Site Factors Associated with Nectria Canker on Black Walnut in Michigan

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ABSTRACT

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More than 75% of the black walnut trees (*Juglans nigra*) in some stands in southwestern Michigan have multiple cankers caused by *Nectria galligena*. A five-county survey of 189 survey sites indicated that high Nectria canker incidence was associated with terminal moraines and till plains and was especially more prevalent on black walnut trees growing near wetlands, kettles, or depressions than on trees growing on uplands ($P < 0.01$). Such lowland sites were more common on the till plains and moraines. Soil type, topography, and surface geology were characterized at 30 of the survey sites. Soil texture, rooting depth, and drainage features were not significant to disease incidence but some surface geology and topographic features were.

Some black walnut stands (*Juglans nigra* L.) in a five-county area of southwestern Michigan have a high incidence of Nectria canker, caused by *Nectria galligena* Bres. Although an occasional Nectria canker on black walnut is common, the situation in southwestern Michigan may be unique. In some stands, almost every tree is affected, usually with multiple cankers. When Nectria canker is present, it reduces the timber and veneer value of infected trees. Because of the premium prices black walnut wood commands, this disease may cause a substantial loss to some landowners in southwestern Michigan. A similar situation exists in central Pennsylvania as well (12).

Preliminary field observations indicated that the disease was persistent in southwestern Michigan for a period of years and did not seem to be spreading to adjacent areas. Nectria canker of hardwoods has been associated with less vigorous trees growing on shallow, poorly drained, infertile soils (2,3,9). Sites in regions of frequent snow and ice storms or at high elevations also may be severely infected (2,3,6,13). Yellow birch (*Betula alleghaniensis* Britton) growing in stands within 5 mi. of Lakes Michigan and Superior in Michigan's upper peninsula had a higher incidence of Nectria canker than yellow birch growing farther inland (1).

Although *N. galligena* is reported as a serious pathogen of black walnut in many states including West Virginia, North Carolina, Georgia, Tennessee (7), Michigan, Pennsylvania (12), Wisconsin, and Rhode Island and the province of Ontario (2), only one study has been published concerning Nectria canker on black walnut (2). Ashcroft (2) did a general county survey of Nectria canker on black walnut in West Virginia; however, his work primarily was

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concerned with fungal taxonomy, host range, and histopathology of the disease and host rather than with epidemiology and ecology.

The purpose of this study was to determine the geographic extent of Nectria canker on black walnut in southwestern Michigan and to quantify the association of site factors with the disease. A preliminary report of this study has been published (16).

MATERIALS AND METHODS

To determine the incidence of Nectria canker on black walnut, a survey was conducted in five counties in southwestern Michigan during 1983 and 1984. Transects were established at 4.8-km intervals from north to south and from east to west for Berrien, Cass, St. Joseph, Kalamazoo, and Van Buren counties. Each stand (10 or more black walnuts) closest to each intersection of the north-south and east-west transect lines was identified by county, township, section, quarter section, and stand number (in case of more than one observation per quarter section), and the locations were recorded on township plat maps. The survey started at Russ Forest, a known area of high disease incidence, and was continued outward in all directions until a one-township-wide border consisting of low Nectria incidence surrounded the surveyed area. Low Nectria incidence exists when <6% of the black walnut in a stand are infected with *N. galligena*. The number of hectares in the stand, tree diameter at breast height (dbh) (pole = <36 cm dbh, mature = >36 cm dbh), site wetness (wet or drained), and origin (roadside, forest, or plantation trees) of each stand also were recorded. Disease distribution within each stand (local, spotty, or general) was recorded at each site.

The percentage of the black walnut trees infected was recorded for each stand according to the scale 0 = no infection, 1 = 1–5%, 2 = 6–15%, 3 = 16–25%, 4 = 26–50%, 5 = 51–75%, and 6 = >75%. Basal area (square meters per hectare) was recorded for each site.

