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RECENT THOUGHTS ON EXPLORATION AND DISCOVERY FOR BIOLOGICAL CONTROL OF WEEDS

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ABSTRACT

Search strategies appropriate to four situations are reviewed. In the first, the centre of diversification of the weed genus or sub-genus, a region in the native provenance of the weed ecoclimatically analogous with the infested region, and the area of origin of pest weed form are all discoverable. If all three areas overlap geographically in the native range then the search for suitable agents should initially be centred there.

In the second case, a centre of generic diversification is not determinable, an ecoclimatically analogous region in the native range cannot be found, and the origin of the weed form is not known. A method of random search is then necessary. The problems involved in the third case when only two out of three areas overlap, and in the fourth when political or locational expediency determines the area searched, are discussed.

INTRODUCTION

The discovery of safe, effective, and virulent biological control agents for weeds will be facilitated by rationalizing the methods of exploration as far as possible. The problems of doing this under different circumstances are discussed below for four situations in classical biological control.

Situation 1.

Three criteria governing exploration strategy have been identified to date:

(a) The safety of biological control agents for weeds depends in most cases on their specificity to the weed or its close relatives, and virulence against the weed is dependent to a certain extent on a considerable amount of adaptation by the agent to the weed. It has been confirmed on several occasions recently that the centre of diversification of a weed genus, or sub-genus in the case of large genera, contains the greatest numbers of organisms highly adapted to that genus. This has been found for *Ambrosia* sp. (Compositae) in the Sonoran Desert (Harris and Piper 1970), *Solanum* spp. (Solanaceae) in northern Mexico (Goeden 1971), *Chondrilla* spp. (Compositae) in southern U.S.S.R. (Wapshere 1974), and *Echium* spp. (Boraginaceae) on the Iberian Peninsula (Wapshere 1981).

(b) The effectiveness of agents depends on their ability to establish and build up to massive populations on their weed host. To do this they must be well-adapted to the ecoclimatic situation where the weed occurs at noxious levels. Strains of agents from the ecoclimatically analogous region in the plant's native range will be suitably pre-adapted. This has been confirmed in the cases of the *Chondrilla* agents (*Puccinia chondrillina* Bubak & Syd. [Uredinales: Pucciniaceae], *Aceria chondrillae* Can.[Acari:Eriophyidae], and *Cystiphora schmidti* [Rübs.] [Diptera:Cecidomyiidae]), which, when introduced from their native ranges in the Mediterranean region, very quickly established themselves in similar ecoclimatic regions in Australia, and soon built up to massive numbers (Cullen *et al.* 1973, Cullen 1974).

(c) The virulence of the agent's attack on the individual plant is influenced by the closeness of match between the agent and its host. Because weed strains

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differ between localities, the strain which has become noxious in the new environment should first be identified and its origin determined. When this is done, and a suitable strain of the agent on the weed form is discovered, extremely virulent attack can occur; this is exemplified by the damage produced by the strain of *P. chondrillina* introduced to control the narrow leaf form of *Chondrilla juncea* L. (Hasan 1972, Cullen *et al.* 1973).

It is evident from the above that, when the centre of the weed's generic diversification overlaps geographically with the region ecoclimatically analogous with the weed-infested region, and the noxious form of the weed occurs in the same region, initially the search for safe, effective, and virulent agents should be centred in that region and radiate progressively from it if suitable agents are not found.

The propitious overlap of the three areas probably occurs in the case of *Echium* spp. whose centre of generic diversification is in the Iberian Peninsula where the climate closely resembles the regions infested by *Echium plantagineum* L. in Australia (Wapshere 1981). The history of the weed's introduction from the western Mediterranean (DelFosse and Cullen 1981) would also place the origin of the Australian weed forms in the same region or close to it. Certainly a wide range of suitably safe and apparently effective agents occurs on *Echium* spp. in the Iberian Peninsula (Wapshere 1981) and all those studied have readily attacked the Australian strain of *E. plantagineum*. It also seems that a similar propitious geographical overlap of regions occurs in the case of *Salvinia molesta* Mitchell (Salviniaceae) in South America (Forno 1981).

Situation 2.

For various reasons, it may not be possible to apply all or any of the three criteria.

