THE POWDERY MILDEWS AS POTENTIAL BIOLOGICAL CONTROL
AGENTS OF SKELETON WEED (CHONDILLA JUNCEA L.)

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INTRODUCTION

There is a growing awareness of the importance of fungi in controlling weed populations and therefore an increasing interest in their use as biological control agents (Wilson, 1969).

Recently a study of the fungal pathogens of Chondrilla juncea L. in Europe has led to a detailed investigation of its rust, Puccinia chondrilli (Nas. and Heau., 1970), and this has been followed by similar investigation of the two powdery mildews, Erysiphe cichoracearum DC. and Leveillula taurica (Lev.) Arnau, which are found on this weed. The most important results of this second study are briefly described below.

THE POWDERY MILDEWS OF CHONDRIlla

Morphology

E. cichoracearum and L. taurica both belong to the Erysiphaceae, all members of which are obligate parasites of flowering plants. Attempts to culture members of this family artificially have not been successful (Josifovic, 1923; Yarwood, 1956; Hein and Gries, 1953).

On C. juncea the two powdery mildews appear on rosettes in autumn and spring as massive white powdery patches of mycelia with conidiophores bearing conidia. Under field conditions the mature asexual conidia readily detach from the conidiophores and disperse and spread the fungus from plant to plant. The germination of conidia can take place in a humid atmosphere, contact with water is not necessary.

The conidia germinate immediately after detachment and the germ tubes fix themselves to the epidermis of the plant by a dilated part of the germ tube which forms an adspressorium. The epidermal cuticle of the plant is ruptured and hyphae enter from the adspressorium into the host tissue where they form haustoria. These haustoria absorb nourishment from the sub-epidermal tissue in the case of E. cichoracearum and the mesophyll cells in L. taurica. The mycelium grows rapidly and invades the host tissue at frequent points producing more haustoria until the whole leaf is covered or invaded.

This process continues throughout spring and early summer and rosettes, and later the flower shoot, become completely covered with a mycelial coating. The mycelium is superficial in the case of E. cichoracearum with unbranched conidiophores. In L. taurica the mycelium is mainly endophytic during the conidial phase and bears usually branching conidiophores which protrude through the host stomata in groups of three to four.

In late summer both species of mildew cover the flower shoot, partially or completely, with a white mycelial felt. Dark, black, sparsely distributed cleistothecia appear immersed within this hyphal felt. These fruiting bodies contain the result of the sexual fusion, the asc, which bear ascospores. These ascospores allow the fungus to overwinter if the temperature is too low. On germination the ascospores give rise to mycelium which restarts the asexual conidial phase.

The conidia, cleistothecia, asc, and ascospores of E. cichoracearum and L. taurica differ both in size and structure and this allows the two mildews to be distinguished from each other under the microscope.
Specificity

Both *E. cichoracearum* and *L. taurica* exist in many forms (Petrak, 1928; Blumer, 1933). Both have been recorded on herbaceous representatives of many plant families. They particularly attack members of the Compositae, Solanaceae, Leguminosae, Cucurbitaceae and Umbelliferae.

The exact status of the forms of powdery mildews which are included in the two species is not clear. Some authors have for instance separated the various strains which occur on different plants and described them as species. Golovin (1956) for instance describes a separate species of *Leveillula* for each plant family and a separate form for each plant within the family, e.g. *L. compositarum* form *Cichorium*, form *Helianthus*, form *Scorzonerae* etc. Some authors (Tramier, 1933; Nour, 1939; 1939) have successfully cross-inoculated physiological forms from one plant family onto plants of another family, and thereby thrown considerable doubt on the existence of distinct forms whereas others after similar detailed cross-inoculation studies have accepted the existence of distinct physiologic and taxonomic entities (Zwirn, 1943; Ciccarone, 1951; Doutear, 1959). Schmitt (1955) exposed a large number of plants from 11 families already known to be hosts of *E. cichoracearum* to the same mildew from the Compositae, *Zinnia elegans*, *Helianthus annuus*; from the Boraginaceaean plant, *Cerinthe major*; from *Phlox sp.* and from *Cucurbita pepo*. He demonstrated that the mildew from *Phlox* was restricted to that genus, that the mildew from *C. pepo* attacked only certain Cucurbitaceae and that the mildew from the Compositae and from *Cerinthe major* was the same form and thus restricted to certain Compositae and to a few Boraginaceaees. Smith (1949) demonstrated that for another powdery mildew, *Sphaispe polygoni* DC., the form attacking pea, *Pisum sativum*, was distinctly different from the form attacking bean, *Phaseolus*, and cross-inoculation was not possible. In the field it was noticed on many occasions that the forms of *E. cichoracearum* and *L. taurica* occurring on *C. juncea* were different in general appearance and in the symptoms produced on the host from the same fungi on other hosts. At the same time it was frequently observed that Cichoraceous plants growing among or near *C. juncea* stands were not or only poorly infected with powdery mildews but that at the same time the *C. juncea* plants were extremely heavily attacked.

