Expansion of Sooty-Bark and Ceratocystis Cankers on Aspen

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ABSTRACT

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Expansion of sooty-bark cankers, caused by *Encoelia pruinosa*, was measured on 143 aspen to predict years to tree mortality. The mean vertical expansion of 87 cankers was 44.9 ± 3.7 cm/yr. Cankers expanded circumferentially at a mean rate of 16.3 ± 0.7 cm/yr. Tree longevity can be predicted by dividing the circumference of the trunk not yet invaded by the canker by the horizontal expansion rate of the canker and adding 1 yr. *Ceratocystis fimbriata* seldom girdles a tree. The mean horizontal and vertical growth rates for 26 Ceratocystis cankers examined were 1.3 ± 0.2 and 2.8 ± 0.4 cm/yr.

Additional key words: *Cenagium singulare, Populus tremuloides*

More than half of the tree mortality in commercial aspen (*Populus tremuloides* Michx.) stands in Colorado is attributed to sooty-bark cankers (1,6). The pathogen, *Encoelia pruinosa* (Ell. & Everh.) Torkelson & Eckblad, is better known by the older name *Cenangium singulare* (Rehm.) Davidson & Cash. Sooty-bark canker (Fig. 1), so called for the black, sootlike residue left on the hands when handling the dead, black bark, is found in the western range of aspen from northern Mexico (F. G. Hawksworth, *personal communication*) into Canada and Alaska (4). This canker occurs on 1.1–2.4% of living aspen in Colorado stands (1,6); however, its occurrence on "high-value" trees in recreational areas is 5% (3). This greater incidence results from infection of trunk wounds caused by recreationists.

Because a cankered tree in a recreational area will eventually die and pose a hazard, information was needed on how long such trees will survive. The objective of this study was to determine rates of canker expansion and to identify factors that significantly affect this expansion so that predictions can be made as to how long trees with sooty-bark canker will survive.

An adjunct to this study was to determine the expansion rate of Ceratocystis cankers, caused by *Ceratocystis fimbriata* Ell. & Halst. (Fig. 2A), which are the most common cankers found in western aspen stands (2,3,6). Limited observations on young cankers (Fig. 2B) indicate a very slow rate of canker expansion (2), suggesting that expansion rate is of little importance in causing tree mortality.

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MATERIALS AND METHODS

In 1982 and 1983, 143 trees, each with a single sooty-bark canker measurable from the ground, were selected: 72 trees in 17 aspen stands in the Arapaho-Roosevelt and White River national forests in northern Colorado and 71 trees in 20 stands in the Rio Grande and San Juan national forests in southern Colorado and the adjacent Carson National Forest in northern New Mexico. Trees were not randomly selected but rather chosen to cover as wide a range of stand and tree categories as possible. Stand variables evaluated were location (northern vs. southern forests), structure (single, double, or multistoried), aspect (northeast, southeast, southwest, or northwest), and slope percent (0–5, 6–10, 11–15, or <15). Tree variables were diameter at breast height,

