Relationship Between Year of Infection, Tree Age, Tree Growth, and Nectria Canker of Black Walnut in Michigan

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ABSTRACT

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The occurrence of Nectria canker, caused by *Nectria galligena*, on black walnut trees (*Juglans nigra*) was studied in a mixed hardwood plantation established during 1945–1946 in southwestern Michigan. Diameter at breast height (dbh), number of cankers on the trunk from 0.3 to 3.7 m above ground, and canker shape (open or closed) were recorded for 2,718 trees. The number of cankers per tree was not correlated with dbh or canker shape ($r = 0.23$). Seven infected and four noninfected trees were harvested to determine tree growth rates. Chronological year and age of trunk section at the time of infection were determined for 200 cankers dissected from the seven infected trees. The number of infections per year (1961–1983) increased from 1961 to 1979, with peak infection years from 1978 to 1980. Most trunk sections were 19–27 yr old when first infected, with peak infection ages at 22 and 24 yr. Tree growth rate was 30% less for black walnut trees with Nectria cankers than for healthy trees ($P < 0.01$).

Nectria canker, caused by *Nectria galligena* Bres., is a serious disease of black walnut (*Juglans nigra* L.) in some stands in southwestern Michigan (12). *N. galligena* attacks a tree through a wound, usually a wound associated with a branch crotch or branch stub (4,5,7). However, preliminary field observations in southwestern Michigan indicated that new cankers were forming on trunks of mature trees where no obvious injury had occurred.

Others report that Nectria canker occurs on young hardwoods 2–20 yr old (2,8). Yet in Michigan, 100-yr-old black walnut trees have new cankers at various heights along the trunk. Kress and Wood (6) postulated that the age of the stem tissue was more important than the age of the tree for Nectria canker of sassafrass (*Sassafras albidum* (Nutt.) Nees.). They also reported peak years of canker initiation.

This study was initiated to determine 1) the ages of trunk or stem sections when infected and chronological years of highest infection levels, 2) the wound type, if any, associated with Nectria canker on black walnut, and 3) the impact of Nectria canker on black walnut growth. A preliminary report of this study has been published (11).

MATERIALS AND METHODS

The occurrence of Nectria canker on black walnut was studied in a mixed hardwood plantation established during 1945–1946 at Russ Forest, 14 km east of Cassapolis, MI. The stand consisted of black walnut planted every fourth row in an east-west direction, with rows of red oak (*Quercus rubra* L.), tulip poplar (*Liriodendron tulipifera* L.) or ash (*Fraxinus* spp.), and black cherry (*Prunus serotina* Ehrh.) interspersed. In every instance, black cherry was in the row to the south and red oak or ash was in the row to the north of a black walnut row. Diameter at breast height (dbh), number of cankers on the trunk between 0.3 and 3.7 m above ground, and whether cankers were predominantly open or closed were recorded for all 2,718 black walnuts in the stand. Cankers were considered open if three or more callus layers were visible on the trunk's exterior (Figs. 1 and 2). Cankers were termed closed if one or two callus layers were visible (Figs. 3 and 4). Because of the perennial nature of the disease, it is doubtful whether a Nectria canker can be completely closed over by the the host.

Eleven black walnut trees, 15 cm dbh or larger within 122 m of each other, were cut from the Russ Forest plantation in 1984. Two hundred cankers were dissected from the seven infected trees. The number of rings from the pith to the first infected ring was recorded to determine the age of the stem section at the time of infection (Fig. 2). The number of rings from the bark to the first infected ring was used to determine the year of infection (Fig. 2). The type of wound

Fig. 1. Open Nectria cankers on a black walnut trunk in southwestern Michigan.

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(branch stub, insect wound, or none) and the canker shape (open or closed) were recorded as well. Cankers were inspected for evidence of insects. The relationship between the date of insect injury and the time of canker development was determined on the basis of spatial locations of each. For example, if insect evidence was present within the canker, it was assumed that insects were secondary to cankering.

