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SCREENING *PINUS SYLVESTRIS* GROWN FOR THE PRODUCTION OF CHRISTMAS TREES FOR RESISTANCE TO WESTERN GALL RUST *PERIDERMIUM HARKNESSII* USING DIFFERENT SOURCES OF AECIOSPORES[†]

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ABSTRACT

Results showed a moderate to high susceptibility of *Pinus sylvestris* to western gall rust *Peridermium harknessii* from *Pinus sylvestris* in Michigan and *Pinus banksiana* in Minnesota. In general, *Pinus sylvestris* seed sources were more susceptible to aeciospores collected from *Pinus sylvestris* than aeciospores collected from *Pinus banksiana*.

INTRODUCTION

In the upper Midwest scots pine *(Pinus sylvestris* L.) is the most widely planted tree for the production of Christmas trees because of its many favorable cultural characteristics and ability to grow on low quality sites (Burnes et al., 1988; Burnes and Blanchette, 1991). Western gall rust or pine-pine rust caused by the fungus *Peridermium harknessii* (J. P. Moore) Y. Hiratsuka *Endocronartium harknessii* is an important disease of scots pine in the upper Midwest and Northeastern United States (Ziller, 1974). Western gall rust can stunt growth and kill branches and stems and result in trees that are unmarketable. Currently the disease is controlled by sanitation (removing galls and diseased trees from windbreaks and plantations) and by applying fungicides. Another control method that could be advantageous is the selection of resistant scots pine varieties to reduce gall rust severity.

Much information has been published on the genetic diversity among scots pine seed varieties grown for Christmas trees in the Upper Midwest including needle color and length, growth rates, cold tolerance and resistance to insects and diseases including resistance to *P. harknessii* (Burnes et al., 1988; Burnes and Blanchette, 1991; Steiner, 1974). Hutchinson (1935) observed resistant and susceptible host responses in several scots pine inoculated with *P. harknessii* and Burnes and Blanchette (1991) demonstrated differences in susceptibility among different scots pine seed sources inoculated in the greenhouse. However, not much is known about the specific susceptibility of scots pine currently being grown by the Christmas tree industry to *P. harknessii* or if infection by aeciospores from different geographical sources could influence disease severity.

The objectives of this study were to determine disease severity among several seed sources of scots pine currently used in the production of Christmas trees in the upper Midwest and to determine if variation in pathogenicity exists between different spore sources.

MATERIALS AND METHODS

In the spring aeciospores were collected from galls on scots pine in Christmas tree plantations in Cheboygan, Emmet, Grand Traverse, Kalkaska, Missaukee, Montcalm and Wexford counties in Michigan and from jack pine *(Pinus banksiana* Lamb.) from three locations in St. Louis County, Minnesota. After removing spores from gall surfaces, they were passed through a 125-µm screen and stored in gelatin capsules at -32° C until time of inoculations.

Open pollinated seed of 19 scots pine varieties originally from Europe and Asia were obtained from nurseries in Michigan. Two additional open pollinated scots pine seed varieties Alpine and Mongolica were obtained from Schumacher Company, Sandwich, Massachusetts. Jack pine seed source 68 was obtained from a University of Minnesota seed orchard in Cloquet, Minnesota, that contained trees previously selected in the field for possible resistance to gall rust (Burnes et al., 1988). Seed source 4E was provided by the General Andrews State Nursery, Willow River, Minnesota, and consisted of seed from many sources and represents the seed routinely used in North Central United States forest tree nurseries.