Moreover, the Chondrilla form of *E. cichoracearum* has for nearly three years been a bad contaminant of greenhouse stocks of *C. juncea*. Cichoraceous, Composite and other herbaceous plants recorded as hosts of *E. cichoracearum* have been grown in close proximity to the heavily infected *C. juncea* plants without any sign of attack. There is therefore strong evidence that the forms of these powdery mildews attacking Chondrilla are distinct from other forms.

During the last year the Chondrilla form of *E. cichoracearum* has been exposed to 38 out of 65 cultivated plants which have been selected either on their importance as crop plants to Australia and/or because they are already known hosts of *E. cichoracearum*. In the latter case the Australian quarantine authorities have requested that three varieties of each plant species be tested. To date the Chondrilla form of *E. cichoracearum* has not infested any of the plants tested. This testing is continuing and will be followed by a similar testing of the Chondrilla form of *L. taurica*.
Field Potential

In the field it is impossible to tell whether rosettes bearing the imperfect conidial stages are attacked by *E. taurica*, by *E. cichoracearum* or by both mildews. Only microscopic examination reveals which species are involved.

The fungal destroy leaves of *C. juncea* rosettes by completely covering them with a hyphal coating and with rapidly developing infestations. Replacement leaves soon become infected and are destroyed in their turn. Heavily infested small rosettes become completely covered by the white powdery masses and die off in spring. The flower shoots of the heavily infested plants which escape destruction become coated with hyphal felt in their turn and there is an important and obvious reduction in size and production of flowers and seeds. There seems little doubt that the hyphal coating and the destruction of the photosynthetic sub-epidermal layers of the rosette and the green flower shoot heavily reduce nutrient production and subsequent storage of reserves.

The powdery mildews were important at only one site in Southern France (mean annual daily temperature 14°C, average yearly rainfall 700-700 mm.). At the other French sites the maximum infestation was observed in late summer after flower and seed development was well underway. In south-eastern Italy (mean annual daily temperature 17°C, average yearly rainfall 450-500 mm.), where *E. cichoracearum* was predominant, powdery mildew attacks on the rosette were particularly important in spring and were considered to cause substantial reductions (Table 1) in rosette populations. In several of the sites here all the seasonal reduction in *C. juncea* populations was attributable to powdery mildew attack. After the rosette stage the flower shoots were less heavily infested. Here, the powdery mildews have been observed to attack large *Chondrilla* rosettes in late spring within wheat cultivations and to infest subsequently the flower shoots after the wheat harvest. During the fallow phase of the wheat sufficient major infestations are already present in autumn and early spring to cause a rapid development of the disease in epidemic proportions.

Table 1. *Chondrilla* population changes due in the greater part to *E. cichoracearum* attack.

<table>
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<tr>
<th>Site</th>
<th>Period</th>
<th>Chondrilla densities per plant/metre</th>
<th>Percentage population reduction</th>
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<tbody>
<tr>
<td>San Marco</td>
<td>March 69 to Aug 69</td>
<td>68.0 At beginning 16.6 At end</td>
<td>75.6%</td>
</tr>
<tr>
<td>near Foggia, S. Italy</td>
<td>March 69 to May 69</td>
<td>129.0 At beginning 46.3 At end</td>
<td>64.1%</td>
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In Eastern Greece (mean annual daily temperature 16-18°C, average yearly rainfall 350-600 mm.) L. taurica is the only powdery mildew of importance in C. juncea stands. It so heavily infects these stands that in late summer the fields containing C. juncea can be distinguished by large patches of white plants that have a complete cover of the fungus. These plants produce few flowers and even fewer mature seeds.

