Incidence of *Cryphonectria parasitica* Cankers on Scarlet Oak (*Quercus coccinea*) in Pennsylvania

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ABSTRACT

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Surveys were conducted in Pennsylvania during 1989 and 1990 to determine the distribution and incidence of *Cryphonectria parasitica* (= *Endothia parasitica*) cankers on scarlet oak (*Quercus coccinea*). Cankered scarlet oak were found throughout the natural range, with incidence levels (15.0%) comparable to those previously reported in North Carolina (13.8%). *C. parasitica* was recovered from 69.7% of attempted isolations. Macroscopic signs (pycnidia or stroma) of *C. parasitica* were associated with 67% of typical cankers. This represents a significant source of inoculum that may serve to further infect scarlet oaks and also American chestnut sprouts. This is the first report of *C. parasitica* cankers on scarlet oak in Pennsylvania.

Additional keywords: chestnut blight

Cryphonectria parasitica (Murrill) Barr (= *Endothia parasitica* (Murrill) P.J. Anderson & H.W. Anderson), the causal fungus of chestnut blight, was first reported in the United States in 1904 and has virtually eliminated the American chestnut (*Castanea dentata* (Marsh.) Borkh.) as a canopy tree throughout its natural range (1). American chestnut now exists in the eastern forest mainly as understory sprouts, which arise from the blight-resistant roots. The loss of overstory American chestnut due to chestnut blight changed much of the eastern hardwood forest from mixed American chestnut and oak to predominantly oak.

Early researchers reported that the fungus was found on oaks in stands of blighted American chestnut. In 1909, the first report of *C. parasitica* from oak was made by Collins (cited in 18) from a small dead branch of black oak (*Quercus velutina* Lam.). Later, Clinton (8) and Fulton (9) found *C. parasitica* on black and white oak (*Q. alba* L.). Fulton suggested that the fungus was saprophytic, since it was found only on dead oak bark. Another species of *Cryphonectria, C. radicalis* (Schwein.:Fr.) Ces. & De Not., was reported to occur on various oaks in southwestern Pennsylvania in 1912 but has not been reported since. In 1913, Anderson and Babcock (4) inoculated sterile twigs of black, chestnut (*Q. prinus* L.), and white oak with *C. parasitica* isolates. Their studies indicated that *C. parasitica* was saprophytic on black oak and weakly parasitic on chestnut and white oak. Rankin (17) reported similar results in 1914 but listed scarlet oak (*Q. coccinea* Münchh.) as a slightly susceptible host. In 1917, Shear et al (19) inoculated *C. parasitica* into chestnut, northern red (*Q. rubra* L.), scarlet, and white oak but reported that the fungus infected only white oak. Mild to severe bole cankering and branch dieback caused by *C. parasitica* was reported on post oak (*Q. stellata* Wangenh.) in 1946 (7). Ham (10) also inoculated several oak species, including black, blackjack (*Q. marilandica* Münchh.), northern and southern red (*Q. falcata* Michx.), scarlet, post, white, and willow (*Q. phellos* L.) oak. Recovery of the fungus was limited to scarlet, post, and white oak. In the 1960s and early 1970s, live oak (*Q. virginiana* Mill.) trees infected with *C. parasitica* were reported to occur in several states (5,12,15,16,21). In 1987, Nash and Stambaugh (14) reported on the results of inoculation trials involving post, scarlet, and white oak; they found that post oak was most susceptible, followed by scarlet and white oak. Nash and Stambaugh (13) also indicated that the virulence of some oak isolates inoculated into American chestnut was equal to or greater than that of isolates collected from American chestnut.

There have been relatively few reports regarding the percentage of trees infected with *C. parasitica* in oak stands. In 1960, Bryan (6) reported that 14.2% of the post oaks sampled in the Piedmont of North Carolina, South Carolina, and Georgia were infected with *C. parasitica*. In 1967, Ham (10) conducted a survey in North Carolina and found that symptoms resulting from *C. parasitica* infection were occurring on scarlet oak in most stands, but he did not quantify the percentage of infected trees. He described the most obvious symptom as an "abnormal pitting and swelling at the base" and concluded that this was a result of a long-term host/pathogen interaction. In 1982, Nash and Stambaugh (13) reported that 13.8% of the scarlet oaks and 15.5% of the post oaks in the Piedmont and mountain regions (combined) of North Carolina were infected with *C. parasitica*.