The relationship between Nectria canker and black walnut growth rate was evaluated. The number of tree rings in the inner 1 cm of the cross section were recorded for the widest and narrowest directions, because infected stems were often asymmetric. Similar measurements were recorded for tree rings in the outer 1 cm (Fig. 2). Preliminary tests indicated that 1 cm provided a sufficient measure of growth rate differences. The values were used to obtain a mean growth rate before (inner) and after (outer) infection. The four noninfected trees were used as controls. The same measurements were recorded for the top, middle, and bottom portions of each noninfected tree (one observation per portion). The difference in growth rate before and after infection was calculated as [1 − (mean no. rings in inner 1 cm/mean no. rings in outer 1 cm) × 100] = percent reduction in growth rate for each canker or noninfected portion, to account for differences in initial growth rates of individual trees. Current age of stem for each canker or noninfected portion also was recorded.

RESULTS

Of 2,718 black walnut trees measured at Russ Forest, 592 were infected. Of the infected trees, 200 predominantly supported open cankers, whereas cankers on the remaining 392 mostly were closed. Observed canker number on infected trees ranged from one to 51 ($x = 5.8 \pm 6.3$). Tree dbh for all trees (including noninfected) ranged from 3 to 40 cm ($x = 15.2 \pm 5.8$ cm). A multiple linear stepwise addition regression was done using only infected trees. This eliminated any genetically resistant or escape trees. Canker shape and tree dbh were used as independent variables, with canker number as the dependent variable. Dbh and presence of closed cankers were positively related to canker number ($P < 0.0005$) but explained only a small portion of the variability ($r^2 = 0.05$). Open cankers were not correlated with canker number ($P = 0.05$).

There was a onefold to fivefold difference in actual canker number compared with observed canker number (Table 1). This partially was because of poor visibility of higher portions of the tree but mainly because many closed cankers were not visible before dissection.

All cankers were initiated after 1960. Peak years of infection were 1978–1980 (Fig. 5). There was a higher frequency of infection for black walnut stem sections 19–27 yr old than other ages, with peak infection years at 22 and 24 yr (Fig. 6). Of the 200 cankers dissected, 9.5% were open cankers. The initiation of open cankers was uniformly distributed throughout the ranges of stem age and year of infection, with one or two open cankers initiated each year or at each age. Therefore, the increase in disease incidence primarily was due to the increase in closed canker occurrence.

Thirty-one percent of the cankers were associated with branch stubs (25% closed cankers, 6% open cankers). One open canker (0.5%) was associated with a wound from a boring insect. There was no apparent wound associated with infection for 68.5% of the cankers (65.5% closed, 3% open). Secondary flat-headed borers and ants were observed in 3.5 and 1.0% of the cankers, respectively. They

