Epidemiology and Host Morphology in the Parasitism of Rush Skeletonweed by *Puccinia chondrillina*

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ABSTRACT

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Puccinia chondrillina was released in 1978 in the Spokane River Valley near Spokane, WA, in an attempt to control rush skeletonweed (*Chondrilla juncea*). The pathogen spread 3, 5, and 10 km from the original release site by 1980, 1981, and 1982, respectively. About 5, 11, and 10% of the leaf and stem surfaces were covered by uredia in 1980, 1981, and 1982, respectively. The rust significantly reduced number of flowers, seed viability, and plant size each year but to date has not significantly reduced the population of rush skeletonweed.

Additional key words: biological control, weeds.

Chondrilla juncea L. (Compositae), commonly known as rush skeletonweed, is a taprooted perennial herb native to Eurasia, especially the Mediterranean region (5). In its native range, the plant occurs primarily on roadsides, waste ground, dry riverbeds, and sandy steppes and is not considered an agricultural pest. It has been inadvertently introduced into Argentina, Australia, and the United States. Rush skeletonweed now occurs on more than 2.4 million ha of rangeland, semiarid pastureland, and cropland in California, Idaho, Oregon, and Washington and is becoming a problem for agricultural producers and urbanites alike.

The seeds of rush skeletonweed germinate when the first rains occur in the fall. Taproots of established plants may sprout and produce new rosettes in the fall or anytime after mechanical disturbance. The rosettes begin to bolt in May and rosette leaves die

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in June. The stem leaves are shed in late summer, leaving the skeletonlike flower-bearing stems (4,5). Skeletonweed is obligately apomictic, and the seeds are therefore clones of the parent plant. This genetic homogeneity in the host provides an excellent opportunity for control by a plant pathogen specific to only one plant biotype, since resistant plant biotypes cannot evolve by sexual reproduction.

In Washington, the late-flowering biotype of *C. juncea*, which is susceptible to *Puccinia chondrillina* Bubak & Syd., flowers from early August until the first frost, a period of 6–8 wk. A single plant may produce more than 1,500 flower heads (5). Each head develops 8–12 seeds (4), with 10 the most common number (5). Each seed (achene) has an attached pappus of fine white hairs that aid in wind dispersal.

The amount of seed produced by rush skeletonweed may be reduced considerably in the field by *P. chondrillina* (6). Severe rust of flower stems causes stunting, deformation, and reduced branching, and branches that do develop have fewer flower buds and fewer viable seeds (3).

At Frederick, MD, by the first year after plants were inoculated with *P. chondrillina* (2), seed set was reduced by 65%, seed weight by 32%, and germination by 34%. By the second year, seed set was reduced by 94%, seed weight by 24%, germination by 30%, and biomass by 89%. Compared with sprayed controls at the end of the second season, rusted plants were stunted and 65% died prematurely. These findings suggest that *P. chondrillina* may control late-flowering rush skeletonweed in Washington.

The objective of establishing *P. chondrillina* in eastern Washington was to initiate a disease of *C. juncea* that could reduce the abundance of this noxious weed to an economically tolerable level. In order to assess the ability of the rust to adversely affect the plant, a series of experiments were conducted to determine the effect of *P. chondrillina* on the reproductive capacity of the weed. This study quantified the reduction in number of flowers per plant, seed weight, and seed viability caused by increasing amounts of rust on late-flowering Washington rush skeletonweed plants in the field.

MATERIALS AND METHODS

Urediospores of isolate PC-16 of *P. chondrillina*, obtained from R. G. Emge, USDA, Plant Quarantine Laboratory, Frederick, MD, were mixed with talc or oil and dusted or sprayed onto plants near Nine Mile Falls, WA, in 1978 and at 72 additional sites within Spokane County in northeastern Washington in 1979 by personnel of the Spokane County Weed Board. Three sites with natural stands of rush skeletonweed were selected for detailed observations. The stands were fairly dense (15–20 plants/m^2) but the plants were not necessarily evenly spaced. Site 1 was near Nine Mile Falls in the Spokane River Valley 25 km north-northwest of Spokane; site 2, also in the Spokane River Valley, was at 13th and Lindeke streets in Spokane near the junction of Interstate Highway 90 and U.S. Highway 195; and site 3 was at 43rd and Havana streets in Spokane on the south rim of the valley, at an elevation about 100 m higher than the other sites.