Three inoculation trials were conducted. In trials 1 and 2, seedlings originating from scots and jack pine seed sources were inoculated with aeciospores from scots pine in Michigan (Table 1). In trial 3 scots and jack pine seed sources were inoculated with aeciospores collected from jack pine in Minnesota (Table 2). For each inoculation seed were sown in a cavity styroblock (Beaver Plastics P.O. Box 118 Roy,

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Washington 98580; 67 cm^3 per cavity) using a Pro-Mix BX growing medium (Premie Brand, IN, New Rochelle, NY) with supplemental light providing an 18 hour photoperiod and a temperature of 21° C for 8 weeks. Three styroblocks were used for each seed source, that is, 90 seedlings per seed source were grown for each trial. About 1.5 x 10^6 aeciospores suspended in 0.5 ml of oil (Soltrol 170, Phillips Petroleum Co., Bager, TX) were placed in a gelatin capsule. This capsule of spores and oil were placed on a venturi atomizer to distribute the spores evenly unto 30, 8-week old scots or jack pine seedlings from each seed variety as described previously (Burnes and Blanchette, 1991). Three replications of 30 seedlings each were inoculated for each variety or total 90 seedlings. Immediately after inoculation seedlings were misted with water, placed in plastic bags, and incubated in darkness at 18° C for 48 hours. Seedlings were then removed from the bags and placed in a greenhouse with supplemental light for an 18-hour photoperiod and kept at 21° C. Presence or absence of galls on seedlings was recorded 24 weeks after inoculation.

To investigate how seed source affected frequency of gall formation, each of three trials were analyzed separately using the standard contingency table method (Fienberg, 1980; Wilkinson, 1992). When significant effects were found in the tables, subtables were created to determine which seed sources were similar. To investigate how inoculum host source affected gall frequency on a subset of the seed sources (that is, the 14 sources tested in trial 3), common seed source data from trials 1 and 2 were analyzed with trial 3 data with standard log-linear modeling using the likelihood ratio test statistic (G^2; Wilkinson, 1992).

RESULTS

Red stem and needle lesions first appeared 2 weeks after inoculation with *P. harknessii* and galls started to form 8 weeks later. Twenty-four weeks after inoculation significant differences in the proportion of

Table 1. Number of scots and jack pine seedlings with galls 24 weeks after inoculation with *Peridermium harknessii* collected from scots pine.

Pine seed source†	Trial 1	Trial 2
	Seedlings with galls‡	
Kinveachy Scottish Highland		53 a
Lake Superior Blue		51 a
Scottish Highland		50 a
Super French		55 a
Lakenheath East Anglis		48 a
East Anglia	59 a	
coded J §	50 a	
Austrian Hills	50 a	
Belgium	49 a	
coded F §	45 a	
Guadarrama	43 a	
Superior French Green		47 a
Alpine	41 a	46 a
Central Massif	37 b	
Storak	34 b	
Casadeen		44 a
Pike Lake Improved		40 a
Riga		37 a
Burgenland		35 b
Jack pine 4E	33 b	26 b
Gevauden	33 b	
Jack pine 68	13 c	14 c
Mongolica	3 d	5 c

† All except jack pine 4E and 68 were varieties of scots pine.

‡ Based on inoculation of 3 styroblocks of 30 seedlings of each seed source, or 90 total seedlings. Values followed by different letters within each trial are different ($p < 0.05$).

§ Seed source/ variety not released by supplier.

Table 2. Number of scots and jack pine seedlings with galls 24 weeks after inoculation with *Peridermium harknessii* collected from jack pine trial 3.

Pine seed source†	Seedlings with galls‡		
Super French	44	a	
Lakenheath East Anglis	43	a	b
Guadarrama	39	a	b
Austrian Hills	37	a	b
Casadeen	37	a	b
Alpine	35	a	b
Jack pine 4E	35	a	b
East Anglia	32	a	b
Riga	32	a	b
Lake Superior Blue	31	a	b
Gevauden	30	a	b
Pike Lake Improved	29	a	b
Jack pine 68	21		b
Mongolica	7		c

† All except jack pine 4E and 68 were varieties of scots pine.
‡ Based on inoculation of 3 styroblocks of 30 seedlings of each seed source, or 90 total seedlings.
Values followed by different letters within each trial are different ($p < 0.05$).