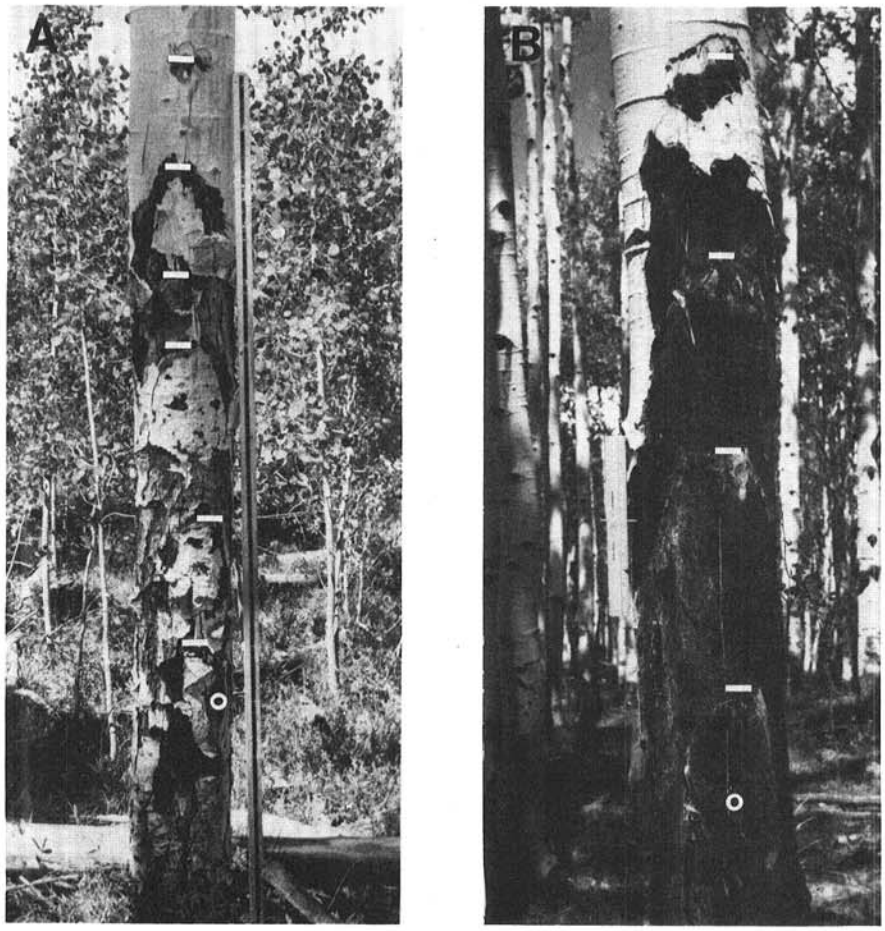

Fig. 1. Sooty-bark canker of aspen. **(A)** Six-year-old canker on dying tree in summer. Tree was 26.9 cm in diameter at point of infection (0) and was girdled within 5 yr. Annual vertical canker expansion indicated by white bars (pole = 2.4 m). **(B)** Four-year-old canker with dead bark removed to expose annual callus ridges. Scale is shown by 1-ft (30.5-cm) ruler attached to tree.

bark color (white vs. yellow), bark texture (smooth vs. bumpy), branch habit (branches in upper one-third vs. upper one-half of tree), pruning (self-pruning vs. branches retained), crown class (dominant, codominant, intermediate, or suppressed), crown density (dense, medium, or sparse), and tree condition (living, nongirdled; living, girdled in the present year; or dead, girdled the previous year). For each tree, canker age was determined by the number of annual callus ridges, and circumferential and vertical expansion measurements were taken from the initial point of trunk infection. For each independent variable, canker expansion differences among categories were tested with a one-way analysis of variance at $P = 0.05$.

Also examined were 13 Ceratocystis cankers in areas in the northern forests and 13 in four areas in the southern forests. Because of the small sample size, expansion differences among categories were not analyzed.

RESULTS

Sooty-bark canker. Canker age ranged from 2 to 7 yr, and tree diameters, from 10.9 to 43.9 cm. The sample trees were well distributed across most independent variables for both the northern and southern stands. Some exceptions were that southern stands contained fewer trees with branches limited to the upper one-half of the trunk than did northern stands, tree diameter classes were well represented for live trees but not for living-girdled or dead-girdled classes, and diameter classes were only well distributed in the northeast aspect.

The annual rate of circumferential expansion was greater in northern than in southern forests, but the largest variation occurred in the southern forests. The maximum rate of expansion was 30.5 cm/yr for a 3-yr-old canker on a 28.5-cm-diameter tree, and the minimum rate was 7.3 cm/yr for a 7-yr-old canker on a 34.0-cm-diameter tree in the southern forests.

