Susceptibility of primocanes of six red raspberry cultivars to late yellow rust *[Pucciniastrum americanum* (Farl.) Arth.]

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Late yellow rust [*Pucciniastrum americanum* (Farl.) Arth.] is a sporadic problem on *Rubus idaeus* L. (red raspberry) in the Atlantic Provinces of Canada. Differences in primocane infection were observed among cultivars *in vivo.* Infection studies done *in vitro* established a clear-ranking order from least to most resistant: Carnival, Festival, Heritage, Royalty, Boyne, and Nova, respectively. Nova and Boyne showed a hypersensitive reaction and apparently possess partial resistance to late yellow rust. Royalty and Heritage also appear to have partial resistance.

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La rouille jaune tardive *[Pucciniastrum americanum* (Farl.) *Arth.]* est un problème sporadique du framboisier rouge *(Rubus idaeus* L.) dans les provinces Atlantique du Canada. Des differences de niveau d'infection dans les tiges vegetatives de divers cultivars ont été observées *in vivo.*

Des etudes d'infection faites *in vitro* ont etablit un classement net des cultivars, du moins resistant au plus resistant: Carnival, Festival, Heritage, Royalty, Boyne et Nova, respectivement. Nova et Boyne ont démontré une reaction hypersensible et semblent posséder une resistance partielle à la rouille jaune tardive. Les cultivars Royalty et Heritage semblent aussi avoir une resistance partielle.

Introduction

Late yellow rust [*Pucciniastrum americanum* (Farl.) Arth.] on red raspberry (*Rubus idaeus* L.) is a sporadic problem in the Atlantic Provinces of Canada (Luffman and Buszard, 1988). Nickerson and Mahar (1987) in Nova Scotia noted that the cultivars Carnival and Festival appeared susceptible to the rust while Nova and Boyne showed some resistance; similar observations were made in 1984 and 1985 in New Brunswick (Luffman, unpublished data). The mechanics of this resistance have not been previously studied. This paper describes the response of primocanes of six raspberry cultivars to infection by *Pucciniastrum americanum* in controlled inoculation experiments in a greenhouse.

Materials and methods

The source of *P. americanum* used was infected leaves of the cultivar Festival collected from the field in Bouctouche, New Brunswick. Urediniospores were brushed from the adaxial leaf surface of the infected leaves onto the adaxial surface of leaves of 3 month-old virus-free greenhouse grown plants of the same cultivar which were then placed in a darkened mist chamber at 20°C for 48 hours. Urediniospores were produced on inoculated leaves in about 7 days. Inoculum was increased and maintained on greenhouse plants throughout the work.

Urediniosporesvacuum harvested into a vial were suspended in distilled water. Spore concentration was determined using a haemocytometer (Tuite, 1969); distilled water was added as necessary to dilute the suspension to 30,000 spores/ml.

Previous research showed this concentration resulted to successful infection of susceptible cultivars (Nickerson, personal communication).

Urediniospore viability was determined *in vitro* using a modifiedversion of the method used by Anthony *et al.* (1985). Spore suspension was sprayed onto 1.5% distilled water agar (DWA) in four petri dishes per test which were placed in the dark at 20°C. Nickerson (personal communication) observed spore germination in as little as 6 hours. Percent germination was determined after 8 hours by counting all spores in each of four fields chosen at random in each plate and averaging the percent germination in each field. The spores were considered to have germinated when germ tube length equalled spore diameter (Zadoks and Schein, 1979).

The cultivars Festival, Carnival, Boyne, Nova, Heritage, and Royalty were inoculated by spraying the adaxial leaf surface of the two youngest fully expanded leaves of 4 month-old virus-free greenhouse grown plants with 0.5 ml of spore suspension per trifoliolate leaf. The plants were then placed in a darkened mist chamber at 20°C for 48 hours. Following this they were kept in a greenhouse at 20°C under a 16-hour photoperiod with supplemental lighting (0.8-1.0 klx, high pressure sodium lamps). There were four replicate plants of each cultivar per test, and the test was repeated four times.

Chlorosis and necrosis of leaves resulting from infection were recorded 28 days after inoculation. Development of the uredinia was also measured; this included the latent period (the time from inoculation to the beginning of sporulation), and the leaf area covered by lesions at the first appearance of spores and 28 days after inoculation. Leaf area covered by uredinia was traced on a transparent acetate sheet and the affected area was determined using a planimeter. After 28 days the leaves were detached, photocopied, and total leaf area was determined by planimeter. Percent leaf area affected by the rust was calculated at the onset of sporulation and after 28 days. A test of homogeneity of variance showed

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Table 1. Response of six red raspberry cultivars to inoculation with urediniospores of *Pucciniastrum americanum* (Farl.) Arth. under controlled environment conditions.

