

Effectiveness: A Comparison of Prediction and Results During the Biological Control of *Chondrilla*

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INTRODUCTORY AND SUMMARY

This paper compares the predictions made concerning the effectiveness of the various organisms attacking *Chondrilla* species as biological control agents for *Chondrilla juncea* L. (skeleton weed) in Australia with the results obtained after their release there. The reasons for the differences between the observed and predicted effectiveness of the agents are discussed.

PREDICTION OF EFFECTIVENESS

(a) Basic Methods

Observations were made on the effect that each of the most important organisms attacking *Chondrilla* in its native range had on the population levels of the plant in ecoclimatic situations as closely similar as possible to the regions infested by *C. juncea* in Australia (Wapshere 1970 a,b). Although the organisms having the greatest effect in reducing the weed's population were regarded as the most important biological control agents in the weed's native range, the predictions of effectiveness were only made after adjustment for any major differences (e.g. different cultivation practices, absence of the parasites of a particular agent in Australia etc.) between the situation in Europe and the Middle East and that in Australia (Wapshere 1970 b).

(b) Complicating Factors

This simple programme was complicated by the following two factors:—

- 1) As *C. juncea* is an apomictic triploid (Rosenberg 1912) geographic clones exist throughout its native range and several of the more highly dependent organisms, notably the rust, *Puccinia chondrillina* Bubak & Syd. (Hasan 1972) and the eriophyid gall mite *Aceria chondrillae* Can. (Caresche & Wapshere 1974) have strains, highly adapted to certain forms of *C. juncea*, which were ineffective against other forms of the weed.
- 2) Because the number of different organisms

specifically adapted to *Chondrilla* was found to increase from the western Mediterranean region to the centre of evolution of the genus in southern Russia (Wapshere 1974 a) it was apparent that different organisms were determining the abundance of *Chondrilla* in different regions throughout this large band of country.

EFFECTIVENESS OF CHONDRILLA ORGANISMS IN THEIR NATIVE RANGE

For each of the different regions the order of effectiveness of the organisms attacking *Chondrilla* was as follows:—

- (a) In the western Mediterranean region (S.E. Spain, S. France and S.E. Italy):—
 - (1) The rust *P. chondrillina*; (2) the powdery mildew *Erysiphe cichoracearum* (D.C.); (3) another powdery mildew *Leveillula taurica* L. and the gall mite *A. chondrillae*; (4) the aphid *Dactynotus chondrillae* Nev. (Wapshere 1970 b). In addition, on strongly calcareous soils various snail species were as important as *E. cichoracearum*.
- (b) In the south-eastern Mediterranean region (Eastern Greece):—
 - (1) *P. chondrillina*; (2) the cecidomyid gall midge *Cystiphora schmidtii* (Rübs.); (3) *L. taurica*, the other species present, playing only a minor role (Wapshere 1973 a).
- (c) In the north-eastern Mediterranean region (Northern Greece):—
 - (1) *P. chondrillina* and the phycitid root moth *Bradyrrhoa gilveolella* (Tr.); (2) *L. taurica*; (3) *A. chondrillae* and *C. schmidtii*. In addition snail species were also important on strongly volcanic soils (Wapshere 1973 a).
- (d) In the Middle East, in north west Iran (Tabriz region) the order of effectiveness of the organisms was:—
 - (1) The tortricid crown moth *Oporopsamma wertheimsteini* (Rebl.); (2) the root coccid *Neomargarodes chondrillae* Ark.; (3) *B. gilveolella* and *P. chondrillina*; (4) *A. chondrillae*,

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L. taurica and *C. schmidtii* (Hasan & Wapshere: unpublished data).

(e) Finally, in the Middle East, in north central Iran (Tehran region) only the buprestid *Sphenoptera clarescens* Kerr. was playing a role, the other organisms being of little consequence (Hasan: unpublished data).

Of these regions the most similar climatically to the regions infested by *C. juncea* in Australia was eastern Greece.

PREDICTION OF EFFECTIVENESS IN AUSTRALIA

For reasons of safety it was not possible to introduce all the effective organisms. Naturally, the polyphagous snail species could not be introduced and the introduction of the *Chondrilla* forms of the powdery mildews was not allowed. Furthermore, the coccid *N. chondrillae*, the buprestid *S. clarescens* (Hasan unpublished date) and the aphid *D. chondrillae* (Carèsche, Hasan & Wapshere 1974) had too broad a host range in the field or in the laboratory. As a result of these quarantine restrictions and because of the two complications discussed previously (p. 2), only the gall midge *C. schmidtii*, the root moth *B. gilveolella*, and the crown moth *O. wertheimsteini* were introduced, together with one strain of the rust *P. chondrillina* and one strain of the gall mite *A. chondrillae*, these strains being particularly effective against the most common form of *C. juncea* in Australia.

