Pine Blister Rust Resistance Screening in *Ribes* Germplasm

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Abstract

A preliminary study at the National Clonal Germplasm Repository in Corvallis, Oregon, determined that 110 field-grown *Ribes* L. genotypes were resistant to natural infection from white pine blister rust (*Cronartium ribicola* C. J. Fischer). Uredinia did not form under conditions of natural infection on these black currant (*R. nigrum* L.), red currant (*R. rubrum* L., *R. sativum* L.) or gooseberry (*R. uva-crispa* L., *R. oxyacanthoides* L.) genotypes for 3 to 5 years. The objective of this study was to determine if uredia would develop on these resistant genotypes after artificial inoculation. *Ribes nigrum* cv. Ben Alder was chosen as a susceptible control. In August 2000, uredinial spores were gathered from infected black currants leaves in the Corvallis field planting. An agar-water suspension (30,000 spores ml^{-1}) was prepared and applied to leaves of four branches of intact plants for each clone. Three weeks after inoculation, 68 of the tested clones developed infection. The abaxial leaf surfaces of the blackcurrants 'Ben Alder' and 'Pilot Alexandr Mamkin' and *R.* × *nidigrolaria* Bauer cv. Jostiki, were covered with uredinia. Fewer uredinia developed on *R.* × *nidigrolaria* Bauer cv. Josta, 26 black, 11 red, 5 white currants and 12 gooseberries. No uredinia developed on 42 clones, including 12 black, 5 red, 1 white currant, or 24 gooseberries. Blackcurrant cultivars with the *Cr* gene for white pine blister rust immunity, i.e., Consort, Coronet, Crusader, or Titania, remained uninfected. The broad range of species and geographical origins of the highly resistant, uninfected clones suggest that several additional genetic mechanisms for rust resistance may exist in *Ribes*. Further studies will seek to identify additional rust-immune genotypes.

INTRODUCTION

White pine blister rust (*Cronartium ribicola* J. C. Fischer) is an Asian disease which was introduced through Europe into the United States at the end of the nineteenth century (Hummer, 2000). *Cronartium ribicola* is expanding its range in the United States and requires both *Ribes* (currants and gooseberries) and five-needled pines (*Pinus* L. section strobus) to complete its life cycle. This disease can cause early defoliation of *Ribes*. In Corvallis, Oregon, leaves of susceptible cultivated *Ribes* become infected with uredia in July, August or September. A number of states have regulations restricting *Ribes* cultivation because of the severe damage or death of pines caused by this rust (McKay, 2000). Agencies that prepare regulations for these states and growers who wish to produce *Ribes* are very interested in cultivars that are resistant or immune to rust. Most cultivars of blackcurrants (*R. nigrum* L.) are susceptible (Brennan, 1996). *Ribes ussuriense* Jancz., a blackcurrant native to the Primorskij region in the Russian far east, carries a dominant gene, *Cr*, for rust immunity (Brennan, 1996). A. W. Hunter, a Canadian breeder, crossed this species with *R. nigrum* in the 1940s to obtain immune cultivars (Bergdahl and Teillon, 2000; Hunter, 1950; Hunter, 1955). Cultivated red currants can be susceptible or resistant. *Ribes sativum* L. is rust-susceptible; *R. petraeum* Wulf. and *R. rubrum* L. are rust-resistant (Bergdahl and Teillon, 2000; Hahn, 1943). Gooseberry (*R. uva-crispa* L., *R. hirtellum*) and jostaberries (*R.* × *nidigrolaria* Bauer) tend to be resistant (Bergdahl and Teillon, 2000; Darrow, 1937).

The Corvallis Repository has been evaluating rust incidence after natural infection on about 300 genotypes of *Ribes* since 1995. More than 100 cultivars of blackcurrants, red and white currants, gooseberries and jostaberries (*R.* × *nidigrolaria* Bauer) were not observed to host the rust, i.e., did not develop uredia, during three years of field testing in Corvallis, Oregon (Hummer and. Finn, 2000). We wondered if these cultivars were rust-immune or just avoided natural infection; and whether these genotypes would produce uredia when subjected to high levels of inoculum under humidity conditions favoring rust infection. The objective of this study was to determine if these resistant genotypes would develop uredia after artificial inoculation.