A visual rating system was used at sites 1 and 2 to record the percentage of leaf and stem area covered by rust (Fig. 1). The percentage of rust was the proportion of the plant surface covered with sporulating rust pustules and did not include an estimate of symptomatic tissue surrounding the pustules. The mycelia extending beyond the limits of the sporulating pustule produced chlorosis and shriveling of surrounding tissues. Because the diseased area is much larger than the sporulating area, our ratings were conservative. Usually there was more rust on the basal stem of the plant than at the tips of the flowering stems. The mean rust intensities of 15 plants at site 1 and eight plants at site 2 were calculated to determine the yearly fluctuation of rust intensity during 1980 and 1981. The averages were plotted and a line connecting the points was drawn to show the yearly cycle.

Spread of the rust from the initial release sites was determined in 1979, 1980, 1981, and 1982, always during the month of July. Plants were examined along roadsides and in fields at increasing distances from the initial release points at sites 1 and 2. The presence or absence of uredia was noted and the maximum spread plotted.

To determine the effect of the rust on reproduction, the percentage of rust on each flower stem was determined; most of the leaves had already been shed. Twenty-five flower stems were collected at random from site 2 at the end of September 1980 and from sites 2 and 3 in October 1981. The height of each stem and the length of each primary and secondary branch were recorded and summed to obtain the total length of the flower stems. The number of branches on each stem was also recorded.

The number of flowers per branch was determined by counting the number of open flowers, remaining bracts, and flower scars on each primary branch. The total number of flowers for each plant was divided by the total number of branch tips to get an average number of flowers per branch tip for each plant. Only mature plants having flower stems with a base diameter greater than 5 mm were included in the evaluation.

Seed was collected from the first blossoms produced at four sites in Spokane County. Twenty collections were made during the first week of September in 1980 and during the third week of September in 1981. Only mature seeds from open flower heads were collected, and all seeds from each plant were harvested on the collection day. The seeds from each plant were counted and weighed after removal of the pappus. The percentage of rust on the stems of plants from which seeds were collected was also recorded.

The seed from each sample was germinated between two moist sheets of filter paper in a petri dish at 20 C. Percent germination was determined after 4 days. The seeds were considered to have germinated when the radicle was longer than the length of the seed.

Regression analyses were used to determine the relationship of plant growth, flower production, and seed production to the percentage of rust on the plants.

RESULTS

In 1979, rust was detected only within a radius of 5 m of any release site. By July 1980, the rust was found 1 km north and south, 3 km east, and 0.5 km west of the point of release at site 1. In contrast, no rust was found further than 25 m from the original

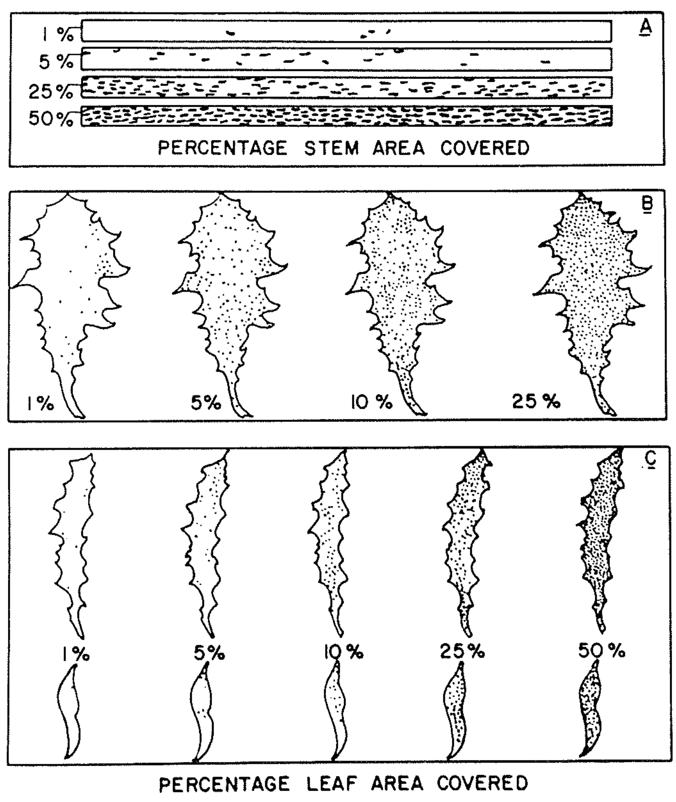

Fig. 1. Rust rating system used to estimate the percentage of *Puccinia chondrillina* on rush skeletonweed in Washington. **A**, Stems, **B**, rosette leaves, and **C**, stem leaves.

release point at site 2. By July 1981, the rust was found 5 km north, 1 km east and south, and 4 km west of the original release point at site 1 and 400 m away from the original release point at site 2. By July 1982, the rust at site 1 had spread to the rush skeletonweed infestation across the river valley (east) and 10 km downriver (north). At site 2, the rust had spread nearly 2 km north from the release site and was established along the river 0.5 km east of the release site.