Rapid-growing scarlet oak is an important component of 14 forest cover types in North America (11) as well as a widely planted shade tree. Although there have been no published reports of scarlet oak trees infected with *C. parasitica* in Pennsylvania, B. L. Nash observed symptomatic scarlet oaks throughout the state (*unpublished*). The objectives of this study were to determine the incidence and geographic extent of scarlet oaks infected with *C. parasitica* in Pennsylvania.

MATERIALS AND METHODS

Field survey. A survey was conducted in 1989 throughout the range of scarlet oak in Pennsylvania to locate mixed-oak stands having a scarlet oak component and to identify symptomatic oaks for future study (22,23). The presence of *C. parasitica* cankers, stroma, perithecia, and/or mycelial fans on scarlet and white oak was recorded for each tree, and bark samples were collected for verification. The results of this survey were used to select eight stands for a more intensive disease incidence survey in 1990 (Fig. 1). Stands were selected on the basis of the level of symptomatic trees as well as their distribution across the geographic range of scarlet oak within Pennsylvania.

A strip-cruise sampling design was utilized in each stand, since the incidence of *C. parasitica* infection on scarlet oak is often clumped (13,20). Each sampling strip was 10 m wide and the distance between each strip was 100 m. The number of strips per stand was based on stand size to ensure at least a 10% stand sample. All oak trees >2.5 cm in diameter at breast height (1.5 m) and within 5 m from the center survey line were characterized by species, diameter at breast height, and crown class (dominant, codominant, intermediate, or suppressed) (20).

Each tree was examined for *C. parasitica* basal cankers and bole cankers. Canker severity was described as none, light, moderate, or severe, based on

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canker size relative to tree diameter. Respectively, these categories represented approximately 0, 1–5, 6–25, and >25% of the circumference cankered. The number of bole cankers located on the first 5 m of the trunk was recorded. Total basal area of all species present was determined in each stand by means of a 10 basal area factor prism (20). One basal area measurement was taken per strip, and data were averaged for the entire stand.

A maximum of 5 min per symptomatic tree was allotted to detect signs of *Cryphonectria* with a 10× hand lens and a flashlight. External signs of the fungus included orange pycnidial stroma and/or perithecia within the canker or at the canker margin. If stroma or perithecia were not found on the surface, then yellow-to-buff mycelial fan material was sought by removing the bark. Cankered bark and underlying cambium, with or without signs of the fungus, were collected in each stand to verify the presence of *Cryphonectria*. The samples were taken from a maximum of 10 cankered trees with visible signs of the fungus. In addition, all cankered trees without visible signs of the fungus were sampled. An increment hammer and/or knife was used to collect 10–15 samples along canker margins or within callus folds. Samples from individual cankers were put into plastic bags and placed on ice for transportation to the laboratory.

Laboratory isolations. Bark samples were examined with a dissecting scope at 45× for signs of *Cryphonectria*. Six subsamples from each canker were flame-sterilized and placed (three per petri dish) on acidified Difco PDA (1 ml of lactic acid per liter of potato-dextrose agar). Subcultures were made from each positive or questionable culture onto PDA containing methionine (100 mg/L) and biotin (1 mg/L) (2). Resultant cultures were grown at 21 C with a 16-hr photoperiod for 3–7 days. Identification of *C. parasitica* was based on culture morphology, including color and the presence of pycnidia. Isolates were transferred to PDA slants for long-term storage.

Because *C. radicalis* turns white cornmeal "perilla purple," a color change considered indicative for this species, all *Cryphonectria* isolates collected in this study and one isolate of *C. radicalis* (obtained from S. Anagnostakis) were grown on white cornmeal in a 100-ml Erlenmeyer flask at 21 C with a 16-hr photoperiod. Cultures were observed periodically for approximately 12 wk (19).

