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Biological Control of Weeds–Past, Present and Future

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Vice-Chancellor, members of the Organizing Committee, Invited Guests, and Fellow Delegates to the VIII International Symposium on the Biological Control of Weeds.

I wish to thank the members of the Organizing Committee for their invitation to give this Opening Address. It is a pleasure to return to Lincoln. In 1981 I spent eight months working with DSIR Grasslands on the campus diagonally opposite this venue. During that time I interacted with several research groups including the relatively small number of research scientists involved in the biological control of New Zealand weeds and came to know something of their research. I was attached, however, not to the biological control group, but to DSIR Grasslands Division, with whom I worked on the tussock grasslands of the Mackenzie country. One of my more important qualifications to be asked to give this Opening Address may be that, unlike most of the audience, I am neither an entomologist nor a plant pathologist, but a plant ecologist with research interests not only in the ecology of weedy species but in natural plant communities also. My background will influence very much what I shall present.

My title is *Biological Control of Weeds–Past, Present and Future*. In this address I wish to inter-weave some personal history and some aspects of the growth of the subject as represented in the proceedings of previous symposia, with a consideration of the biological control of weeds as a branch of science. I shall try to predict where future growth and an increased rate of success may be achieved.

Firstly then, some personal history.

I began my career in the biological control of weeds when in October 1966 the new CSIRO *Chondrilla* Biological Control Unit was established at Montpellier, France. On the field trips made at that time, the most common organism to be found on *Chondrilla juncea* L. (Asteraceae) plants was a rust *Puccinia chondrillina* Bubak & Syd. (Uredinales). About 6 yrs later, a strain of that rust was released in south-eastern Australia and began to exert its powerful controlling influence on the competitiveness of the widespread form of *C. juncea* in wheat crops. Results of that biological control program have been the subject of many papers in previous *Proceedings* of Biological Control of Weeds Symposia (e.g., Hasan 1970, Cullen 1978) and elsewhere (e.g., Cullen and Groves 1977, Groves and Cullen 1981). The very success of that program led to a greatly increased emphasis on the use of plant pathogens as agents of biological control (Charudattan and Walker 1982). Such emphasis continues to grow, with a session of this symposium being devoted to the subject.

I wish to emphasise another point from that early research on *C. juncea* and its biological control by a rust. I spent time in the herbaria at both Kew and Montpellier looking at specimens of *C. juncea*. In retrospect, that was wasted time. It wasn't until seed was collected and rosettes grown that differences within both the European and Australian populations became apparent. So-called *alpha*-taxonomy based on pressed specimens of flowering material that lacked rosette leaves revealed much less about variation within the species of that particular weed than did the growing of rosettes and the quantitative characterisation of leaf shape (Hull and Groves 1973). These differences in leaf shape became significant subsequently because different strains of the rust were shown to be specific to different forms of the weed. The similarity in rosette leaf shape of the widespread Australian form to a population in Italy enabled the rust populations be "matched,"

it was the strain of rust from this particular Italian population that was introduced and released in Australia.

Twenty or more years later, the use of more precise genetic markers, such as isozymes, to characterise both pathogen and host biotypes is a powerful diagnostic tool and an essential part of many biological control programs. It has become a major part of the on-going program for biological control of the other 2 forms of *C. juncea* present in Australia (Burdon *et al.* 1980) and the western United States (Hasan *et al.* 1993). Methods are now available to characterise DNA composition and use of these and other methods will continue to refine results of some biological control programs. Such methods have been used recently in the program on *C. juncea*, for instance. The methods of molecular biology are finding their way into the discipline of biological control and a wider use of such methods may advance our science considerably. I look forward to more papers on this aspect at future symposia.

These 2 points–an increasing role for fungal pathogens in biological control and the need to accurately distinguish the genetic constitution of both host and natural enemy–are both strong features of many contemporary biological control programs, including those currently under way at the CSIRO unit at Montpellier, 25 yrs later. I look forward to following more closely future developments in both aspects.

Science is an international activity and in few branches of science is it more evident than in biological control. The very spread of venues at which previous symposia have been held bears out this contention–Délèmont (Switzerland), Rome (Italy), Montpellier (France), Gainesville (USA), Brisbane (Australia), Vancouver (Canada), Rome (Italy), and now Lincoln. Not only are the symposia held at various international venues, but the contacts made to facilitate the research are also international in their range. I well remember making helpful contact with a Russian colleague about the taxonomy of the genus *Chondrilla* long before the "cold war" began to be "perestroika." That contact arose because the centre of taxonomic diversity for the genus is southwestern Russia. The taxonomic centre of diversity for the species *C. juncea* seems to lie in Turkey, however, far away from the Montpellier station that was set up by CSIRO for *Chondrilla* research. The present program on biological control of *Chondrilla* benefits from being a co-operative one with some Turkish pathologists, thereby minimising the effects of distance, even within Europe. Partly as a result of this co-operation, there are greater hopes for being able to identify strains of rust effective against the other two forms of the weed present in Australia and the three forms present in western United States (Hasan *et al.* 1993).