Rust severity in the skeletonweed populations followed a yearly cycle (Fig. 2). The rust increased rapidly during late spring and early summer on stem-producing plants. Total rust decreased as the pathogen moved from old flower stems onto new rosettes in the fall and continued to decrease through the winter. In the spring, the rust again increased rapidly. The maximum rust levels at site 2 remained nearly the same for 1980 and 1981, but rust intensity at site 1 was nearly three times greater in 1981 than in 1980. In 1982, rust severity was estimated at 10% of the leaf area covered with pustules at sites 1, 2, and 3.

Plant growth was adversely affected by the rust, with damage related to the amount of rust present (Table 1). Plant height was negatively correlated with the amount of rust on the flower stem at site 2 in 1980 and at site 3 in 1981 but not at site 2 in 1981. The total length of the flower stem was also negatively correlated with the percentage of rust at site 2 in 1980 and at site 3 in 1981 but not at site 2 in 1981.

The reproductive capacity of the weed was adversely affected by the rust, but a better fit to a straight-line relationship of damage to the log of the rust intensity was obtained (Table 1). The number of flowers produced per branch was negatively correlated with the log of percent rust. Seed weight and seed germination were also negatively correlated with the log of percent rust in 1980 and 1981.

DISCUSSION

All the sites sampled in this study were inoculated with rust during the spring of 1979. Not only did the pathogen survive but the amount of rust on the plants increased and the distribution of rust from the release site extended over a wide range. However, use of the rust as a biological control agent has not been as successful in Washington as in Australia, where a spread of 320 km was reported the first season (1). Maximum spread in the Spokane River Valley was 10 km in nearly 4 yr. This may be due to a less favorable rainfall pattern than in Australia. In the Spokane River Valley, precipitation (442 mm annually) occurs mainly during the winter months, which is comparable to the drier Mediterranean regions where *P. chondrillina* is found. In southeast Australia, where rust spread was greatest, the rainfall occurs predominantly during the summer months.

The rust has not yet destroyed rush skeletonweed at the release sites, but the number of flowers produced per branch was reduced

TABLE 1. Relationship of growth and reproduction of *Chondrilla juncea* in Washington to rust intensity produced by *Puccinia chondrillina*

	Correlation coefficient and significance[a]		
	1980	1981	
Parameters	Site 2	Site 2	Site 3
Plant height (cm)/rust intensity (%)	−0.507*	NS	−0.688**
Total stem length (m)/rust intensity (%)	−0.619**	NS	−0.520*
Flowers per branch (no.)/rust intensity (log %)	−0.730**	−0.639*	−0.580**
Seed weight (mg)/rust intensity (log %)	−0.513**	−0.472*	–
Germination (%)/rust intensity (log %)	−0.422*	−0.537**	–

[a]NS = not significant, * = significant at $P = 0.05$, ** = significant at $P = 0.01$, – = no data.