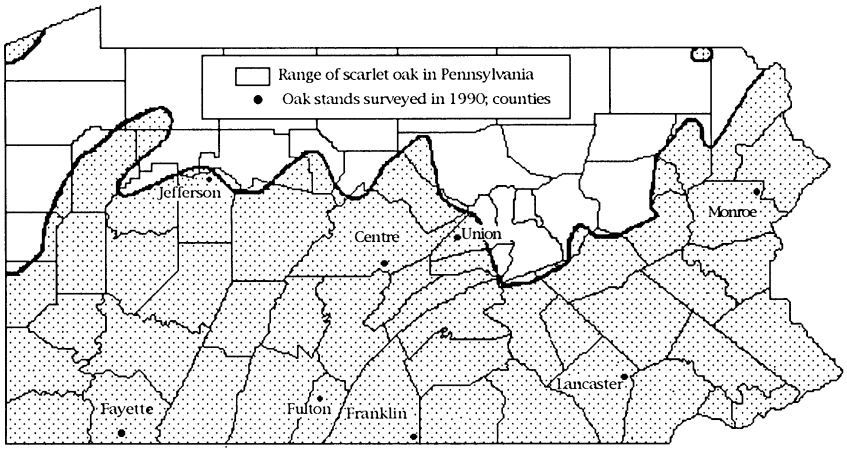

Fig. 1. Range of scarlet oak in Pennsylvania and location of oak stands used in a 1990 incidence survey.

RESULTS

Only one white oak from a sample of 554 white oak trees exhibited a typical *C. parasitica* (bole) canker during the 1990 survey. In contrast, 123 (15%) of 821 scarlet oak trees surveyed exhibited one or more cankers (basal and/or bole) typical of infection by *C. parasitica* (Table 1); 6.9% had only basal cankers, 6.3% had only bole cankers, and 1.7% had both canker types on the same tree. Disease incidence was greatest in the Kittanning (23.1%) and Buchanan (22.1%) stands and least in the Delaware (4.5%) and Bald Eagle (3.6%) stands. One canker type tended to dominate at a particular location. For example, only basal cankers were observed in the Valley Forge stand, whereas most cankers in the Kittanning stand were bole types. Both canker types were found in approximately equal numbers in the Buchanan and Forbes stands. The Forbes and Valley Forge stands had a higher incidence of severe basal cankers, and the Buchanan and Kittanning stands had a higher incidence of the light to moderate bole cankers. Overall, the number of light to moderate cankers (bole or basal) approximately equaled that of severe cankers.

C. parasitica stroma was evident in 60% of scarlet oaks with at least one visible canker. Only 4.4% of the trees had stroma without cankers. Perithecia were associated with 3.6% of the cankers. Examination of samples with the dissecting scope revealed greater amounts of stroma than were apparent in the field. Basal and bole cankers had similar amounts of fungal signs.

Isolations from 89 cankers on symptomatic scarlet oak trees yielded positive *C. parasitica* cultures in 69.7% (Table 1). On the basis of perilla purple test results, *C. radicalis* was not present among the isolates examined.

DISCUSSION

Cankered scarlet oaks occurred commonly throughout the tree's range in Pennsylvania, with no evidence of a regional pattern. The incidence of *C.*

Table 1. Description of oak stands surveyed in 1990, incidence of symptoms on scarlet oak, and number of positive isolations of *Cryphonectria parasitica*

State forest	County	Stand size (ha)	Basal area (m^2/ha)		No. of trees examined	No. (%) of cankered trees[a]	No. of cankers sampled[b]	No. of cankers yielding positive isolations
			All oak spp.	Scarlet oak				
Bald Eagle	Union	3.1	5.6	1.7	56	2 (3.6%)	3	2
Buchanan	Fulton	2.6	5.6	2.8	104	23 (22.1%)	16	10
Delaware	Monroe	6.6	6.5	2.8	88	4 (4.5%)	5	3
Forbes	Fayette	2.4	9.3	6.5	157	24 (15.3%)	18	14
Kittanning	Jefferson	4.4	9.3	2.8	78	18 (23.1%)	11	5
Michaux	Franklin	5.1	5.6	4.7	96	14 (14.6%)	11	7
Rothrock	Centre	10.0	11.1	...[c]	172	28 (16.3%)	16	14
Valley Forge	Lancaster	3.2	8.4	1.7	70	10 (14.3%)	9	7
Total					821	123 (15.0%)	89	62 (69.7%)