Cultivar	Latent period (days)	Percentage of leaf area diseased at onset of sporulation"	Percentage of leaf area diseased 28 days after inoculation*
Nova	15.50a	0.12a	0.20a
Boyne	12.19b	0.41 b	1.08a
Royalty	8.81 c	0.90c	41.51 b
Heritage	7.63d	0.99d	49.59c
Festival	7.19d	1.36e	60.53d
Carnival	7.19d	1.39f	71.96e

*Arcsin transformation used for analysis; untransformed means presented in table.

a-f Within each column means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

no differences among the four tests so the results were pooled before analysis of variance was performed on the data; Duncan's multiple range test was used to separate the means (Steel and Torrie 1980).

Results

Germination of the urediniospores was in the range of 51-60% in all 16 fields per test. The average germination was 57, 56, 55, and 57% for tests 1, 2, 3 and **4,** respectively. The germ tubes tended to grow straight up from the DWA plate, so that it was sometimes difficult to see them.

Sporulating uredinia were produced on inoculated leaves of all six cultivars. The latent period was significantly longer on Nova than on all other cultivars. The next longest was on Boyne, followed by Royalty. Festival, Carnival, and Heritage had the shortest latent periods (Table 1). There were significantly fewer and smaller uredinia produced on Nova than on the other cultivars at the onset of sporulation. Only a few of these uredinia sporulated, most simply produced necrotic flecks. Boyne developed more sporulating and larger uredinia but less necrotic flecking than Nova. Carnival had the greatest area covered by uredinia at the onset of sporulation. Festival followed Carnival with significantly more and larger uredinia developed at this stage compared with the other cultivars.

Nova and Boyne still had the smallest and fewest uredinia at the end of the 28-day observation period. The area affected on Nova had increased from 0.12% to 0.20%, and on Boyne from 0.41% to 1.08%. Carnival had the greatest area (71.96%) covered by sporulating uredinia, with Festival second. The uredinia were filled with masses of yellow-orange urediniospores. The flecking on Nova and Boyne persisted throughout the experiment, and was not observed on any other cultivars.

No symptoms were present on the abaxial leaf surface of any of the six cultivars at the onset of sporulation. By the end of the 28-day period, Nova and Boyne had some very small chlorotic lesions and some necrotic flecking. Almost all of the abaxial leaf surfaces of both Carnival and Festival were generally chlorotic with spreading necrotic lesions. Curling of the leaves was also evident. Heritage and Royalty were similarly affected, but to a lesser extent.

Discussion

The observed differences among the six cultivars in response to artificial inoculation with urediniospores of *Pucciniastrum* arnericanurn clearly established a ranking order from the least to most resistant: Carnival, Festival, Heritage, Royalty, Boyne, and Nova, respectively. The ranking of Carnival and Festival as least resistant and Boyne and Nova as most resistant confirms observations of field infection previously reported (Nickerson and Mahar, 1987; Luffman and Buszard, unpublished data).

Nelson (1978) classified disease resistance into two major types. In the first, the host restricts the infection site and the infection process; this is often referred to as hypersensitivity. In the second type, following successful infection, the host resists subsequent colonization and reproduction of the parasite. This is characterized by the terms partial resistance and slow rusting. Applying Nelson's definitions, Nova and Boyne were the only cultivars which showed a hypersensitive reaction.

The range of latent periods observed is similar to that (7-11 days) found by Darker (1929) in his inoculation work using aeciospores from the alternate host, *Picea glauca* (Moench) Voss. The longer latent period and fewer and smaller uredinia developed on Nova and Boyne very markedly slowed the rate of disease increase, indicating that these cultivars also possess "partial resistance" as defined by Nelson (1978), comparable to "slow-rusting" in cereals (Wilcoxson, 1981).

Disease severity is usually the cumulative result of infection frequency, latent period, spore production, and infectious period. Disease symptoms usually quantitatively reflect growth of the pathogen in the host, and are a measure of disease severity (Parlevliet, 1979). Disease severity (percent of plant area diseased) can be used to assess disease resistance. Both spore production and percent leaf area affected were reduced on Royalty and Heritage, *i.e.*, development of the pathogen was quantitatively hindered. Royalty and Heritage can therefore be assumed to have partial resistance to the rust.

The race composition of the rust present in any given raspberry producing area must be determined for a better understanding of cultivar reactions. Even in the absence of such information, the use of cultivars with some resistance to late yellow rust is recommended in areas where this disease is a problem. As all tests were made by mass inoculation with field inoculum, no information was obtained on the possible differential reaction of the cultivars studied to various races of the pathogen.

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