

THE ASSESSMENT OF BIOLOGICAL CONTROL POTENTIAL OF THE ORGANISMS ATTACKING *CHONDRILLA JUNCEA* L.

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Introduction

On many occasions in the past the choice of candidate biological control organisms has been based on their inability to attack important cultivated plants. However, it has become clear recently that other methods of assessment are required which consider the biological and ecological factors involved both to determine whether it is worthwhile to undertake a prolonged testing programme and to understand the likelihood of the success of the introduction. A proper method of assessment is even more important when there is a possible choice between introducing an organism with a suspect host range and the potential good it might accomplish (e.g. *Mecas* and *Nupserha* in the case of *Xanthium* (Stride and Straatman, 1963) where the beetles were known to attack sunflower, and the *Chondrilla* aphids which can feed but not breed on *Lactuca*).

Theoretical considerations

All organisms that in some way reduce the fitness (i.e. reduce reserves; reduce competitiveness; reduce seeding ability) have the potential to act as biological control agents as a natural corollary of their excessive natural reproductive capacity.

Except for distinguishing between organisms which in no way affect fitness (i.e. dead plant feeders or the *Dasyneura* species occurring in the capitula of *Chondrilla*, which appears to do no damage to the seed), there are no *a priori* grounds for rejecting organisms because of the type of damage they cause.

Even seed feeders of already established perennials can reduce the rate of spread and the invasion of newly created sites by a weed species.

The damage produced by an individual organism, i.e. insect or fungal species, varies greatly but the differences become unimportant should a sufficient population or severe enough infection develop.

Basically, therefore, in assessing potential one is trying to determine whether an organism which attacks a particular weed plant or closely similar plant species can, on introduction into a new locality, produce a sufficient population or infestation level to reduce the fitness of the weed species within its habitat situation below economic levels.

The *Chondrilla juncea* investigation

In this investigation the assessment of the biological control potential of organisms attacking *Chondrilla juncea* has been based on three types of study.

The first has been a detailed study in the field of the abundance of the plant in Australia and of the plant and the organisms which attack it in Mediterranean Europe. Measurements have been made several times a year of plant density and infestation levels of the attacking organisms at many sites in relation to climate, edaphic factors and cultivation methods.

These studies were undertaken to discover whether the organisms in Europe were already functioning as biological control agents and to indicate whether they would function in a similar way in Australia.

Any factor which reduces the fitness of a weed species, whether cultural, competition or attacking organisms, will, because distribution and abundance are reflections of the fitness to survive, produce a reduction in the habitat range of a weed species to restrict it to particular climatic, cultural and edaphic situations and at the same time reduce density levels in a given environmental situation.

By comparison with the Australian situation, *C. juncea* in Europe is much more restricted to Mediterranean type climates, to sandy or pebbly soils and to non-competitive and non-cultivated situations. In Australia the weed occurs, often abundantly in summer rainfall climates, in more clayey soils and in competing pastures and wheat crops.

By collecting sufficient data and by comparing sites as closely similar as possible in Australia and Europe, it is possible to separate the effect of the various factors and to estimate the reduction produced by climatic, cultural, competitive factors and the plant feeding organisms.

In the *Chondrilla* study, to avoid undue bias, maximum *Chondrilla* density sites in Mediterranean Europe are being compared with similar maximum density sites in Australia in similar climatic areas. Since no two sites are exactly the same, the data collected on climate, soils, plant competition etc. allow adjustments to be made for the inevitable differences.

The last year's comparisons have been between similar maximum density sites in the similar cold Mediterranean climate areas, between Barcelona and Nice in Europe with Fishwick near Canberra in Australia.

TABLE I

Comparison of *Chondrilla juncea* densities at closely similar sites in Australia and Western Europe

	Fishwick	Le Soler	Les Campeaux
Habitat	Semi-improved pasture	Waste and abandoned land	Overgrazed pasture
Average yearly temperature (°C)	13.3	14.3	14.8
Average yearly rainfall (mm.)	570	590	557
Abundant organisms attacking <i>Chondrilla</i>	None	<i>Puccinia</i> <i>Eriophyid</i> <i>Leveillula</i>	<i>Puccinia</i>
<i>Chondrilla</i> density range (plants/m ²)	99-332	2-10	3-5

A typical comparison is presented in Table I and it is clear that the maximum density of *Chondrilla* in Australia where no organisms are found attacking it is nearly 100 times greater than in Europe where both specific and polyphagous organisms are found on the plant.

The only specific organisms which have the observed ability in the field to produce this reduction are *Puccinia chondrillina* Bubak & Syd., the rust fungus, and *Aceria chondrillae* Can., the eriophyid gall mite, and of these *P. chondrillina* is by far the most important and occurs in all sites investigated. Of the polyphagous organisms, various species of common Mediterranean snail appear to be the most important.