**DISCUSSION**

There is little doubt that the two powdery mildews are playing an important role in controlling and reducing C. juncea populations in two parts of the Mediterranean, South-Eastern Italy and Eastern Greece, which are climatically similar to the regions infested by the weed in Australia. L. taurica is regarded as a fungus of hot, dry, sub-tropical regions and could play an important role in the hotter, northern parts of the range of C. juncea in Australia.

Moreover, both fungi have been observed to invade, immediately after cultivation, C. juncea stands within wheat cultivations, the habitat in which control of the plant is most needed in Australia, and to rapidly infest most of the plants.

There is therefore a clear enough indication of the biological control potential of these fungi to make an introduction to Australia worthwhile.

Before this is implemented it will, however, be necessary to demonstrate that the *Chondrilla* forms of the C. juncea are specific enough not to cause any damage to crops. There is already strong field and greenhouse evidence that this is the case. Not unnaturally, however, the quarantine authorities in Australia have insisted on the rigorous testing of a large number of crop plant species and varieties. To date the testing of the *Chondrilla* forms of *E. cichoracearum* has demonstrated its complete specificity to *C. juncea*.

**ACKNOWLEDGMENTS**

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**REFERENCES**


DISCUSSION

LITTLE Is it reasonably practical to inoculate plants with fungi by spraying or some other technique.

WAPSHERE We haven't tried to use the fungi as Chondrilla control agents by spraying spore suspensions directly from knapsacks, sprayers, etc. But we have, as Dr. Hasan says, used the spray technique to obtain infections of the Puccinia both in the field and in the laboratory. The problem with this as a possible method for the powdery mildews, according to Dr. Hasan, is that the conidia have a very short period of viability in the field.

HASAN Regarding the powdery mildews they do have very short lived conidia and one can't expect to store the conidia and use them as a spray except immediately after collection. On the other hand there is possibility of using the resting stage oospores which can be stored for a considerable time.

OPPINGER How does attack by the fungal diseases alter the availability of the plant for insect attack?

WAPSHERE This point has not been examined in detail by us.

SANKARAN If the fungus spores are disseminated by wind currents and so on (and Dr. Wapshere has listed several species of insects which are associated with this Chondrilla), do you know if these insects also play a part in the dissemination of the spores you have studied.

HASAN Yes. My work has been the dissemination of fungi with the help of insects and insects. Naturally if an insect is feeding on a plant, spores get in the intestine and are expelled in the course of its movements. I think insects have a role by taking spores on their body and then spreading them to other plants. I have also found a sort of relationship between Aealia chondrillae and Puccinia chondrillae. Puccinia gets into the respiratory tissues during gall formation in the case of Aealia, and both of them together sometimes destroy the plant.

DREA I would like to direct my comments to Mr. Balohe. In a survey of the insects attacking a particular plant, or group of plants, for potential for weed control agents I found that, quite often, the parasites that we uncovered from various insects were often neglected because we were not interested in them and because the host insect involved was eliminated as a candidate for introduction. However, as Dr. Zwilfer pointed out earlier in a discussion, for us in the insect pest work this represents an invaluable source of potential material. The Phytocnemodes naralis (Hübner) that was eliminated because of its attack on several plants, belongs to a group of insects, the webworms that are serious pests of many of our crops in the United States. There are several parasites of this Phytocnemodes that I think could be usefully imported into the United States.

I think that an invaluable service could be rendered by the people who are working on these surveys because they are working with host insect material which we ordinarily wouldn't encounter, even in a survey. The identification of the parasites associated with these species represents a potential and actual source of material for insect pest control, in addition to being information of a strictly scientific value.

Balohe We do record parasites from the weed insects. You will find records for Coliasphora, Cerobiasis, and Pucophyes. I just failed to mention that work. Also, I have the percentage of parasitism in my paper.

END OF DISCUSSION

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