

Puccinia carduorum on *Carduus tenuiflorus* in California

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ABSTRACT

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Rust fungi (*Puccinia* species) were not reported to occur on *Carduus* species in North America, but in May 1980, *Puccinia carduorum* was collected from *Carduus tenuiflorus* in Alameda and Santa Barbara counties of California. Examination of vascular plant herbaria records indicated that the rust has been present since 1951 and probably occurs throughout the distribution range of its host in California. The form of the rust may be specific to *C. tenuiflorus* because *C. pycnocephalus* growing in association with *C. tenuiflorus* remained free of the rust and no specimens of *C. pycnocephalus* with rust have been deposited in herbaria.

As many as seven introduced *Carduus* species are serious weeds in North America (12), with *Carduus pycnocephalus* L. (Italian thistle) and *C. tenuiflorus* Curt. (slenderflower thistle) generally confined to California (3,4). Control of these noxious *Carduus* is difficult and the possibility of using exotic *Puccinia carduorum* Jacky as a biological control agent of the large-flowered thistle (*C. nutans* complex) is being evaluated (14). No reports of *P. carduorum* or any other *Puccinia* species known to occur on *Carduus* were found in North American literature (2,16). Therefore, when a rust was observed on *C. tenuiflorus* in California, efforts were

initiated to obtain positive identification of the rust pathogen, to determine the history of the organism in North America, and to determine its present distribution.

MATERIALS AND METHODS

In May 1980, rusted *C. tenuiflorus* plants were observed and collected in Alameda and Santa Barbara counties of California. A limited field survey was conducted in the spring of 1980 in Alameda, Monterey, Orange, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, and Santa Cruz counties to determine the present distribution of the rust in California. Herbarium specimens of *C. tenuiflorus* and *C. pycnocephalus* (a closely related species) from major California herbaria were obtained and examined for rust. Small quantities of rust spores were obtained from the herbarium specimens, mounted in lactophenol, and heated gently. Spore features were studied under

bright-field and phase-contrast microscopy and scanning electron microscopy (SEM). Material was prepared for SEM by using a procedure modified from Brown and Brotzman (1). Small (2-mm) leaf samples bearing uredinia and telia of *P. carduorum* were fixed at 4 C for 24 hr in 5 ml of 2% OsO₄ containing Kodak Photo-Flo 200 (one drop in 50 ml of the 2% OsO₄), then rinsed for 30 min with three changes of distilled water. Five milliliters of saturated thiocarbonylhydrazide solution was added and the samples were allowed to stand for 1 hr at room temperature, then rinsed for 30 min with three changes of distilled water. Finally, 5 ml of OsO₄ was added and the samples were allowed to stand for 1 hr at room temperature, then rinsed for 30 min with three changes of distilled water. After osmium-coating, the samples were dehydrated in an ethanol series (20, 40, 60, 80, 95, 100, and 100% for 20 min each), dried in a Polaron critical-point dryer, and coated with gold in an Akashi coater. Prepared samples were examined with a Cambridge Stereoscan 600 scanning electron microscope at 15 kV.

RESULTS

The rust specimen (Fig. 1) collected from the Berkeley Marina, Alameda County, CA, in May 1980 was identified as *P. carduorum* by J. A. Parmelee and D. B. O. Savile of the Biosystematics Research Institute, Agriculture Canada, Ottawa. A voucher specimen (81M-46) has been deposited in the Biosystematics

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Research Institute at Ottawa. Savile (15) placed *P. carduorum* in the *P. centaureae*-*P. laschii* lineage and distinguished *P. carduorum* from closely related *Puccinia* on teliospore and urediniospore morphology and host plant specialization. The teliospores of *P. carduorum* are slightly constricted at the septum, with warts covering the whole surface (Fig. 2). The teliospore germ pores are apical (Figs. 2 and 3) with basal to slightly offset pedicels (Fig. 3). Urediniospores have three equatorial germ pores with echinulations on the upper two-thirds to three-fourths of the spore (Fig. 4). The survey of the eight counties in 1980 and subsequent examination of herbarium specimens indicated that the rust probably occurs throughout the distribution range of *C. tenuiflorus* in California (Fig. 5), because it was found in most counties along nearly the entire length of the state. It has been present in California since at least 1951 (University of California, Davis Herbarium Acc.