[a] Number of trees with at least one basal or bole canker, or both.
[b] More than one canker may have been sampled per tree.
[c] No data.

parasitica infections on scarlet oak in Pennsylvania (15.0%) was comparable to that reported by Nash and Stambaugh (13) in North Carolina (13.8%). Nash and Stambaugh (13) reported that 15.5% of the post oaks in the Piedmont and mountain regions of North Carolina were infected with the fungus. Bryan (6) reported that 14.2% of the post oaks sampled in the Piedmont of North Carolina, South Carolina, and Georgia were infected with *C. parasitica*. The similar results among these surveys indicate that the natural incidence of *C. parasitica* cankers within scarlet and post oak populations may be approximately 14–15%.

Basal cankers on scarlet oak in North Carolina were more evident (10.7%) than bole cankers (1.4%). In Pennsylvania, the two symptom types occurred at approximately the same frequency (6.9% for basal cankers and 6.3% for bole cankers). A similar number of trees (1.7%) exhibited both types of *C. parasitica* cankers in North Carolina and Pennsylvania. The reasons for the higher incidence of basal cankers in North Carolina are unknown but could relate to differences in host or pathogen genetics, microclimate, stand structure, and stand history (e.g., fire), since all of these factors may influence infection by *C. parasitica*. As was observed in North Carolina (13), diseased scarlet oaks in Pennsylvania often occurred in clumps rather than as randomly scattered trees. This may be related to the factors just listed, such as pockets of susceptible host genotypes or virulent pathogens, and/or the presence of predisposing or wounding agents in local areas. B. L. Nash (*unpublished*) frequently observed carpenter ants in association with *C. parasitica* basal cankers. The relationship between these factors and basal cankers or clumping should be investigated.

Bole cankers appeared to be associated with branch stubs, and since scarlet oaks exhibit poor natural pruning (11), there also may be a relationship between branch pruning and subsequent infection. The only relationship between the incidence of infection by *C. parasitica* and tree size (diameter at breast height) or stand basal area was the possibility of a higher incidence associated with low basal area/poor pruning. In terms of canker severity, the incidence was distributed uniformly among the symptom classes. However, in most stands, there were slightly more cankers recorded as light to moderate than as severe.

We encourage researchers conducting similar surveys to utilize the orange pycnidial stroma as the most obvious sign of the fungus in the field. Mycelial fans also were apparent under the bark of infected scarlet oak trees in the field but should be sought only if other fungal signs are absent. Isolations should be conducted to confirm the presence of *C. parasitica* in those scarlet oak cankers showing no visible signs of the pathogen.

Growing the isolates on cornmeal indicated that *C. radicalis* was not present within the collection of isolates from scarlet oak. Although this test is not definitive, the result was not surprising, since *C. radicalis* has not been reported from the United States for 80 yr and was previously isolated from the buttress roots (3), which were not sampled in this survey.

Massive amounts of conidial ooze emanating from pycnidia located within bark crevices on declining or recently dead trees with no apparent external cankers were observed on six scarlet oaks in this study. These masses of spores were found in most of the bark crevices along the entire length and circumference of boles. Considerable inoculum is produced on these dead scarlet oaks, as compared to the relatively small amount of fruiting associated with cankers on living trees. These masses of oozing spores could be an important source of insect- or bird-disseminated inoculum.

These findings indicate that scarlet oaks infected with *C. parasitica* may be a significant source of inoculum for infecting scarlet oaks or American chestnut. This reservoir of inoculum in oaks should be considered when planning the use of biological control in American chestnut (1).

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