The comparisons have also revealed that despite the high Australian *Chondrilla* density, the amount of vegetation cover by *Chondrilla* is not much different from that in Europe. In Europe, in the dense stands the plants are just at the point when interspecific competition begins to play a more important role and in the less dense stands, interspecific competition is more important. In Australia, however, plants are in strong intraspecific competition and interspecific competition plays only a small role. Finally, the dense sites are extremely localised in Europe and the distribution of *C. juncea* is extremely fragmented compared with the Australian situation where the weed is abundant over large areas.

The above discussion could be considered to give a definition of a situation ready for biological control as follows:- A weed situation most likely to be controlled by the introduction of biological factors is one where, compared with the areas where biological control is already assumed to be effective, the weed species has an exceptionally high density over large areas, competition within the weed stand is almost solely intraspecific and the habitat range of the weed is much wider. A survey of the important weed biological control successes, e.g. of *Opuntia bentonii*, *Hypericum perforatum*, *Clidemia hirta*, *Cordia macrostachya* etc. (reviewed by Sweetman, 1958 and DeBach *et al*, 1964) shows that, as weeds, they all fulfilled all the above criteria. It is not necessary that all these criteria should be fulfilled in a given case but it seems reasonable to suggest that the more that are the more likely one is to have a biological control success.

The *C. juncea* situation is even more complicated since, although the plant occurs as a weed in roadsides and abandoned land and pastures, it is as a weed in the particular type of wheat/fallow cultivation system practised in Australia that the plant is really important. There is strong evidence that the method of wheat cultivation leads to high populations of *C. juncea* whereas the European methods are biased against *Chondrilla*. Also, in Europe, the organisms attacking *Chondrilla* do not maintain themselves in cultivations but enter after cultivation has stopped. Compared with the European situation, it is the maintenance of these high levels once cultivation has stopped which is the biggest difference between the two areas. In Europe initially high populations just after cultivation decline to lower levels. In Australia this does not seem to happen unless a competitive pasture is sown and, even then, reduction appears to be less than would be expected in Europe.

The second study which is still continuing is a detailed consideration of the effects of the various specific organisms on individual *Chondrilla* plants by a combination of observations in the field, in semi-natural field cages and in the insectary and greenhouse. These observations have revealed the damaging effect of each of the organisms, the population or infestation level for these effects to appear and the relation of population and infestation build-up to seasonal climatic factors and to phenological stages of the plant. Observations have also been made to discover any inbuilt crowding or territorial effects which would stabilize the population below a damaging level by producing excessive field emigrations from the infested plants.

Finally, the amount of predation and parasitisation of the *Chondrilla* organisms is being observed in Europe and the parasites and predators identified to compare with the situation in Australia to determine whether the same or similar parasites and predators would limit population or infestation levels after introduction. Although, theoretically, the absence of parasites or predators, when all else is equal, should lead to higher population levels, this is a difficult thing to demonstrate under field or semi-field conditions since any observations of organisms which are protected from their predators or parasites by field cages always involve the problem that the natural emigration of the organisms is also restricted. These emigrations are often provoked by the inbuilt density-dependent crowding effects or territorial behaviour mechanisms which often contain population expansion below injurious levels. To demonstrate and estimate the effect of an introduction into a region where the normal parasite and predator complex is absent, an experimental method is required which would allow the population or infestation level to develop naturally with emigration taking place but which at the same time restricts parasite and predator entry.

The potential of the organisms attacking *Chondrilla juncea*

The potential discussed below, which has been assessed by observations and comparisons between Barcelona and Nice, is the potential for the introduction of the organisms attacking *Chondrilla* into the colder Mediterranean climate areas around Canberra in Australia. In future the collection of similar data from different climatic areas will enable comparisons of abundance and occurrence which indicate climatic adaptability of the organisms to be made, and this will throw further light on their potential to

be successful in each climatic region of the weed occurrence in Australia.

Since *C. juncea* is a perennial, which regenerates from year to year mainly by rosettes growing from already established vertical rhizome, and since especially in the colder climate areas the main importance of the seeds is to spread the plant and to accomplish the initial invasion of newly-created sites, the potential of the organisms attacking *Chondrilla* can be considered in two parts: first, the ability to reduce already established perennating stands of *C. juncea* (stand reduction); second, the ability to reduce the spread of the weed and its invasion of newly-created sites (reduction in invasiveness). In an annual like *Xanthium pungens* whose stands are derived from dispersing seeds each year, only one potential need be considered for stand reduction and reduction in invasiveness are one and the same. The following is considered to be the biological control potential of the organisms attacking *C. juncea*, the biologies of which have been detailed at this meeting by Caresche and Hasan.