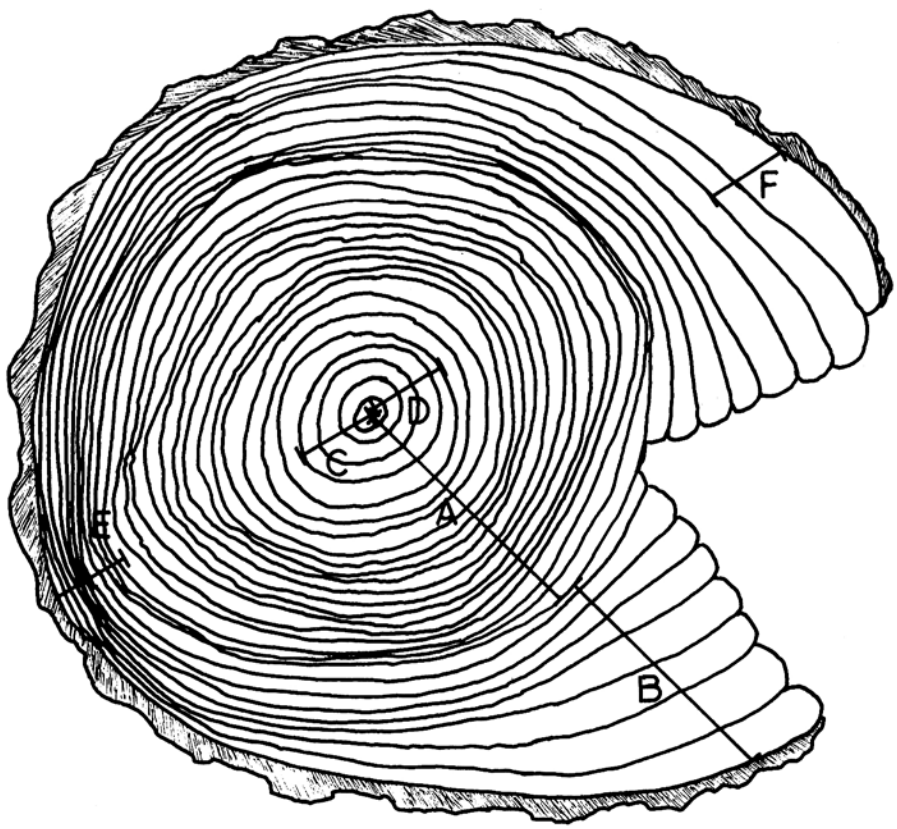

Fig. 2. Schematic diagram of a typical open Nectria canker cross section illustrating measurements used in this study. A = Number of tree rings from pith to first infected ring to determine age of stem section at time of infection. B = Number of rings from first infected ring to bark to determine year of infection. C = Number of rings in inner 1 cm at narrowest direction and D = at widest direction. E = Number of rings in outer 1 cm at narrowest direction and F = at widest direction. C–F were used for percent reduction in growth rate measurements. (C + D)/2 = mean number of rings per inner 1 cm and (E + F)/2 = mean number of rings per outer 1 cm. A + B = current age of stem section.

Fig. 3. Closed Nectria cankers on a black walnut trunk in southwestern Michigan.

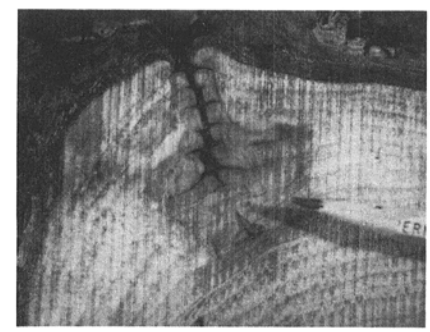

Fig. 4. Cross section of a closed Nectria canker on a black walnut trunk in southwestern Michigan.

were all associated with open cankers.

Differences in preinoculation and postinfection growth rates were not correlated with the current age of the stem section for the 200 cankers and the 12 portions of the noninfected trees (r = 0.26, P = 0.001) in a linear regression analysis. Thus data were pooled for each tree. There was a reduction in growth rate of healthy and infected trees as they became older. Black walnut infected with Nectria canker had a greater percent reduction in growth rate ($\bar{x}$ = 51.39%, n = 200) than did noninfected black walnut ($\bar{x}$ = 36.12%, n = 12) according to the GT2 test (P = 0.05), a conservative test for designs with unequal replications (10). The individual trees also had a significant effect on percent reduction in growth rate (Table 2). Percent reductions in growth rates were similar for open and closed cankers ($\bar{x}$ = 51.29 ± 15.05% and $\bar{x}$ = 52.84 ± 9.46%, respectively).

DISCUSSION

In this study, black walnut vigor, measured as dbh or canker shape, was not correlated with the number of cankers per tree. In another study of other hosts, dbh was not correlated with canker number but was correlated with size of canker (7). Diameter was positively correlated with number of cankers for oaks (*Quercus* sp.) and birches (*Betula* sp.) but negatively correlated with Nectria canker number for maples (*Acer* spp. [5]). Grant and Childs (3) found the opposite was true for maples and birches, that dbh was positively correlated to Nectria canker number. However, these studies were not done on even-aged stands and may reflect differences other than tree vigor. Tulip poplar with closed cankers increased dbh and basal area more quickly than trees with open cankers, but there was no relationship between rate of closing and rate of increase of basal area (9).