The order of effectiveness of these organisms in Australia was predicted to be as follows:

- 1) The strain of *P. chondrillina* would be most effective because it is highly effective in similar climatic regions in Europe. Its principal parasite, the fungus *Darluca filum cast*, occurs both in Europe and Australia so that it can be assumed not to affect the prediction (Wapshere 1970 b, 1973 a; Hasan & Wapshere 1973).
- 2) *C. schmidtii* is also very effective in Europe, in spite of a very heavy attack by parasites. Therefore in similar climatic regions in Australia it would be expected to be even more effective, because the parasites do not occur there (Wapshere 1973 a; Carèsche & Wapshere 1975 a).
- 3) In Europe and the Middle East *A. chondrillae* is most effective in regions cooler than the Australian infested areas and less effective in the hotter, drier regions (Wapshere 1973 a; Carèsche & Wapshere 1974). It would therefore be expected to be generally less effective

in Australia than in Europe and the Middle East.

- 4) *B. gilveolella* would probably be less effective in Australia than in the eastern Mediterranean region and Middle East because of the apparent dependence of ephemeral moth populations in warmer regions on infusions from stable populations in cooler, northerly regions lacking a counterpart in Australia. However, this reduction in effectiveness could be mitigated in Australia by a lower rate of parasitisation and by the greater prevalence of sandy soils to which the moth larva is better adapted (Wapshere 1973 a; Carèsche & Wapshere 1975 b).
- 5) Although one of the most effective organisms in N.W. Iran (Hasan & Wapshere, unpublished data), *O. wertheimsteini* would probably be less effective in Australia because of its clear adaptation to the much colder, more extreme continental climates of eastern Europe and the Middle East.

RESULTS OF RELEASES IN AUSTRALIA

To date *O. wertheimsteini* is still undergoing quarantine safety testing and has not been released. The impact of the four organisms released has been as follows:—

- 1) *P. chondrillina* became established immediately, spread very rapidly and quickly exerted an effect as a population controlling agent. As in Europe it infests all the aerial parts of the plant throughout the whole range of infestation by the weed. It has caused a rapid decline in weed abundance in Australia (Cullen *et al.* 1973; Cullen 1974). As expected, the high host specificity of the rust resulted in only the most common form of *Chondrilla* in Australia being affected by the rust, the other forms remaining resistant (Cullen 1974).
- 2) *C. schmidtii*, the gall midge, also became established immediately in many places throughout the *Chondrilla* infestations in S. E. Australia and, although not spreading as rapidly nor with such damaging effect as *P. chondrillina*, it has after only two seasons caused plant deaths through heavily infesting individual plants. It is important in controlling the forms of the weed resistant to *P. chondrillina* (Cullen 1974).
- 3) *A. chondrillae*, the gall mite, also became established readily but only spread rapidly and increased to damaging levels in the drier and

hotter sandy Mallee regions and not in the wetter Riverina regions further to the east (Cullen 1974). In the Mallee it is as effective as in the cooler regions of Europe and the Middle East.

- 4) *B. gilveolella*, the root moth, has proved difficult to establish (Cullen 1974) and, even if this is achieved, it seems doubtful if it is adapted to playing a role as important as any of the three other organisms.

COMPARISON AND DISCUSSION

In general the biological control agents released have performed as expected, *P. chondrillina* being the most effective, followed by *C. schmidtii* and *A. chondrillae*, and only *B. gilveolella*, on whose climatic adaptability doubts were expressed, has not become established readily.

C. schmidtii has, indeed, behaved almost exactly as predicted, having become most effective in regions in Australia closely comparable ecologically to the regions in Europe and the Middle East. However, there are differences between the behaviour of *P. chondrillina* and *A. chondrillae* in Australia and in Europe which require further explanation. *P. chondrillina* initially produced a much greater effect than expected on the common form of *C. juncea*, i.e., it was more successful than expected from observation made in Europe and the Middle East. In part this may have been due to the heavy density of *Chondrilla* populations in Australia at the time of release of the rust but, more important, the population of the most common form of *Chondrilla* in Australia was probably highly susceptible to the rust since it was descended from plants that had never been exposed to it since the introduction of the weed to Australia and so contained very few resistant plants (Wapshere 1973 b).