13204). *C. tenuiflorus* and the rust also occur in Oregon (R. B. Hawkes, *personal communication*). The rust was not observed on the closely related *C. pycnocephalus* in the field survey or on herbarium specimens.

DISCUSSION

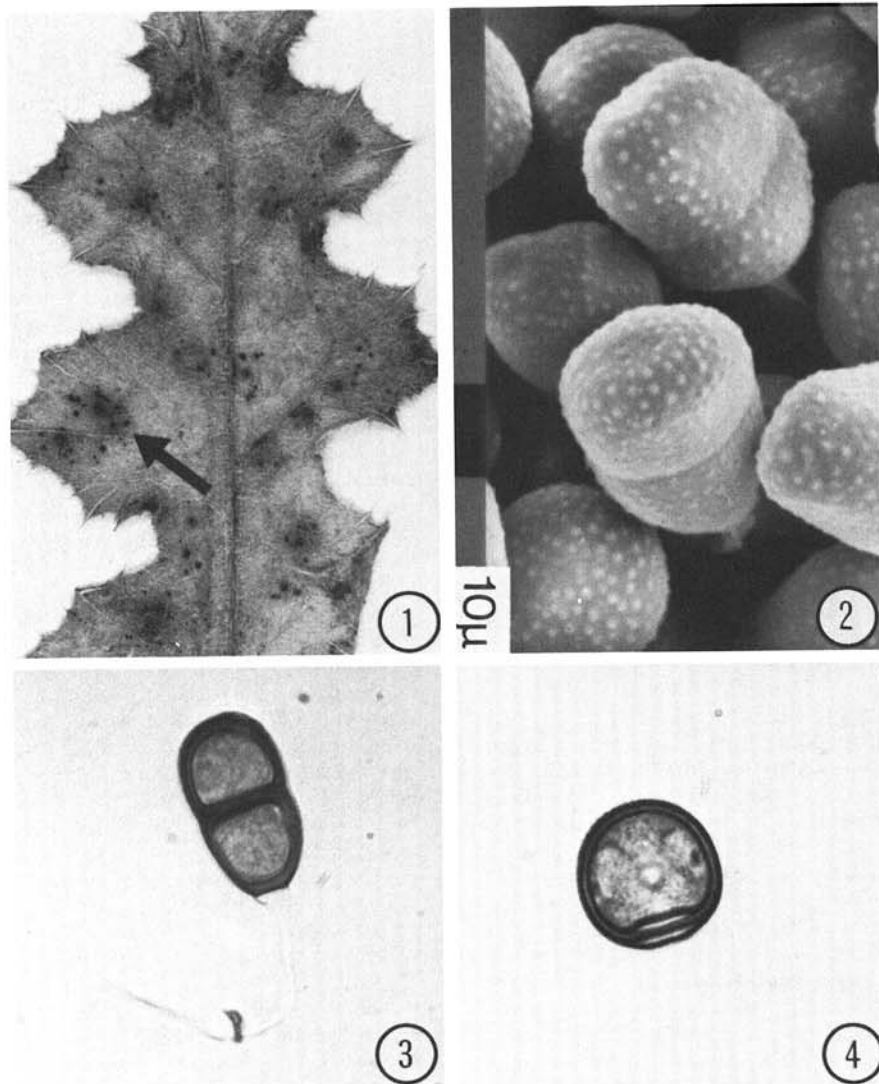
In Eurasia, seven *Puccinia* species have been reported on the genus *Carduus* (Table 1). Thirty-seven *Carduus* species are reported as hosts of *P. carduorum*, eight *Carduus* species as hosts of *P. cardui-pycnocephali* Syd., two *Carduus* species as hosts of *P. hadacii* Urban, and one species each as hosts for *P. cardui-carlinoidis* Petr., *P. galatica* Syd., *P. armeniaca* D. Babaj., and *P. calcitrapae* DC. Both *P. carduorum* and *P. cardui-pycnocephali* have been reported to occur on *C. tenuiflorus* in Eurasia.

