aurantiaca* Lindley (Cactaceae) is adequate for most purposes, but where there is nil tolerance, e.g. in recreation areas, additional control is provided by local application of herbicides. A characteristic of these programmes is the separation of approaches in space and, sometimes, in time. The overall programmes require an integrated approach, but the actual control of an infestation may require very little integration of the technologies employed.

Ecological integration

The term ‘ecological integration’ is given to situations where different approaches are used on the same infestation, often at the same time. The characteristic is that where biological control is involved, there is recognition of the need to preserve populations of the natural enemy or enemies.

Integration with herbicides

The commonest challenge in integrated management is the effective combination of herbicides with biological control. The number of good examples is still limited. At this Symposium, Findley and Jones have demonstrated the value of herbicides in providing initial knockdown of water hyacinth *Eichhornia crassipes* (Martius) Solms-Laubach (Pontederiaceae), followed by biological control to maintain it at an acceptable level. Regular monitoring is often a feature of such systems so as to allow timely intervention by herbicides, should they be necessary occasionally, but care must be taken to preserve sufficient of the weed (5-10% in the case of the water-hyacinth programme) to maintain a reservoir of the agent. An elegant example is that described by Julien and Storrs, where the weevil *Cyrtobagous salviniae* Calder & Sands maintains control of salvinia, *Salvinia molesta*
interaction between competition and the action of natural enemies. While the nature of the interaction is important from the point of view of knowing sufficient about the system to manipulate it further, as long as it is proportional, additive or synergistic (sensu Willis and Ash) and not substitutive, the integration is beneficial for control. Unfortunately, the number of documented examples is limited, particularly in the field.

Most debate and attempts at integrating plant competition with biological control have been concerned with agricultural situations and DiTommaso et al. present a field example of a positive interaction whereby the effect of a pathogen is enhanced by competition from the crop. However, it is likely that with the increasing importance being attached to the impact of weeds in natural ecosystems, and the appropriateness of biological control in such systems, there will develop a need to look more closely at the value of competition from the native flora in enhancing the effect of biological control. At present such consideration is limited to rehabilitation and revegetation efforts to ensure that the system is sufficiently competitive to resist reinvasion from the weed once biological control is effective. This in itself is a valuable strategy for such systems and is recognized as important in the programme against *Chrysanthemoides monilifera* (L.) Norlindh (Asteraceae) in Australia (Adair and Edwards). It is likely that there will be increasing attention given to integrating all available approaches, including herbicides and manual methods that can be used by volunteer groups, in addressing the problem that weeds pose in natural environments.

**Optimization**

What is referred to here as ‘optimization’ has been variously considered previously under the heading of augmentative control, cultural control and in this Symposium as ‘system management’ (Müller-Schräer and Frantzen). The latter contribution describes the principles well, but suggests it is limited to the use of endemic biological control agents rather than exotic species. It would seem that the principle is applicable to both. It is essentially a holistic approach that encompasses all modifications to the environment that may favour the effectiveness of biological control. Müller-Schräer and Frantzen provide an effective example in the approach taken to control of *Senecio vulgaris* L. (Asteraceae), as do Scott and Yeoh in their
suggestion of providing resources to maintain the presence of the aphid *B. rumexicolens* during the season when the weed *E. australis* is not present. Gassmann also advocates the improvement of the food resources for biological control agents as a means of improving their effectiveness.

The interaction of the nutritive status of the weed and the effectiveness of agents has been demonstrated previously in the programmes against *Opuntia inermis* de Candolle (Cactaceae) (Dodd 1940) and *Salvinia molesta* (Room et al. 1989). In both cases, the provision of additional nitrogen and its uptake by the weed increased the effect of the agent significantly. Winterton and Heard demonstrate the important interaction between the nutrient level of eutrophic waters and the biological control of water hyacinth, *E. crassipes*, and it is apparent that effective control of this weed in the more polluted environments, where it often occurs, will require attention to modifying the nutrient level, as well as ensuring the establishment of the most appropriate biological control agents.

**Physiological integration**

There was not much attention given at the Symposium to the synergistic interactions between the changes in the biochemistry of weeds, often produced by sublethal effects of herbicides, and the effectiveness of biological control agents. What has been described has concerned pathogens, which is typical of the worldwide trend where there is considerable interest in the interaction of herbicides and pathogens (Christy et al. 1993), particularly where they might be used as mycoherbicides and perhaps be applied out of the same nozzle.