(a) A centre of generic diversification either may not exist, as in the case of two *Emex* spp. (Polygonaceae) (one in South Africa, the other in North Africa), or may be impossible to locate, as in the case of the Eurasian species of *Senecio* (Compositae) related to *S. jacobaea* L. or that of the cosmopolitan weed *S. vulgare* L. whose origins and relations are now impossible to determine.

(b) A region ecoclimatically analogous to the infested range may not occur in the native range of the weed. This is essentially the case for *Emex australis* Steinheil. In its native range in South Africa *E. australis* occurs in a region of predominantly summer rainfall, whereas the greater part of the infested region in Australia has more rain in winter (Julien 1981).

(c) The origin of the noxious forms of a weed may not be readily discernible. This is so for the pest forms of *Lantana camara* (Verbenaceae) in Australia which appear to have been developed as garden cultivars from unknown lantana stock from South America (Sands and Harley 1981).

Finally, although the three criteria may be applicable, the geographical overlap may not occur in the native range, the pest form of the weed originating in one region, the ecoclimatic analogue being in a second region and the centre of diversification in a third.

If any of these three circumstances applies, or if propitious overlap does not exist, then random search is necessary. Random search is usually conducted by searching the whole of the native range of the weed and selecting apparently-effective and virulent agents wherever they are found. Also, to increase the chances of discovering suitable strains of the agents, a wide genetic stock is selected (Winder and Harley 1977, Sands and Harley 1981). There are other

genetic principles that could be applied in a search (Marshall *et al.* 1981).

Situation 3.

In some cases there is geographic overlap within the native range of the weed of two of the regions, but the third region occurs in another part of that range. Thus, the virulent forms of *P. chondrillina*, *A. chondrillae*, and *C. schmidti* all occur in the ecoclimatic analogues of *Chondrilla* infestations in Australia (Wapshere *et al.* 1974, 1976, Hasan 1972, Caresche and Wapshere 1974, 1975) in the Mediterranean region, but the centre of diversification is in the cold, dry, intensely continental regions of the southern U.S.S.R. The success of the three *Chondrilla* organisms is sufficient to indicate that this single overlap is enough to provide effective and virulent agents, and search and selected introductions can initially be restricted to that overlap region (Cullen 1974).

The second possibility in this case is that the occurrence of a virulent agent and the centre of diversification overlap, but the ecoclimatically analogous region is outside this range. For example, *Oporopsamma wertheimsteini* (Rebel) (Lepidoptera:Tortricidae) readily damages the Australian pest forms of *Chondrilla* and occurs in the centre of diversification of *Chondrilla*. However it is limited to that region and to areas with similar, extremely dry and cold continental climates, and has a biology and life cycle adapted to that type of climate (Hasan and Wapshere 1977). These two authors argued that this insect would be poorly-adapted to the warmer Mediterranean climates of *Chondrilla* infestations in Australia. However only its release could confirm or refute this hypothesis.

A third possibility is that the centre of diversification and the ecoclimatically analogous region overlap but apparently no virulent organisms occur there. This third case resembles a situation when all three regions overlap but no suitable agents can be found after preliminary searches. In these situations the search area should be expanded to cover the full native range of the weed. If suitable agents are still not found, the search should then be extended to cover the non-native range of the weed species, encompassing close relatives of the weed and ecoclimatically analogous situations within these new regions. As Room (1981) points out there is still a good chance of discovering suitable agents in non-native ranges of weeds.

Similar principles apply to cosmopolitan weeds whose origins are unknown. Suitable agents for this type of weed are sometimes found. They have more chance of success if they are ecoclimatically adapted to the infested region.

Situation 4.

There is one case which is not related to the biological principles discussed above. This is when a decision on the area to be searched is based on grounds of suitable scientific contacts and/or presence of laboratories, or availability of finance in a particular region, or the scientist's personal convenience, or on political grounds. It is unlikely that such searches will be of great value since only by chance will they cover the most appropriate areas. Even then, they will often lead to the discovery of only a few of all the possible biological control agents for a given weed.