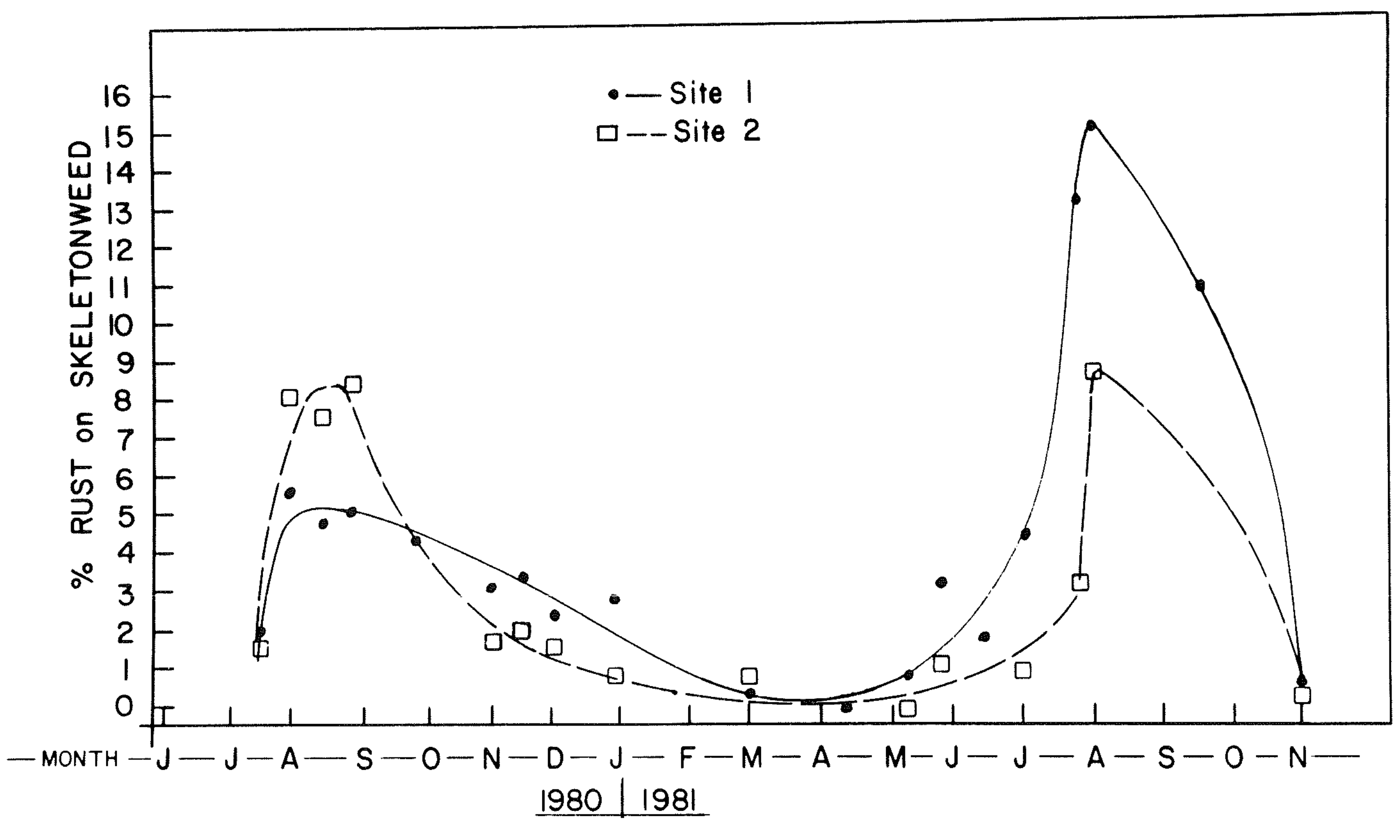

Fig. 2. The average total rust on rush skeletonweed at sites 1 and 2 in 1980 and 1981.

in both 1980 and 1981. The reduction in flowers correlated most highly with the log of the amount of rust on a flower stem. An increase of rust on the stem from 0.1 to 5% reduced the number of flowers by nearly 50%. After a 5% intensity, however, large increases in rust were needed to further reduce the number of flowers produced. This same relationship to rust intensity was found for seed weight and germination. In contrast, plant growth, as measured by height and total length of all stems, was directly related to the amount of rust present. Therefore, high-intensity levels were needed to produce significant stunting.

The effects of the rust on *C. juncea* were similar for 1980 and 1981. The reductions in amount of viable seed produced were similar for both years at all sites. Plant growth, however, differed from year to year and from site to site. Plant growth was reduced at site 2 in 1980 but there was no significant relationship between rust and plant growth in 1981. Plant growth was reduced at site 3 in 1981. The effect of rust on plant growth was neither as significant nor as consistent as the effect of rust on seed production. This may be due to differences in weather between the two years. These results indicate that *P. chondrillina* has the capacity to reduce the spread of the late-flowering biotype of rush skeletonweed in Washington by reducing the number of viable seeds produced.

Although population levels of rush skeletonweed at sites 1, 2, and 3 have remained stable to date, the rust has been observed to affect plant vigor and reduce the ability of the weed to reproduce and spread by seed. In Australia, the population of the weed was reduced within 4–5 yr (1). It may be several more years before population reductions are observed in Washington.

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