A. chondrillae was less successful in the cooler, wetter regions in Australia, where it was predicted its maximum impact would occur, and surprisingly successful in the relatively dry, hot Mallee region. Two reasons can be advanced for these discrepancies. Firstly, the strain of *A. chondrillae* which was introduced was found in drier south-eastern Greece (Carèsche & Wapshere 1974) and was therefore probably pre-adapted to hot, dry conditions and, secondly, climatic differences between Europe and the Middle East and south-eastern Australia could have an important influence on the situation. In Europe and the Middle East the cooler regions studied were mainly in or influenced by strongly continental climates with very cold winters and

warm summers and relatively low rainfall spread almost evenly throughout the year. It was in the moister regions influenced by these continental climates that *A. chondrillae* was most effective. Most of the *Chondrilla* infestations in S.E. Australia occur in inland regions whose climates can be described as intermediate between Mediterranean and continental, as they have neither pronounced winter rainfall maxima nor extremely cold winters. It would seem that the continental nature of the Mallee climate with its even rainfall spread has been of more importance in determining the success of *A. chondrillae* than any considerations of temperature favourability.

Analogous problems may be hindering the establishment of *B. gilveolella* which was expected to become established readily in the cooler regions of the Australian *Chondrilla* infestations, though more likely it and *O. wertheimsteini* are adapted to very cold continental winters which do not occur in the *Chondrilla* infested regions of Australia. This discussion indicates once again the importance of matching as closely as possible the climatic situation in the native range with that of the infested region before accurate predictions can be made from field observations in the native range.

REFERENCES

- Carèsche, L. A., Hasan, S. & Wapshere, A. J. 1974. The biology and host specificity of two aphids *Dactynotus chondrillae* (Nevsk.) and *Chondrillobium blattnyi* (Pintera) (Hemiptera) living on *Chondrilla juncea* L. Bull. Ent. Res. 64: 277-288.
- Carèsche, L. A. & Wapshere, A. J. 1974. Biology and host specificity of the *Chondrilla* gall mite *Aceria chondrillae* (G. Can.). (Acarina, Eriophyidae). Bull. Ent. Res. 64: 183-192.
- Carèsche, L. A. & Wapshere, A. J. 1975 a. The *Chondrilla* gall midge, *Cystiphora schmidtii* Rübsaamen (Diptera, Cecidomyiidae). II. Biology and host specificity. Bull. Ent. Res. 65: 55-64.
- Carèsche, L. A. & Wapshere, A. J. 1975 b. Biology and host specificity of the *Chondrilla* root moth *Bradypyrhoa gilveolella* (Treitschke) (Lepidoptera, Phycitidae). Bull. Ent. Res. 65: 171-185.
- Cullen, J. M. 1974. Seasonal and regional variation in the success of organisms imported to combat skeleton weed, *Chondrilla juncea* L., in Australia. Proc. 3rd Int. Symp. Biol. Control Weeds. C. I. B. C. Misc. Publ. N° 8: 111-117.
- Cullen, J. M., Kable, P. F. & Catt, M. 1973. Epidemic spread of a rust imported for biological control. Nature 244: 462-464.
- Hasan, S. 1972. Specificity and host specialisation of *Puccinia chondrillina*. Ann. Appl. Biol. 72: 257-263.

- Hasan, S. & Wapshere, A. J. 1973. The biology of *Puccinia chondrillina*, a potential biological control agent of skeleton weed. *Ann. Appl. Biol.* 74: 325-332.
- Rosenberg, O. 1912. Über die apogamie bei *Chondrilla juncea*. *Svensk. Bot. Tidskr.* 6: 915-919.
- Wapshere, A. J. 1970 a. The assessment of the biological control potential of organisms for controlling weeds: introduction to the subject. *Proc. 1st Int. Symp. Biol. Control Weeds. C.I.B.C. Misc. Publ. N° 1: 79-80.*
- Wapshere, A. J. 1970 b. The assessment of the biological control potential of organisms attacking *Chondrilla juncea* L. *Proc. 1st Int. Symp. Biol. Control Weeds. C. I. B.C. Misc. Publ. N° 1: 81-89.*
- Wapshere, A. J. 1973 a. Recent work on the assessment of the biological control potential of the *Chondrilla juncea* organisms. *Proc. 2nd Int. Symp. Biol. Control Weeds. C.I.B.C. Misc. Publ. N° 6: 151-160.*
- Wapshere, A. J. 1973 b. Selection and weed biological control organisms. *Proc. 2nd Int. Symp. Biol. Control Weeds. C.I.B.C. Misc. Publ. N° 6: 56-62.*
- Wapshere, A. J. 1974. Host specificity of phytophagous organisms and the evolutionary centres of plant genera or sub-genera *Entomophaga* 19: 301-309.