Commencing in July 1992 when I moved to Montpellier, I hoped to continue forging closer links between the CSIRO laboratory and the USDA Biological Control Laboratory, newly located from Rome to a site at Montpellier adjoining the CSIRO site. I am optimistic that those closer links will come about in many areas of co-operative endeavour, especially when we are working on the same weed species, such as *Carduus pycnocephalus* L. (Asteraceae).

A corollary of this international aspect of biological control is the need to study the candidate weed in its country of origin. Such study should include not only the biology of the potential natural enemies of the weed but also, I submit, the ecology of the plant in its natural community over several years. This requirement for international residence makes biological control programs expensive relative to some more "home"–and laboratory-based branches of science. A future problem for research managers, as the pool of funds for research ceases to grow (and even to contract in real terms), is that it will become increasingly difficult to obtain the relatively high level of funding required to finance research in the countries of origin of those weeds we wish to study. This problem may become worse in the future, partly because of the international aspect of our research and partly because of its long-term nature. But I hasten to add that although our research may be relatively costly to the research agency, the returns from that research are invariably high. Cost-benefit analyses for biological control of several weeds, such as *C. juncea* and *Echium plantagineum* L. (Boraginaceae) in southern Australia, have shown extremely favourable ratios (Marsden *et al.* 1980, Industries Assistance Commission

1985). What is more, the products of biological control research come at no cost to the primary producer or to the land management agency, unlike other control methods. I predict that it will become increasingly difficult to fund research programs on the biological control of weeds in the future, despite the widespread goodwill shown our type of research by the community.

One way to increase the chances of receiving a fair share of the pool of increasingly scarce research funds is to carry out better economic analyses of the costs to the community of those weeds to be controlled *prior to* the initiation of biological control programs. Such formal analyses are rarely a feature of biological control programs, nor of previous symposia programs. I applaud the initiative of the Organizing Committee to include a Keynote Address to this symposium from an economist with experience in this aspect of biological control (Greer 1993). It should not require resolution of conflicts-of-interest or legal injunctions, as in the case of *E. plantagineum*, before doing such analyses!

Just as the CSIRO Unit at Montpellier and other units elsewhere have grown considerably over the last 25 years, so too has the discipline, as represented by the *Proceedings* of previous symposia, no matter what the index (numbers of papers presented, page numbers of the *Proceedings*, etc.) used to show such an increase. Whether the discipline continues to grow at a similar or even increasing rate depends on many factors. Those under some control by us depend partly on an increased success rate of current projects and the way those successes may influence the allocation of funds for future research programs.

I wish to conclude on a more scientific note and, because my training and research experience have been in plant ecology, on an ecological note. Most research scientists in chemical control usually consider only the weedy plant that interferes in some way with the growth of the crop or pasture or native vegetation they wish to maximise. Research scientists in biological control usually consider as well the invertebrates and/or pathogens in the system. A highly simplified pasture-weed ecosystem becomes slightly more complex as a pasture-weed-natural enemy ecosystem. It is rare in the literature on biological control of weeds, however, to find these effects quantified as they interact in exerting control. Let me cite two examples of what I mean.

In a Mediterranean-climate pasture in southern Australia the plant density of *C. juncea*, introduced from the Mediterranean Basin, can be reduced significantly after four years of continuous pasture between cereal crops (Moore and Robinson 1964). Moreover, it was the presence of subterranean clover plants in the grass-clover pasture that exerted control (Table 1). The horizontally-oriented leaves of *Trifolium subterraneum* L. (Fabaceae) (also of Mediterranean origin) shaded the rosette leaves of *C. juncea* through the winter and reduced the vigour of the weed in the medium term.

Table 1. Effects of competition from two pasture species *Lolium rigidum* (Wimmera ryegrass) and *Trifolium subterraneum* (subterranean clover) on density of *Chondrilla juncea* (skeleton weed) plants (from Moore and Robertson 1964).