The mean rate of circumferential canker expansion was 16.3 ± 0.7 cm/yr (mean ±95% confidence interval). Of the 12 stand and tree factors analyzed, only four showed significant differences in circumferential expansion categories: stand location, stand aspect, tree condition, and crown class (Table 1). The regression of circumferential horizontal expansion rate on tree diameter at breast height was significant but accounted for little variability in rate ($r^2 = 0.03$). Similarly, the relationship between the rate of expansion and the combination of canker age and trunk circumference at point of infection was significant but had a low r^2 (0.14).

The mean rate of vertical expansion of cankers above the point of trunk infection (135 cankers) was 25.9 ± 1.9 cm/yr. Stand location, stand structure, tree condition, bark color, pruning, branch habit, and crown density were significantly related to rate of upward canker expansion. Living, self-pruning, white bark trees of good crown density with branches in the upper one-third, in single-story stands of southern forests had smaller rates of canker expansion. The mean rate of vertical expansion below the point of infection was 21.6 ± 1.9 cm/yr for 87 cankers that had not reached ground level. Downward expansion varied significantly in relation to stand structure, tree condition, bark color, and crown density. Living trees with white bark and good crown density in single-story stands had lower rates of canker expansion.

The total mean vertical expansion of the 87 cankers was 44.9 ± 3.7 cm/yr. Stand location and structure, tree condition, bark color, pruning, branch habit, and crown density significantly influenced total expansion (Table 2).

Ceratocystis canker. Canker ages ranged from 10 to 38 yr, and tree diameters, from 9.7 to 33.3 cm. The small sample precluded testing for differences among categories of stand and tree variables. The mean rate of horizontal expansion for 26 cankers was 1.3 ± 0.2 cm/yr. There was a significant difference in rate of expansion between the northern and southern forests; however, this was confounded by canker age. The average canker age in northern forests was 17 yr compared with 25 yr for southern forests. For cankers 10–20 yr old, the mean annual rate of circumferential expansion was 1.5 ± 0.3 cm vs. 1.0 ± 0.2 cm for cankers 21–38 yr old.

The mean rate of vertical canker expansion for 24 cankers was 2.8 ± 0.4 cm/yr. Again, there was a difference in

Table 1. Mean annual rate of circumferential expansion of sooty-bark canker on aspen as affected by stand and tree characteristics

Characteristics	Trees (no.)	Mean[y,z] (cm)
Location		
North	72	17.0 ± 1.0 a
South	71	15.6 ± 0.9 b
Aspect		
Northeast	18	18.0± 2.3 a
Southeast	48	16.6 ± 1.1 ab
Northwest	21	14.0 ± 2.4 b
Southwest	56	16.4 ± 0.9 ab
Tree condition		
Live	93	15.7 ± 0.7 a
Live-girdled	29	17.9 ± 1.5 b
Dead-girdled	21	17.0 ± 2.4 ab
Crown class		
Dominant	22	18.3 ± 2.1 a
Codominant	47	16.0 ± 1.2 ab
Intermediate	54	16.3 ± 1.0 ab
Suppressed	20	14.8 ± 1.5 b
Total	143	16.3 ± 0.7

[y] Mean ± 95% confidence interval.
[z] Means within a category followed by the same letter are not significantly different at $P = 0.05$ as tested by a Bonferroni t test.