Most of the Nectria cankers on any one black walnut were predominantly open or were predominantly closed. Whether a tree has open or closed cankers may depend on an individual tree's vigor and defense mechanisms. Canker shape also could be influenced by pathogen virulence. Any or all of these factors could be responsible for differences in the types of cankers observed.

In the Russ Forest plantation, Nectria canker infection was greatest on black walnut in the late 1970s. Most of these cankers were of the closed type. Sections from tree stems between the ages of 22 and 24 yr had higher levels of infection. The average age of tree sections examined was 30 yr, but all trees were planted in 1945, 40 yr ago. Therefore, it was about 10 yr after planting before the trees were at the height of the sections sampled. The year with highest infection level was 1978. Years of high canker infection could be due to 1) favorable environmental factors during certain years or 2) especially susceptible host ages, because all of the black walnut trees in the plantation were the same age. The increase in the number of infections from 1960 to 1980 may be due to factors other than an increase in inoculum potential over time, because infection levels decreased after 1980.

Merrill and Finley (8) reported susceptible ages for Nectria canker on black walnut in Pennsylvania, with most infections occurring before tree sections were 5 yr old. Differences in the results of this study could be explained by the suggestion that the environment influences the occurrence of disease. Merrill and Finley postulated that 5 yr was the age at which branches became shaded. After infection of shaded branches, branch cankers could have extended down the branch to the trunk as the branches died.

Table 1. Summary of Nectria canker data for black walnut trees collected in 1984 from a mixed hardwood plantation in southwest Michigan

Tree no.	Diameter at breast height (cm)[a]	No. externally apparent cankers[a]	Predominant canker shape[a]	No. cankers dissected[b]
1	20.1	8	Closed	13[c]
2	21.1	13	Open	14[c]
3	15.2	8	Open	24
4	22.4	11	Closed	13
5	22.4	21	Closed	60
6	22.6	7	Open	30[c]
7	18.3	9	Closed	46[c]
Mean (1–7)	20.3	11	···	29
8	28.7	0	···	0
9	19.3	0	···	0
10	17.8	0	···	0
11	21.6	0	···	0
Mean (8–11)	21.9	0	···	0

[a] From field observations October 1983. Cankers were open if three or more callus layers were observed on the tree's exterior. Cankers were closed if one or two callus layers were observed.
[b] The number of cankers dissected is greater than the number of externally visible cankers because of the presence of closed cankers that were not detected from the outside of the tree, particularly in the upper levels of the tree.
[c] Not all cankers from the tree were dissected.

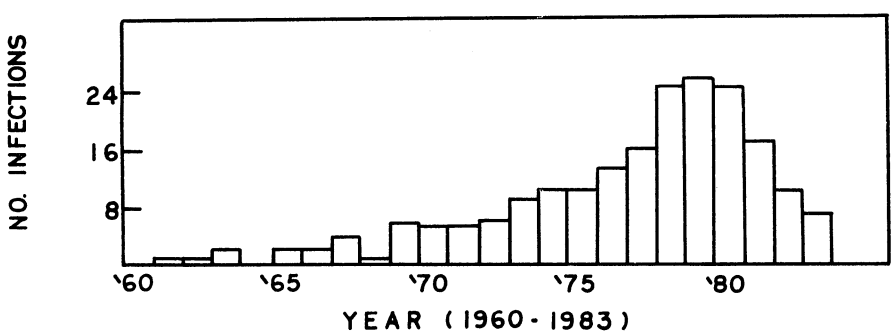

Fig. 5. Frequency of year of infection for 200 Nectria cankers from seven black walnut trees collected at Russ Forest in southwestern Michigan. No cankers were initiated before 1961.