Treatment	% Change in Density Relative to Unsown Control	
	2 yr	4 yr
Wimmera ryegrass	−6	−19
Subterranean clover	−14	−63
Wimmera ryegrass + subterranean clover	−53	−41
Unsown control (no./unit area)	8.5	8.7

When the rust for that particular form of skeleton weed was released in the early 1970s, a reduction in density of *C. juncea* plants was initially more rapid where the weed occurred in pasture. This controlling effect is explained by the results of a glasshouse experiment that measured the effects of both competition from *T. subterraneum* plants and infection by *P. chondrillina* on growth of *C. juncea* plants (Groves and Williams 1975). Competition from *T. subterraneum* plants reduced the growth of the weed by about 66% (Table 2). Infection by *P. chondrillina* reduced growth by about 50%. When both the pasture plant and rust interacted in this three-species system, growth of the weed was reduced by about 95%. That is, there was

a synergism that was greater than the sum of either individual effect.

To show that such a synergistic effect is not confined to a pathogen-pasture plant-weed system but applies also to an insect-pasture plant-weed system, let us consider the control of *Carduus nutans* L. in eastern United States. The results of Kok *et al.* (1986) apply equally to *C. nutans* in New Zealand or in southern Australian pastures. One plant of *C. nutans*/m^2 produced about 2,000 seeds in Year 1 of the experiment (Table 3). Infection of 1 plant of *C. nutans*/m^2 by *Rhinocyllus conicus* (Froelich) (Coleoptera: Curculionidae), a seed-eating weevil, reduced seed production to about 1,500. A *C. nutans* plant competing with the perennial pasture grass *Festuca arundinacea* Schreb. (Poaceae, tall fescue) produced only about 200 seeds. When insect and pasture plant interacted, the number of seeds produced/plant was only 116. Essentially the same order of interaction was obtained when there were 4 plants of *C. nutans*/m^2, although the reductions in seed number per plant were greater.

Table 2. Effects of competition from *Trifolium subterraneum* (subterranean clover) and infection by *Puccinia chondrillina* (rust) on % growth of *Chondrilla juncea* (skeleton weed) plants (from Groves & Williams 1975).

Treatment	Effects
Skeleton weed alone	100
Skeleton weed + subterranean clover	30
Skeleton weed + rust	49
Skeleton weed + subterranean clover + rust	6

In an earlier paper Trumble and Kok (1980) had looked at the controlling effect of a herbicide applied to the thistles at the stage of late stem elongation. Their results showed that careful timing of an application of herbicide did not affect adversely the controlling effects of the seed-eating larvae of *R. conicus* in the developing thistle head.

These two different sets of results provide a quantitative basis for a greater research effort into an integration of different control methods–competing pasture plants, strategically-timed application of herbicide and the release of natural enemies in a biological control program. I submit that research scientists in biological control of weeds have often been too narrow in their consideration of the ecosystem in which their weed occurs. I look forward to the time when the planned release of natural enemies will be seen as one aspect of an overall weed control program. If this wider approach is not adopted more widely, we may successfully control one weed only to find its place taken by another weed and not by the desirable crop or pasture or native plant that may make the system more stable and thereby make control more long term.

Table 3. Seed production of *Carduus nutans* (nodding thistle) plants as affected by growth of *Festuca arundinacea* (tall fescue) plants and infection by *Rhinocyllus conicus* (insect) (from Kok *et al.* 1986).

Treatment	Year 1	Year 2
Nodding (1 plant/m^2)	1961	119
Nodding (1 plant/m^2) + insects	1549	49
Nodding (1/m^2) + tall fescue	209	0
Nodding (4/m^2) + tall fescue	60	0
Nodding (1/m^2) + tall fescue + insects	116	–
Nodding (4/m^2) + tall fescue + insects	33	–
Tall fescue alone	0	–

In this address I have interwoven some personal history with some selected aspects of growth in the discipline of the biological control of weeds, with emphasis on the biology and ecology of those weeds I have studied. I look ahead to hearing the week's papers and discussions with a mixture of anticipation and regret. I am pleased that there are to be so many papers on the use of pathogens as natural enemies while at the same time I regret that there appear to be relatively few papers presented that use new methods from other branches of biology, or that deal with fine-scale plant or insect taxonomy. I greatly regret that there are not more papers that look at weedy ecosystems rather than at individual weedy

species. But most of all at this opening of the VIII International Symposium on the Biological Control of Weeds I delight in the internationalism of our branch of science. It has greatly enriched me personally and professionally to have so many colleagues in different countries. May you who regularly attend these symposia enjoy renewing old acquaintances and forging new ones; and to those of you attending your first symposium may you obtain continuing and increasing satisfaction from the scientific and personal contacts you make in the next 5 days and on the excursions.

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