

RESPONSE OF SAFFLOWER CULTIVARS TO *Puccinia jaceae* COLLECTED FROM DIFFUSE KNAPWEED IN EASTERN EUROPE

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ABSTRACT

Rust was collected from diffuse knapweed (*Centaurea diffusa* Lam.) in Bulgaria and Romania and investigated as a possible biological control agent. Collected material consisted of both *Puccinia jaceae* Oth. and *Puccinia centaureae* DC., but was predominately *P. jaceae*. All samples of North American diffuse knapweed were highly susceptible to the pathogen. However, pustules also developed on inoculated safflower (*Carthamus tinctorius* L.). Subsequent inoculations on different safflower cultivars has indicated resistance to this pathogen within this crop.

INTRODUCTION

Diffuse knapweed, *Centaurea diffusa* Lam. is a widespread introduced weed species in the semi-arid grasslands of western Canada and the northwestern United States (Watson and Renney 1974). Biological control is probably the most economic, long-term solution for this problem (Harris and Cranston 1979) and three biological control agents, *Urophora affinis* Frfld., *U. quadrifasciata* (Meig.) and *Sphenoptera jugoslavica* Zell., have become established on the weed in British Columbia. However, additional biocontrol agents are probably required to suppress this noxious weed as Harris (1979) suggested that four or more biotic agents are generally required for successful control of a target weed.

In its native range of Eurasia, diffuse knapweed is attacked by two rust fungi (Gäumann 1959, Guyot 1967, Savile 1970, 1973) and during a collection trip in the spring of 1978, 73 samples of *Puccinia* (*P. jaceae* and *P. centaureae*) were collected from diffuse knapweed in Bulgaria and Romania (Watson *et al.* 1980). All collections were composed predominantly of *P. jaceae* with only a few spores of the *P. centaureae* type in some of the samples. Savile (1970, 1973) has given varietal rank to both *P. jaceae* and *P. centaureae* on diffuse knapweed and suggested that *P. jaceae* var. *diffusae* and *P. centaureae* var. *diffusae* were promising potential biological control agents. The objectives of this study were: 1) to determine the virulence of the pathogens on North American diffuse knapweed; and 2) to investigate the host specialization of *Puccinia* collected from diffuse knapweed.

MATERIALS AND METHODS

General

All plants used in the subsequent experiments were grown from seeds in plastic pots containing PRO-MIX. Potted plants were randomly arranged within controlled environment chambers at 20°C light (1800 ft candle) for 14 hr and 150°C dark for 10 hr. Relative humidity was maintained at 60 per cent.

In all experiments test plants were inoculated with fresh urediospores collected from eruptive sori on diffuse knapweed. Plants were inoculated as follows: 1) plants sprayed with a 0.5 per cent gelatin in distilled H₂O solution; 2) urediospores transferred to all leaves with a spatula; 3) plants sprayed with

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gelatin solution; 4) pots covered with plastic bags; 5) pots placed in dark for 16 hrs at 15 to 20°C; 6) bags removed and pots returned to growth chamber. Control plants were treated in a similar manner with the exception of step 2.

Pathogenicity of the rust on inoculated plants was visually assessed using the following plant reaction types:

- 0 no sign of infection, no host reaction
- 1 few small uredia, chlorosis
- 2 few to numerous, small eruptive sori
- 3 numerous small to medium eruptive sori occasionally coalescent, or few large eruptive sori
- 4 numerous large eruptive sori, often coalescent.

Experiment I

Seeds of diffuse knapweed were collected from 15 different locations in western Canada (British Columbia) and the western United States (Washington, Oregon and California). Sixteen plants from each of the 15 locations were inoculated at the 4-leaf stage with rust collection No. R-04. Four plants from each location were not inoculated.

Experiment II

Preliminary host specificity studies were conducted on five *Centaurea* spp. and seven related species from the Cardueae tribe. Nine plants of each test species were inoculated at the 4-leaf stage with rust collection No. R-04. Three plants of each species were not inoculated.

Experiment III

The response of six cultivars of safflower to two rust collections was studied. Six plants of each cultivar were inoculated at the 4-leaf stage with collection R-11 and six were inoculated with R-14. Three control plants of each cultivar were maintained with the R-11 and the R-14 treatments. Diffuse knapweed at the 4-leaf stage was also inoculated with each rust collection.

Experiment IV

Two of the three plants in one pot of each of the safflower cultivars which were inoculated with R-11 at the 4-leaf stage in the previous experiment, were inoculated again at the heading stage of development. All leaves of these plants (approximately 40 days old) were inoculated. The other plant in each of the pots was not inoculated. Diffuse knapweed plants inoculated in the previous experiment were also re-inoculated.

RESULTS AND DISCUSSION

Experiment I

Pustules developed on all inoculated diffuse knapweed plants 11 to 12 days after inoculation. Most inoculated leaves of the plants from the 15 locations responded with plant reaction type of 3 or 4 with five of the 240 inoculated leaves showing a 2 reaction type. This rust collection was virulent on all diffuse knapweed tested. These results demonstrated that diffuse knapweed populations in western North America are generally highly susceptible to this rust and that host plant resistance should not be a major deterrent to the potential success of this organism as a biocontrol agent.

Experiment II

Because of morphological distinctiveness and host adaptation of both *P. jaceae* var. *diffusae* and *P. centaureae* var. *diffusae* (Savile 1970, 1973),

it was expected that these rusts would have a restricted host range.