Savile (16) described the taxonomic problems in the rusts of Cardueae and the compounding effect of the taxonomic confusion of the hosts. He suggested that

it was not uncommon to find 25% of host plants misidentified when conducting a rust revision. *Carduus* is taxonomically complex (11,12), but the revision by Kazmi (11) has greatly improved the situation; however, it cannot be assumed that all *Carduus* species in Table 1 have been correctly identified.

It is apparent that *P. carduorum* has the broadest host range of the *Carduus* rusts, with *P. cardui-pycnocephali*, *P. galatica*, and *P. hadacii* more restricted. Jacky (10) reported that *P. carduorum* was confined to *Carduus* and could not experimentally be transferred to *Cnicus* or *Cirsium*. Furthermore, *P. carduorum* can be further subdivided into formae speciales on the basis of host range (6), with f. sp. *deflorati* Jacky limited to *C. defloratus* L., f. sp. *crispi* Probst limited to *C. crispus* L. and weakly infecting *C. personata* (L.) Jacq., and f. sp. *nutantis* Gäumann limited to *C. nutans* L. (syn. *C. platylepis* Saut.) (6).

The taxonomy of the *Puccinia* associated with *Carduus* species in their native range is certainly not settled. The two most authoritative treatments on these rusts differ remarkably. Gäumann (6) viewed *P. galatica* as a synonym of *P. cardui-pycnocephali* and *P. cardui-pycnocephali* as different from *P. carduorum*, whereas Savile (15) suggested that the differences between *P. carduorum* and *P. cardui-pycnocephali* may be due to inappropriate spore preparation and, therefore, *P. cardui-pycnocephali* should be considered a variety of *P. carduorum*. Savile (15) did state that *P. hadacii* and *P. galatica* were distinct from *P. carduorum*. Pantidou (13), however, suggested *P. cardui-pycnocephali* and *P. galatica* were synonyms of *P. carduorum*. At best, one must agree with Savile's (15) comment on the difficulty of appropriately naming *Carduus* rusts. The other rusts listed in Table 1, *P. cardui-carlinoidis*, *P. armeniaca*, and *P. calcitrapae*, could be



Figs. 1-4. *Puccinia carduorum* on *Carduus tenuiflorus*. (1) Urediniosori (arrow) of *P. carduorum* on a *C. tenuiflorus* leaf. (2) Scanning electron micrograph of teliospores of *P. carduorum* from *C. tenuiflorus*. (3) Teliospore of *P. carduorum* from *C. tenuiflorus* ($\times 610$). (4) Urediniospore of *P. carduorum* from *C. tenuiflorus* ($\times 620$). Note the three equatorial germ pores.



Fig. 5. Earliest record (●) and present known distribution (■) (by county) of *Puccinia carduorum* on *Carduus tenuiflorus* in California.