MATERIALS AND METHODS

This study examined 110 elite *Ribes* genotypes which had not been observed to host rust uredia for three years in Corvallis, Oregon. These seven to eight-year-old plants were growing in the field of the National Clonal Germplasm Repository, Corvallis, Oregon. A uredinial spore suspension from severely naturally-infected leaves of susceptible blackcurrant cultivars in the Repository field, was prepared on August 22, 2000. About 26 infected leaves, each with the abaxial surface covered with rust uredia, were placed in 0.7% agar. The solution was agitated to dislodge uredinial spores and the leaves were removed. The resulting spore suspension contained 30,000 uredinial spores ml^{-1}. On August 24, 2000, branches about 15 cm long, containing 5 or more fully mature, green leaves, were chosen from two plants of each genotype. The undersides of all leaves on each branch were inoculated with 2 ml of sprayed suspension from a hand mister. The branches were individually enclosed in polyethylene bags with twist-ties. The bags and ties were removed after 24 hours. On September 14, 2000, leaves were evaluated for presence or absence of uredia. On October 14, 2000, uredia were counted from four infected leaves, the two most infected leaves from each of the treated branches.

RESULTS AND DISCUSSION

Of the 110 rust-resistant genotypes that were artificially inoculated with uredinial spores, 68 genotypes were observed to produce at least one uredium on the four inoculated branches. The genotypes had low levels of infection with distinct, countable uredinial areas. These infections comprised a much smaller surface area than that of the susceptible cultivars. For example, almost the entire abaxial leaf surface of naturally infected or artificially inoculated ‘Ben Alder’ was covered with uredia. We suspect that the sporulation from the inoculated leaves of resistant cultivars was lower than that of naturally infected leaves of susceptible cultivars, although this measurement was not quantified.

The jostaberry genotypes produced an average of 18 or less uredia per leaf. Jostaberry genotypes are noted for their resistance to natural infection (Brennan, 1996) so uredia formation on these clones was unexpected.

No uredia were observed on any leaves of the inoculated branches of 42 genotypes (Table 1). These non-infected plants included 12 black, 5 red, and 1 white currant and 24 gooseberries. The blackcurrants ‘Docz Siberjoczk’ and ‘Lunnaja,’ have *R. nigrum* var. *sibiricum* W. Wolf in their pedigree. This taxon has been used in rust resistance breeding in Poland (Somorowski, 1964) and Russia (Volunez, 1966). The red currant *R. rubrum* cv. London Market produced no uredia in our study and is also known for rust resistance (Brennan, 1996). We conclude that these genotypes are highly resistant because no uredia were observed under natural infection (Hummer and Finn, 2000) or after artificial inoculation in the field (Table 1). Zambino (2000) demonstrated that some rust-resistant cultivars can become infected and produce uredia under controlled laboratory conditions (100% relative humidity in a growth chamber). Therefore, further artificial inoculation must be performed in the laboratory to determine if these cultivars can be considered “immune.”

The four blackcurrant cultivars with the *Cr* gene, ‘Crusader’, ‘Coronet’, ‘Consort’ and ‘Titania’, remained non-infected after artificial inoculation. This concurs with Zambino (2000), who observed no infection on these genotypes after artificial inoculation in his growth chamber. These clones with the *Cr* gene have remained non-infected by rust under natural infection over the past 50 years (Bergdahl and Teillon, 2000; Hummer and Finn, 2000) as well as following artificial inoculation in the field (Table 1) or in the laboratory using 21 different rust pathotypes (Zambino, 2000). These cultivars are immune to rust.

The red currant *R. petraeum* × *R. rubrum* ‘Viking’ did not produce any uredia after artificial inoculation in the field. Zambino (2000) observed many uredia on young leaves and petioles of ‘Viking’ after artificial inoculation in a growth chamber. We inoculated an additional ‘Viking’ plant with 2 ml of 30,000 spore ml^{-1} in a subsequent greenhouse test. The ‘Viking’ leaves developed 1 uredia per leaf (data not shown). This result, concurring with Zambino (2000), places the identity of the present-day ‘Viking’ in question relative to Anderson’s report (1939) which identified ‘Viking’ by its hypersensitive response to rust without formation of uredia. No hypersensitive response was observed on our ‘Viking’ or by Zambino (2000). The ‘Viking’ genotype that we have can be considered highly resistant but not rust-immune. The high humidity of the growth chamber or incubator was more favorable to rust infection than were those of open field conditions.