However, collection R-04 was found to be virulent on other *Centaurea* species and also on safflower (Table 1). Pustule development and plant reaction was similar for diffuse knapweed and for safflower when inoculated with R-04. It is interesting to note that *Centaurea* species other than diffuse knapweed were less susceptible than safflower.

Table 1. Pathogenicity of the diffuse knapweed rust collection R-04 to some members of the Cardueae Tribe.

Host plant	Appearance of pustules (days after inoculation)	Plant reaction (Type No.)
<i>Centaurea diffusa</i> Lam.	12	4
<i>Centaurea cyanus</i> L.	13	3
<i>Centaurea nigra</i> L.	13-14	3
<i>Centaurea montana</i> L.	14	2
<i>Centaurea maculosa</i> Lam.	13-14	2
<i>Carthamus tinctorius</i> L.	12	4
<i>Cirsium vulgare</i> (Savi) Ten.	—	0
<i>Cirsium arvense</i> (L.) Scop.	—	0
<i>Aster</i> sp.	—	0
<i>Inula helenium</i> L.	—	0
<i>Helianthus annuus</i> L.	—	0
<i>Lactuca scariola</i> L.	—	0

Experiment III

When the six cultivars of safflower were inoculated with the R-11 and R-14 collections of the diffuse knapweed rust, pustules developed on the inoculated leaves 12 to 13 days after inoculation. However, in all cases the first and second leaves were more susceptible than the third and fourth leaves (Table 2).

Table 2. Response of six safflower cultivars to diffuse knapweed rust collections R-11 and R-14.

Safflower cultivar	Plant reaction (Type No.)			
	R-11		R-14	
	1st and 2nd leaves	3rd and 4th leaves	1st and 2nd leaves	3rd and 4th leaves
14-5	3	2	3	2
Oleic Leed	3	2	3	2
Reduced Hull-3	3	2	3	2
Reduced Hull-2	3	2	3	2
PCOY	3	2	3	2
Partial Hull	3	2	3	2

The first two leaves of inoculated plants died 20 to 22 days after inoculation, with those of the non-inoculated control plants remaining alive for 6 to 10 days longer. The third and fourth leaves of the inoculated plants died 28 to 32 days after inoculation with those of the non-inoculated controls remaining alive for one week longer. The effect of the rust infection appeared to increase normal rate of senescence of the lower leaves by approximately one week. Further development (heading and flowering) was similar for both the inoculated and non-inoculated safflower plants.

Experiment IV

Safflower plants that were originally inoculated at the 4-leaf stage and subsequently re-inoculated at heading did not develop any pustules. Some minor chlorosis of inoculated leaves was observed which indicated a resistant response of safflower to later inoculations of this rust. Inoculated leaves of diffuse knapweed all developed characteristic pustules 12 days after inoculation.

Two basic criteria for any biological weed control agent are its ability to: 1) stress its weed host; and 2) not to adversely affect the growth of any desirable plant species. In controlled conditions, the diffuse knapweed rust was found to be virulent on all collections of diffuse knapweed tested and potentially very destructive. In contrast to the taxonomic position (varietal rank) of the diffuse knapweed rusts (Savile 1970, 1973), safflower also was found to be susceptible.

Wherever safflower is grown, it is commonly attacked by another rust, *Puccinia carthami* Cda. However, studies in commercial areas of production in the United States have demonstrated that foliage rust has little if any effect on yield or yield attributes of safflower (Urie *et al.* 1968, Zimmer and Urie 1968). Safflower, in the United States, is grown in semi-arid climates on irrigated land. Under these conditions adequate free-moisture conditions may persist long enough to permit heavy rust infection of the lower leaves, but these conditions seldom persist long enough for rust infection on upper leaves (Urie *et al.* 1968). However, the lower leaves of safflower can be removed or destroyed without significantly reducing yield (Urie *et al.* 1968, Zimmer and Urie 1968).

Safflower plants inoculated with collections of the diffuse knapweed rust developed pustules on lower leaves which eventually died, but the infection did not appear to interfere with subsequent plant growth. Subsequent inoculation of older leaves of six safflower cultivars suggests resistance within this crop to later infections of the knapweed rust. Additional experiments are under way to further investigate the effects of the knapweed rust on safflower.

Rust taxonomy

In 1815 de Candolle described *Puccinia centaureae* on *Centaurea scabiosa* L. and in 1865 Otth described *P. jaceae* from *C. jacea* L. Since then disagreement among workers concerning the taxonomy of *P. centaureae* and *P. jaceae* has occurred. Jacky (1899) recognized two types (A and B) of *P. centaureae* and that *P. jaceae* corresponded to Type A. He concluded that *P. centaureae* DC., *P. jaceae* Otth and *P. hieracii* (Schum.) Mart. are all synonyms of *P. centaureae* Mart. Hasler (1908) supported Jacky and agreed that *P. jaceae* was equal to Type A of *P. centaureae*. Sydow and Sydow (1902) reported *P. jaceae* as a synonym of *P. centaureae*. Some recent taxonomists (Guyot 1967, Savile 1970, 1973) have retained *P. jaceae* and *P. centaureae* separate on the basis of spore morphology and limited host records. The most recent treatment of North

American rusts (Cummins 1978) has *P. centaureae* DC., *P. carthami* Cda., *P. cirsii* Lasch in Rabh., *P. laschii* Lagerh. and *P. irrequisita* H.S. Jack. all as synonyms of *P. calcitrapae* var. *centaureae* (DC.) Cummin. Extensive cross inoculation studies are planned which hopefully will shed some light on this taxonomic chaos.

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