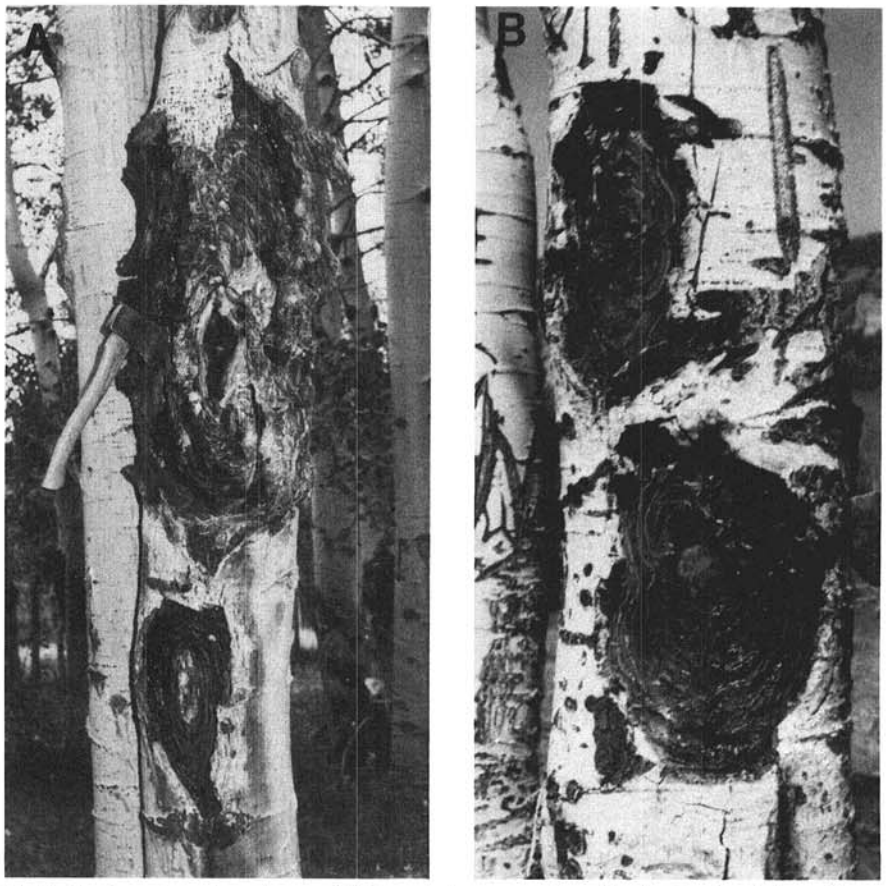

Fig. 2. Ceratocystis canker of aspen. **(A)** Twenty-four-year-old canker (bottom) and about 59-yr-old canker on 83-yr-old tree. **(B)** Twelve-year-old cankers that originated at trunk wounds.

Table 2. Mean annual rate of total vertical expansion of sooty-bark canker on aspen as affected by stand and tree characteristics

Characteristics	Trees (no.)	Mean[y,z] (cm)
Location		
North	40	49.4 ± 7.1 a
South	47	41.2 ± 3.1 b
Stand structure		
Single-story	61	42.5 ± 4.1 a
Two-story	18	42.5 ± 5.3 a
Multistory	8	69.3 ± 19.9 b
Tree condition		
Live	65	39.7 ± 3.0 a
Live-girdled	15	60.9 ± 12.1 b
Dead-girdled	7	59.1 ± 20.6 b
Bark color		
White	56	39.1 ± 3.1 a
Yellow	31	55.5 ± 7.8 b
Pruning		
Self-pruning	58	41.2 ± 3.9 a
Retention	29	52.4 ± 7.7 b
Branch habit		
Upper one-third	73	43.1 ± 3.4 a
Upper one-half	14	54.9 ± 15.2 b
Crown density		
Good	44	40.2 ± 4.9 a
Medium	26	48.0 ± 6.8 ab
Poor	17	52.6 ± 9.9 b
Total	87	44.9 ± 3.7

[y]Mean ± 95% confidence interval.
[z]Means within a category followed by the same letter are not significantly different at $P = 0.05$ as tested by a Bonferroni t test.

rate of expansion between the northern and southern forests as related to canker age. The mean annual rate of vertical expansion was 3.0 ± 0.6 cm for cankers 10–20 yr old and 2.5 ± 0.6 cm for cankers 21–38 yr old.

DISCUSSION

Sooty-bark canker. The sample trees were selected to cover a wide range of tree and site factors to capture the variability of canker expansion. Stratification by site and tree factors did not materially account for the variability. Although canker expansion was significantly related to a few stand and tree variables, the regression equations were poor predictors. Since no variable accounted for a useful amount of the variation, the mean horizontal expansion of 16.3 ± 0.7 cm/yr is recommended for estimating the number of years to trunk girdling by sooty-bark canker.