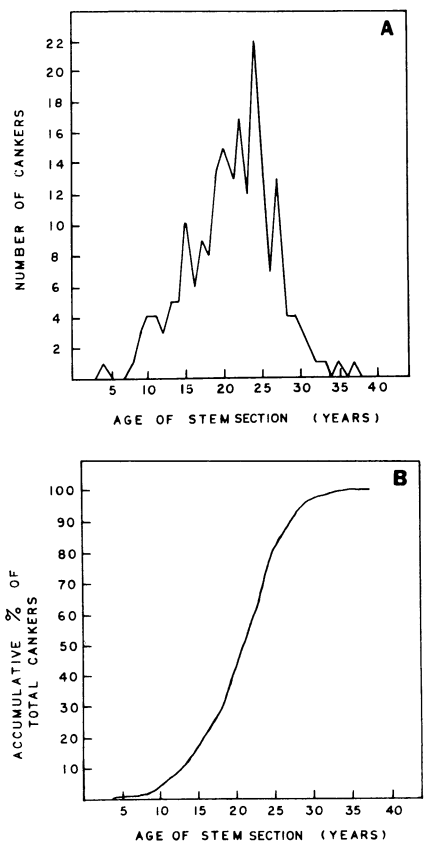

Fig. 6. Relationsip between age of black walnut stem sections at infection and **(A)** frequency of Nectria canker infection; **(B)** accumulative percentage of total Nectria canker infection for 200 cankers from seven trees.

Table 2. Analysis of variance table for percent reduction in growth rate over time of diseased and healthy black walnut (current stem section ages pooled)[a]

	Analysis of variance			
Source	**DF**	**SS**	**MS**	***F***
Canker	1	2,641.21	2,641.21	15.04***
Tree number	9	10,395.30	1,155.03	6.58***
Error	201	35,287.75	175.56	...
Corrected total	211	48,324.27	...	...

[a]*** = Significance of $P<0.0001$.

They studied shade-tolerant and shade-intolerant species and attributed black walnut's early age of infection to its shade intolerance.

This study indicates that other environmental factors are more important than the age of shading of the tree, because lower limbs were probably shaded before the trees were 23 yr old and most cankers were not associated with branch crotches or stubs. Environmental factors occurring in cold pockets were associated with Nectria canker incidence on black walnut in a previous study (12).

Some workers have reported that 54–100% of dissected Nectria cankers were associated with branch stubs or crotches (5–7). These studies also described cankers associated with dormant buds, stem wounds, borer injury, wounds from snow, wind and frost cracks, and rubbing injuries. Grant and Spaulding (4) found that 29% of dissected Nectria cankers were associated with dead branch stubs, 27% with dead branch remnants, and 15% with axils of living branches. They stated that usually infection of branches greater than 1.2 cm in diameter near the crotch resulted in cankers. When branches less than 1.2 cm in diameter were infected near the crotch, the branch died and no canker resulted.

We have made no effort to separate dead branch stubs and remnants from living branches or to separate branches by size. However, only 31% of the cankers were associated with branch crotches or stubs. This is lower than values from other studies. Many of the hard-to-see closed cankers showed no apparent wound but may have been initiated from minute branch traces or insect wounds. In Ashcroft's study (1) of Nectria canker on black walnut, branch stubs or crotches were associated with some cankers. Still other cankers were not associated with branch stubs but instead started from a swelling and cracking of the bark. This also may be the case in Michigan.

In our study, Nectria canker reduced diameter growth rates by 30% in black walnut. However, dbh was not correlated with the number of cankers. Whether or not a tree is infected may be more important to growth reduction than the number of cankers on a tree. Other factors also may influence dbh more than Nectria canker, when the entire plantation is considered. A comparison of tree dbh may be a more accurate measure of the effect of Nectria canker on tree growth rate than a comparison of tree diameters at the canker site, because many variables enter into ring size at the canker site (i.e., available host reserves near the canker). Because the dbh of each black walnut tree at the Russ Forest plantation was recorded, future research will include remeasurements of dbh to determine diameter growth rates for infected and noninfected trees over time.

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