DISCUSSION

Three criteria (centre of generic diversification, ecoclimatic analogies, and origin of weed form) have been identified as aiding in delimiting initial search for

areas for classical biological control. It is possible that new criteria will be discovered in the future and these should then be combined with those above to further delimit the initial areas of exploration.

Successful biological control is most probable for a weed species which conforms with Situation 1. It is somewhat less likely, although probable, when both ecoclimatically adaptable and virulent agents occur together in suitable parts of the native range. Possibly, success will be less likely when the agent is not ecoclimatically adapted, and still less likely when there is no overlap of the three areas and a random search has to be undertaken. The probability of success will also diminish progressively as one, two or all three of the criteria cannot be applied. Once again a random search becomes necessary which could well extend beyond the native range of the weed.

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REFERENCES

Caresche, L.A., and Wapshere, A.J. (1974). Biology and host specificity of the *Chondrilla* gall mite *Aceria chondrillae* (G. Can.) (Acarina; Eriophyidae). *Bull. Ent. Res.* 64: 183–92.

Caresche, L.A., and Wapshere, A.J. (1975). The *Chondrilla* gall midge, *Cystiphora schmidti* Rubsaamen (Diptera;Cecidomiidae). II. Biology and Host Specificity. *Bull. Ent. Res.* 65:55–64.

Cullen, J.M. (1974). Seasonal and regional variation in the success of organisms imported to combat skeleton weed, *Chondrilla juncea*, in Australia. Proc. III Int. Symp. Biol. Contr. Weeds, Montpellier, France, 1973, pp.111–7.

Cullen, J.M., Kable, P.F., and Catt, M. (1973). Epidemic spread of a rust imported for biological control. *Nature* 244:462–4.

DelFosse, E.S., and Cullen, J.M. (1981). New activities in biological control of weeds in Australia. II. *Echium plantagineum*: Curse or Salvation? Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980. (In Press.)

Forno, I.W. (1981). Progress in the exploration for biological control agents for *Salvinia molesta*. Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980. (In Press.)

Goeden, R.D. (1971). Insect Ecology of Silver Leaf Nightshade. *Weed Science* 19:45–51.

Harris, P., and Piper, G.L. (1970). Ragweed (*Ambrosia* spp.; Compositae), its north American insects and the possibilities for its biological control. C.I.B.C. Tech. Bull. 13:117–40.

Hasan, S. (1972). Specificity and host specialization of *Puccinia chondrillina*. *Ann. Appl. Biol.* 72:257–63.

Hasan, S., and Wapshere, A.J. (1977). Biology and host specificity of the *Chondrilla* crown moth, *Oporopsamma wertheimsteini* (Rebel) (Lepidoptera: Tortricidae). *Bull. Ent. Res.* **67**:619–25.

Julien, M.H. (1981). A discussion of the limited establishment of *Perapion antiquum* and a review of the current status of biological control of *Emex* spp. in Australia. Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980. (In Press.)

Marshall, D.R., Burdon, J.J., and Brown, A.H.D. (1981). Optimum sampling strategies in the biological control of weeds. Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980. (In Press.)

Room, P.M. (1981). Biogeography, apparency and exploration for biological control agents in exotic ranges of weeds. Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980. (In Press.)

Sands, D.P.A., and Harley, K.L.S. (1981). The importance of geographic variation in agents selected for the biological control of weeds. Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980. (In Press.)

Wapshere, A.J. (1974). Host specificity of phytophagous organisms and the evolutionary centres of plant genera or sub-genera. *Entomophaga* **19**:301–9.

_____(1981). The biological control of Paterson's curse, *Echium plantagineum*: Northern hemisphere studies. Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980. (In Press.)

Wapshere, A.J., Caresche, L.A., and Hasan, S. (1976). The ecology of *Chondrilla juncea* in the eastern Mediterranean. *J. Appl. Ecol.* **13**:545–53.

Wapshere, A.J., Hasan, S., Wahba, W.K., and Caresche, L.A. (1974). The ecology of *Chondrilla juncea* in the western Mediterranean. *J. Appl. Ecol.* **11**:783–99.

Winder, J.A., and Harley, K.L.S. (1978). Exploration for organisms for biological control of weeds. Proc. IV Int. Symp. Biol. Contr. Weeds, Gainesville, Florida, 1976, pp.102–4.