Table 1. Host records for *Puccinia* on *Carduus* in Eurasia^a

<i>Puccinia</i> species <i>Carduus</i> species	References	<i>Puccinia</i> species <i>Carduus</i> species	References
<i>P. carduorum</i> Jacky		<i>P. carduorum</i> Jacky (continued)	
<i>C. acanthoides</i> L.	5,15,17,18	<i>C. personata</i> (L.) Jacq.	6,15,17,18,19
<i>C. acanthoides</i> L.		<i>C. platypus</i> Lange	
× <i>C. crispus</i> L.	15	(as <i>C. granatensis</i> Willk.)	8
<i>C. ammophilus</i> Hoffm. et Link (as <i>C. reuterianus</i> Boiss.)	5,6,8	<i>C. pycnocephalus</i>	5,13,19
<i>C. arabicus</i> Jacq.	18	<i>C. pycnocephalus</i> (as <i>C. albidus</i> M. Bieb.)	19
<i>C. assoi</i> Willk.	5,6	<i>C. pyrenaicus</i> (L.) Kazmi (as <i>C. carlinoides</i> Gouan)	6,19
<i>C. aurosicus</i> Vill.	6	<i>C. seminudus</i> M. Bieb.	18
<i>C. baeocephalus</i> Webb et Bert.	15	<i>C. spachianus</i> Dur.	6
<i>C. balli</i> Hook. f.	6	<i>C. tenuiflorus</i> Curt. ^c	5,18
<i>C. candicans</i> Waldst. et Kit.	6	<i>C. thomeri</i> Weinm. (as <i>C. leiophyllus</i> Petr.)	6
<i>C. cephalantus</i> Viv.	15	<i>C. uncinatus</i> M. Bieb.	18
<i>C. chevallieri</i> Barr.	6	<i>P. cardui-pycnocephali</i> Syd.	
<i>C. chysacanthus</i> Ten.	6	<i>C. acanthoides</i> L.	6
<i>C. clavulatus</i> Link	15,18	<i>C. ammophilus</i> Hoffm. et Link (as <i>C. malacitinus</i> Boiss.)	8
<i>C. collinus</i> Waldst. et Kit.	6	<i>C. ammophilus</i> Hoffm. et Link (as <i>C. reuterianus</i> Boiss.)	5,6
<i>C. crassifolius</i> Willd. (as <i>C. glaucus</i> Ledeb.)	6,18	<i>C. balli</i> Hook. f.	9
<i>C. crispus</i> L.	5,6,7,15,17	<i>C. pycnocephalus</i> L.	5,6,7,8,9,18,19
<i>C. cronius</i> Boiss. et Heldr.	6	<i>C. pycnocephalus</i> L. × <i>C. tenuiflorus</i> Curt. (as <i>C. theriotii</i> Rouy)	18
<i>C. defloratus</i> L.	6,15,17	<i>C. spachianus</i> Dur.	9
<i>C. defloratus</i> L. (as <i>C. viridis</i> Kern.)	6	<i>C. tenuiflorus</i> Curt.	5,6,7,9,19
<i>C. gayanus</i> Dur. (as <i>C. carpetanus</i> Boiss. et Reut.)	5,6	<i>P. cardui-carlinoidis</i> Petr.	
<i>C. hamulosus</i> Ehrh.	18	<i>C. pyrenaicus</i> (L.) Kazmi (as <i>C. carlinoides</i> Gouan)	6
<i>C. kernerii</i> Simk.	6	<i>P. galatica</i> Syd.	
<i>C. litigiosus</i> Nocc. et Balb.	6	<i>C. pycnocephalus</i> L.	15,17
<i>C. macrocephalus</i> Desf.	6	<i>P. hadacii</i> Urban	
<i>C. medius</i> Gouan	19	<i>C. nutans</i> L.	19
<i>C. medius</i> Gouan (as <i>C. carlinaefolius</i> Lam.)	6	<i>C. pycnocephalus</i> L.	15,19
<i>C. meonanthus</i> Hoffm. et Link	6	<i>P. armeniaca</i> D. Babaj.	
<i>C. myriacanthus</i> Salzm.	6	<i>C. sp.</i>	19
<i>C. nutans</i> L.	5,6,7,17,19	<i>P. calcitrapae</i> DC	
<i>C. nutans</i> L. (as <i>C. platylepis</i> Saut.)	6	<i>C. olympicus</i> Boiss. ^b	19
<i>C. olympicus</i> Boiss. ^b	18		

^a *Carduus* taxonomy of Kazmi (11) was followed.

^b Species not present in treatment by Kazmi (11).

^c Identity of host taxa questioned by Tranzschel (18) as possibly *C. pycnocephalus*.

found in only one reference each and these names probably should not be used for rusts of *Carduus*. Gäumann (6) found *P. cardui-carlinoidis* to be similar to *P. carduorum*, and the reports of *P. armeniaca* and *P. calcitrapae* may be associated with incorrect host identification. Furthermore, *P. calcitrapae* is considered to be confined to *Centaurea calcitrapa* L. (6,15).

It is obvious from this study that a form of *P. carduorum* was present and well established in California and Oregon on *C. tenuiflorus* before the initiation of the USDA biological control program to evaluate Eurasian collections of *P.*

carduorum for control of North American *C. nutans* (14). The form, or perhaps variety, of *P. carduorum* present in California may be host-limited because the closely related *C. pycnocephalus*, when growing in association with rusted *C. tenuiflorus*, was never found to be attacked by the rust. Further studies are required to determine the host range of the *C. tenuiflorus* strain and to compare this strain with Eurasian strains being studied in containment facilities.

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