The rust fungus *P. chondrillina* severely damages and kills plants in both field and laboratory at all stages of the life cycle. It is considered to be the most important of the specific organisms in the observed density differences between Australia and Mediterranean Europe and is abundant in this cold Mediterranean climatic area. It is extremely probable that it reduces overwintering storage capacity of the rhizome. It has only one important parasite, *Darlucia filum*, a fungus which already occurs in Australia. It, therefore, has a high potential for stand reduction. It also reduces seeding rate in the field considerably and, therefore, has a high potential to reduce invasiveness.

The greatest problem with *P. chondrillina* is its extreme specificity to a particular *C. juncea* strain.

The eriophyid gall mite *Aceria chondrillae* Can. damages the flowering shoot only, sometimes radically but usually after considerable growth has taken place. Its part in the observed density difference between Australia and Europe is considered to be slight. No parasite or predator has been observed to have any important effect. Its potential for stand reduction in Australia is therefore low. However, since it destroys many flowers and seeds by replacing them with a leafy gall and is abundant in this cold Mediterranean climate, it has a high potential to reduce invasiveness.

Uroleucon chondrillae Nev. - This aphid attacks all stages of the plant but extremely heavy infestations are required both in the laboratory and in the field to kill a rosette let alone an established plant with a flowering shoot.

There are definite density-dependent crowding effects leading to emigration which are associated with a preference to attack rapidly growing leaves, buds or stems. Population growth rates are low during autumn and spring when the aphid could damage the rosette. The aphid appears to play no part in determining field densities of *Chondrilla* and, although there are at times high populations on the flowering shoot in the field, the reduction in seeding ability appears to be negligible. Although often heavily attacked by predators and parasites, the above-mentioned features suggest that this aphid has a low potential both for stand reduction and for reducing invasiveness.

Chondrillobium blattnyi Pint. - This aphid is almost entirely limited to attacking the rosettes in spring in the field but does not damage the rosettes. However, in the laboratory it kills rosettes at reasonably low population levels. It is not considered to play any part in stand reduction in Europe but its potential in Australia depends on whether the restricted population level in the field is due to parasites and predators or due, as seems more likely, to a combination of poor climatic adaptability and density-dependent crowding effects associated with the undersurface of the leaf of *C. juncea*. If the latter, then potential for stand reduction is low. Also, since the aphid is rare in summer and only feeds on the thin flowering stem leaves it has no potential for reducing invasiveness.

Leveillula taurica (Lev.) Arnaud, form *chondrillae* Jacz. - This white mould attacks both rosettes and, more effectively, the flowering shoot but in the field it does not kill or damage rosettes and the heaviest attack occurs towards the end of the flowering season after much of the seed has been produced. It is not thought to play any part in determining field population levels and no natural enemies have been found. It has a very patchy distribution suggesting certain very specific environmental requirements. At least in these colder Mediterranean climate areas its potential for reducing established stands and invasiveness is low.

Finally, there is a large group of polyphagous insects, including the seed flies, and a few polyphagous

fungi found on *C. juncea* but all are relatively rare in the field and most are known to have other hosts. It seems likely that *Chondrilla* is not the main host but one of the least preferred hosts of these species. For this reason, their potential as biological control agents, even if their main hosts are present in Australia, is likely to be low.

It must be stressed that the above description of the potential of the organisms attacking *C. juncea* applies only to colder Mediterranean areas of Australia. Recent observations at the beginning of this year's work in Southern Italy have suggested that the biological control effectiveness of *Puccinia*, *Leveillula*, and perhaps even of *Aceria*, the gall mite, may be much greater in these warmer Mediterranean areas and hence their potential in similar Australian areas could also be greater.

With *C. juncea*, which is essentially a weed of wheat/fallow cultivations, effectiveness also depends on the ability and speed of entry into cultivations after the harvesting of the wheat since it has been found that populations of the *Chondrilla* organisms are minimal during the cultivation phase. Both *Puccinia* and *Aceria* have this ability and rapidly attack *Chondrilla* after harvest and during the fallow phase provided that there is a sufficient abundance of the two organisms in the surrounding locality.

Discussion

Since research is still continuing, the above description of the potentiality of the organisms attacking *Chondrilla juncea* should be considered an interim account until all important factors have been observed or considered.

Moreover, it is realised that it is not possible to allow for all biological possibilities that may affect the outcome of an introduction. The potentialities described above are, therefore, a series of probabilities of success based on the observed characteristics of the organisms. Each subsequent observation or each new feature of the organism considered will either increase or decrease these probabilities.

At the present time *P. chondrillina* has the greatest probability of success whereas *A. chondrillae* is likely to reduce the spread of the plant while the two aphid species *U. chondrillae* and *C. blattnyi*, and *L. taurica* form chon-

drillae have a much lower probability of success in the colder Mediterranean climate areas of Australia.

References

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