Because canker growth is continuous throughout the year (5), a trunk can be girdled at any time. Trunk girdling by sooty-bark canker occurs within several years of infection, but tree mortality can occur the following year. A tree girdled during the dormant season may still produce leaves and be considered alive the following spring (Fig. 1A). Thus, 1 yr should be added to the prediction of girdling from the mean rate of horizontal expansion. This gives a simple method of estimating years until tree death: divide the circumference of uninfected trunk at the midpoint of the canker by 16.3 cm/yr and add 1 yr.

The projected years to trunk girdling as predicted on the basis of continued girdling at the present rate for each of the 93 living trees were compared with the projection from the average rate of 16.3 cm/yr. The two projections agreed within ±1 yr for 73% of the cankers. When canker expansion on nongirdled trees proceeds slower than the mean rate (Table 1), the factor of 16.3 cm/yr will give a slight underestimation of the longevity of nongirdled trees. This is the preferred direction of error for management of trees in recreational areas. This method is also much easier to apply than estimating the expansion rate for each canker.

The equation predicts the year of death for a tree infected with a single canker. For trees infected with multiple cankers, the equation should be applied to the largest canker. However, multiple cankers are not common, and single cankers are most commonly occur on lower tree trunks that have been exposed to wounds. These wounds more often occur in or near recreational areas.

There was considerable variation in rates of canker expansion above and below the point of infection as well as in total vertical expansion. Annual expansion is occasionally halted by callus for 1 or 2 yr along portions of the canker perimeter; however, the fungus eventually penetrates the callus or spreads around it, and canker expansion resumes. The resulting cankers may be odd in shape. That is, a canker on a live tree may extend vertically for 3 or 4 m when the infection is callused along the sides and only 1 m or less when callused along the top and/or bottom. Cankers partially callused on the side were excluded from this study. Cankers completely surrounded by callus were not observed; thus, trees rarely if ever survive this disease.

The maximum annual rate of vertical canker expansion above the point of infection was 48.6 cm and the minimum was 10.4 cm, both for 5-yr-old cankers. The maximum annual downward rate of expansion was 45.1 cm for a 2-yr-old canker, and the minimum was 6.7 cm for a 4-yr-old canker. Total vertical canker expansion varied from 79.2 cm for a 4-yr-old canker to 289.6 cm for a 3-yr-old canker. The elliptical shape of young cankers, as seen on larger tree trunks, results because the vertical expansion rate is about three times the horizontal expansion rate.

Ceratocystis canker. Trunk circumference growth is usually greater than Ceratocystis canker expansion. The fungus is frequently quiescent or halted by callus around some portions of the canker perimeter, causing a somewhat ragged, elliptical shape with flaring, dead bark on older cankers. Canker ages of 40–60 yr are not uncommon; however, the large callus tissues and flaring dead bark around the canker perimeter preclude circumference measurements for rate of expansion (Fig. 2A). The annual expansion in width and total height of this canker averaged 2.0 and 7.3 cm, respectively, after 2 yr but decreased to 1.9 and 4.6 cm, respectively, 6 yr after inoculations with the fungus (2). Decreasing expansion rates may continue. The mean annual width and height growth amounted to 1.5 and 3.0 cm, respectively, for 10- to 20-yr-old cankers and 1.0 and 2.5 cm, respectively, for the 21- to 38-yr-old cankers measured in this study.

The diminishing mean rate of canker expansion may reflect intermittent expansion of older cankers. Expansion of an older canker often stops and callus begins to cover the affected area, but the infection recurs around certain portions of the callused perimeter. For this reason, many infections with their slow rate of spread are erroneously considered slowly callusing wounds. The canker width-to-height ratio was about 1:2 for cankers in this study; however, they originated at a point source of infection. *Ceratocystis* infection occurs at fresh trunk wounds (2), and the subsequent cankers may not be elliptical in shape but may follow the irregular perimeter of the wound.

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