The geographical origin and the range of species represented by 42 clones that did not develop uredia was quite diverse (Table 1). For example, the highly resistant gooseberries, which produced no uredia after artificial inoculation, included Belgian, Canadian, English, Finnish, Dutch, German, Hungarian, and American cultivars. These locations are geographically removed from the Russian Far East where the *Cr* gene was obtained. This broad diversity of species and origins suggests that several genetic mechanisms for rust resistance may exist within the genus.

Some of the highly resistant clones could be recommended for direct planting for production in North America. Others have defects, such as mildew-susceptibility, poor yield, or poor fruit quality. However, as a whole, these clones represent a broad initial gene pool for breeding and development of rust-resistant cultivars for North American *Ribes* production.

In summary, currants, gooseberries and jostaberries can be divided into categories of rust susceptibility. We consider the four clones with the *Cr* gene, ‘Consort,’ ‘Coronet,’ ‘Crusader,’ and ‘Titania,’ to be immune; the other 38 clones which did not develop uredia after artificial inoculation in field conditions are highly resistant to rust (Table 1). The amount of rust infection on leaves of currant and gooseberry cultivars depends on the density of inoculum, the environmental conditions during the infection period, as well as the genotype. Highly resistant genotypes growing in agricultural settings with low spore-counts pose little risk of becoming infected and passing rust-infection to white pines.

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Tables

Table 1. Highly resistant and immune [1] *Ribes* genotypes with no observed white pine blister rust, *Cronartium ribicola,* uredia after artificial inoculation with 2 ml of 30,000 spores ml^{-1} per 15 cm branch on August 24, 2000, in Corvallis, Oregon.

Plant name	PI number, Local number	Origin	Year introduced
Black Currants *R. nigrum* L. unless noted			
Consort [1]	556071, 319	Ontario, Canada	1952
Coronet [1]	556049, 122	Ontario, Canada	1948
Crandall (*R. odoratum* Wendl.)	556256, 216	Kansas	1888
Crusader [1]	556050, 121	Ontario, Canada	1948
Docz Siberjoczk	556218, 423	Russia	
Lowes Auslese	556225, 671	Germany	
Lunnaja	556220, 425	Russia	
Polar	556211, 416	Sweden	1992
Rain-in-the-face (*R. americanum*)	617878, 1131	South Dakota	1997
Sligo	556086, 676	England	
Titania [1]	922	Sweden	1984
Willoughby	556202, 385	Saskatchewan, Canada	1940
Red Currants *R. rubrum* L.			
London Market	556036, 94	England	1850's
New York 72,	556060, 225	New York	
Sabine (O-273)	1068	Canada	1950s
Rondom	556043, 114	The Netherlands	1949
Viking [2]	556037, 95	Norway	1930s
White Currants *R. rubrum* L.			
Gloire de Sablons	556309,314	France	1854

Gooseberries *R. uva-crispa* L.

Careless	555837, 65	England	< 1864
Clark	556076, 362	Ontario, Canada	1922
Columbus	555842, 104	New York	<1890
Crown Bob	555868, 360	England	< 1823
D. Young	555832, 56	Unknown	
Downing	556040, 106	New York	1855
Early Sulfur	555869, 365	England	1800
Glenton Green	555843, 109	England	1800s
Golda	555854, 205	The Netherlands	1972
Greenfinch	555998, 724	England	1984
Hinnonmaen keltainen	556444, 228	Finland	
Hoennings Frueheste	555848, 127	Germany	1900
Howard's Lancer	555844, 108	England	1831
Industry	555867, 358	England	1800
Josselyn	556018, 10	Ontario, Canada	1886
Jumbo	555835, 61	New Jersey	1900
Poillaji dindis	1116	Uncertain	
Red Gooseberry	1027	Belgium	
Robustenta	555969, 624	Germany	1950s
Schultz	555857, 217	Oregon, U.S.	<1986
Told gyostes	1134	Uncertain	
Whitesmith	555828, 8	England	<1802
White Lion	1017	England	1800s
Weisse Voltragende	555870, 675	Germany	1800

[1] Immune genotypes; no uredia present in field study or in laboratory (Zambino, 2000).
[2] Uredia observed after artificial inoculation in the greenhouse and in the laboratory (Zambino, 2000).