scots and jack pine seedlings with galls among the different seed sources were found using categorical analysis (Tables 1 and 2). Four different ($p < 0.05$) groups among the different seed sources tested were found for gall incidence in trial 1. Incidence ranged from 45 to 65% for the most susceptible seed source ($p = 0.15$), and 36 to 41 % for the next most susceptible ($p = 0.92$; Table 1). In trial 2, all but two scots pine seed sources (Burgenland and Mongolica; $p < 0.05$) exhibited similar gall incidence ($p = 0.18$) when inoculated with aeciospores from scots pine. When aeciospores from jack pine were used as inoculum in trial 3, gall incidence among all seed sources except Mongolica were similar ($p \geq 0.12$) and ranged from 23 to 49% (Table 2). Scots pine seedlings from the Mongolica source had the least gall incidence in all 3 trials. Mongolica was lesser in percent galled seedlings than all other seed sources in trial 1 and 3 ($p < 0.01$) and it was lesser ($p < 0.04$) in all seed sources but jack pine 68 ($p = 0.29$) in trial 2.

The effect of host inoculum source on gall incidence was also analyzed. A three-way interaction was found between seed source, aeciospore source and gall incidence ($p = 0.005$) using the saturated model. Subset modeling showed the three way interaction could be eliminated by dividing all seed sources into two groups: jack pine seed sources plus Mongolica ($p = 0.75$). and the remaining seed sources ($p = 0.25$). With each subset, we found effects of gall rust host source on gall incidence for the jack pine seed sources plus Mongolica ($p = 0.037$) and for the remaining seed sources ($p = 0.0001$). In other words, aeciospores from jack pine were significantly more virulent (caused more galls to form) on Mongolica and the two jack pine seed sources than aeciospores from scots pine. Similarly, inoculum from scots pine was significantly more virulent than that from jack pine on the remaining seed sources.

Discussion

Results of our first two trials showed that scots pine seed sources Mongolica, Gevauden, Storak, Burgenland and Central Massif were the most resistant to disease resulting from inoculations with aeciospores collected from scots pine. The amount of infection may be unacceptable in a Christmas tree planting although rust susceptibility indicated by greenhouse screening tests may be greater than expected in field plantings. These greenhouse studies provide the only available method to screen large numbers of trees in a reasonable amount of time. Although Mongolica was the most resistant (Table 1), it has undesirable cultural characteristics including slow growth and apparently is not suitable for the Christmas tree industry (Wright et al., 1966; Wright et al., 1976.)

In our third trial where seedlings were inoculated with aeciospores from jack pine, Super French had the greatest incidence of galled seedlings but the level was similar statistically to all scots pine varieties tested except Mongolica (Table 2). Of the two jack pine seed sources, 68 had the least disease incidence and it was statistically different from that of 4E.

Several isolates of a variety of stem and gall rust fungi collected from different geographical areas and

from different tree species have demonstrated variability in pathogenicity including *P. harknessii*. For example, considerable variation in virulence among *Cronartium quercuum* f. sp. *banksianae* and *C. quercuum f. sp. fusiforme* isolates has been shown among pines (Kais and Snow, 1972; Powers, 1972). Van Der Kamp (1988) observed differences in the amount of galls formed in scots and lodgepole pines *(Pinus. contorta* Doug.) caused by *P. harknessii* collected in several geographical areas in British Columbia, Canada and a few seed sources were more susceptible to local western gall rust isolates than to isolates from other areas.

Aeciospores collected from jack pine in Minnesota resulted in significantly more galls on Mongolica and both jack pine seed sources than on the other scots pine seed sources. Conversely, inoculating with aeciospores collected from scots pine in the lower peninsula of Michigan resulted in significantly less disease on Mongolica and the two jack pine seed sources than on the other scots pine seed sources. It would appear that jack and scots pine are more susceptible to gall rust isolates from their respective host species or particular geographical area. Selecting resistant scots pine seed varieties for areas where gall rust is severe should be a viable management option to combine with other integrated pest management procedures to reduce losses as well as reduce the amount of fungicides currently being used to control this disease.

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