Watson and Wymore (1989) reviewed work in this area and, more recently, Sharon et al. (1992) gave a detailed analysis of the synergistic interaction between sublethal doses of glyphosate and the action of *Alternaria cassiae* on *Cassia obtusifolia* L. (Caesalpiniaceae), while Heiny (1994) also found synergistic effects between 2,4-D and MCPP and *Phoma proboscis* on field bindweed *Convolvulus arvensis* L. (Convolvulaceae). Prasad (1994) however, found mainly negative interactions between a range of common adjuvants and pesticides and herbicides and *Chondrostereum purpureum* Fr. Pouzar.

Shearer reports on significantly-enhanced effects of the pathogen *Myceloplastus terrestris* on *Hydrilla verticillata* (L.) Royle (Hydrocharitaceae) in the presence of very low application rates of the herbicide fluridone, while Yang and Schnad suggest a challenging proposal, based on the interaction of low virulence, but broad-spectrum, pathogens with special carriers. The specificity is given by the targeted application of the carrier, which must be present for the pathogen to infect the host.

There have been few contributions from entomologists on this issue. Some attention has been paid to direct effects of herbicides on insects in relation to ecological management, but almost none to the indirect effect via the physiology of the weed. It is possible that there is some effect of this sort in the interaction between *A. nigriscutis* and herbicides as reported by Lyn et al., but there is insufficient known of the mechanism at this stage.

The phenomenon of weeds being more palatable for grazing stock after sublethal doses of certain herbicides is well known, but little seems to have been done to investigate similar effects for insects. However, it is worth mentioning the effect of a weevil, *Trichostrongylus horridus*, on *Carduus nutans*, whereby the foliage becomes much less spiny and quite soft (T. Woodburn personal communication), thereby rendering it more acceptable to stock. This suggests an interesting integrated programme of biological control and grazing management, which is currently under study.

**The future of integrated weed management**

There are some questions that we should consider at this point. The promotion of Integrated Pest Management (IPM) followed an upsurge in interest in insect biological control and was taken up enthusiastically, particularly by the chemical industry in some instances, but suffered from misinterpretation and lack of successful application. Will the same thing happen with integrated weed management? Will it become as important or more important than biological control? Or will it only be used when biological control does not work straightaway? If integrated control is going to be used more widely, what do we need?

I refer to a point made by Fowler and Waage. Many countries are now signatories to the International Convention on Biodiversity. One of the most telling paragraphs from that Convention reads, “Integrated Pest Management is recognized as the preferred strategy to achieve sustainable agricultural production”. An obvious aim is to reduce disruptive
chemical inputs and this is tempered by the recognition that, while biological control is highly desirable, it doesn’t always work, but what it does mean is that we need to exploit it to the maximum. Biological control needs to be augmented if it is not completely successful and it needs to fit into existing management systems.

While a relatively simple application of herbicide, as required, might be satisfactory in some biological control situations, many more are going to require a good knowledge of the system. This in turn would support the argument for more pre- and post-release studies, without which it will be almost impossible to know sufficient of the system requiring intervention. The examples provided by Julien and Storrs and by Lym et al. have demonstrated how critical the timing of herbicide application can be if the population of the agent is to be maintained at effective levels. The holistic systems approach is extremely relevant to obtaining the maximum benefit from biological control, as is an appreciation of what is a realistic aim. Suppression to a particular level is often a legitimate result, rather than complete control. Ultimately, optimal management, with minimal intervention, requires a good understanding of the weed control-agent system, and its population dynamics in particular.

I believe that, as scientists concerned with reducing disruptive inputs by establishing an ecologically-sound approach to control, we have a mandate to extend our expertise in order to help provide the basis for programmes of integrated management. We have probably a better opportunity to understand the ecology of weed population-dynamics than many other weed scientists have the chance to understand biological control, so the opportunity is there to build the necessary bridges between the different disciplines.

I have referred to one area where there seems to be inadequate research, the interaction between chemicals, principally herbicides, and the effectiveness of insect biological control agents, and I have emphasized again the importance of increasing our knowledge of the weed system we are dealing with. Finally, however, it is important that we realize that these research areas are not the whole answer to better integrated management. IPM for insect pests has often not been implemented because of poor information-delivery systems. The best methods rely on community involvement. Involving a volunteer dune-care group in biological control, or a community farmer-group in working out how biological control agents can be fitted into their farm routines, is an extremely effective means of creating understanding and implementation.

We need more biological control, not less, but we need to know more about what we are doing so we can use it in more situations and we need to create an understanding in the community, for us to help deliver the best sustainable management practices possible.

References