To determine the variability in distribution of disease within a more local area, Volinia Township in Cass County was surveyed intensively during 1983. The survey was conducted by driving all roads in the township and recording the information mentioned above for all black walnut stands located. Occasional yard trees or roadside trees were ignored unless there were more than five at a site. All woodlots were surveyed on foot if black walnut was observed growing at the edge of the stand. The regional survey contained 149 sites. Forty additional sites were located in the Volinia Township survey, resulting in a total of 189 observations.

Elevation above sea level and approximate depth to the water table were recorded from quadrangle topographic

Table 1. Relationship of soil and topographic features of 30 black walnut stands in southwestern Michigan to Nectria canker disease incidence

Disease ratings[a]	Macrorelief index[b]	Microrelief[c]	Presence of wetlands[d]	Microsite topographic position[e]	Glacial mode of deposition[f]	Texture of C horizon[g]
0	0.8	Flat	−	TF	OTWS, NP	S
0	0.8	Flat	−	TF	OTWS, NP	S
0	1.8	Flat	+	TF	OTWS, NP	S
0	2.0	Flat	−	TF	OTWS, NP	S
0	3.5	Flat	+	BF	OTWS, NP	GSC
0	8.0	Flat	−	MS	OTWS, P	S
0	9.3	Flat	+	LS	DEPM	SC
1	2.0	Flat	−	US	TLPL, P	GS
1	3.0	Flat	−	US	OTWS, T	GS
1	3.5	Flat	−	LS	KM	GSL
1	3.8	Rolling	+	TF	TLPL	S
1	5.3	Rolling	+	BF	TLPL	SC
1	5.5	Rolling	−	MS	OTWS, P	SC
1	5.5	Rolling	−	MS	OTWS, T	SL
1	7.3	Rolling	−	BF	DEPM	C
1	8.0	Rolling	−	US	TLPL, T	GLS
1	8.5	Rolling	−	LS	TLPL	S
1	8.5	Rolling	−	US	TLPL	GS
1	11.0	Rolling	−	US	OTWS, P	GS
1	11.8	Rolling	−	TF	TLPL	
6	2.0	Flat	+	BF	OTWS, NP	GS
6	3.0	Flat	+	BF	OTWS, NP	GS
6	3.0	Flat	+	BF	OTWS, NP	S
6	6.5	Steep	+	BF	OTWS, KL	GSC
6	8.5	Steep	+	MS	STMR, KL	GS
6	8.8	Steep	−	MS	TLPL	
6	10.3	Steep	+	LS	STMR, KL	SIC
6	12.5	Steep	−	US	STMR	GSC
6	12.8	Steep	−	MS	OTWS, KL	GS
6	18.0	Steep	−	BF	OTWS, KL	SC
P =	0.04[h]	0.0005	0.08	0.06	0.02	0.02
R^2 =	0.15					

[a] Disease rating was based on percent infection of Nectria canker on black walnut in the stand: 0 = none, 1 = 1–5%, 2 = 6–15%, 3 = 16–25%, 4 = 26–50%, 5 = 51–75%, and 6 = >75%.

[b] Relief index was calculated as the average of four values obtained by counting 6.1-m contour lines encountered along 2-km grid lines drawn from the stand to the north, east, south, and west.

[c] Sites were chosen on the basis of 10 apparently flat with low disease, 10 apparently rolling with low disease, and 10 with high disease levels.

[d] Locations were considered to have wetlands present if they were within 200 m of at least 0.4 ha of standing or slowly moving water and at elevations similar (±3 m) to that water.

[e] TF = top flat, US = upper slope, MS = middle slope, LS = lower slope, and BF = bottom flat.

[f] OTWS = outwash, DEPM = moraine associated deposition of eroded material, TLPL = till plain, STMR = Sturgis Terminal Moraine, P = pitted, NP = not pitted, T = top bank of creek, KL = kettle, and KM = Kame.

[g] S = sand(y), G = gravelly, C = clay, L = loam(y), and SI = silty.

[h] Qualitative variables were analyzed by χ^2 contingency tests. Quantiative variables were analyzed by linear regression. Disease rating was the dependent variable for all analyses.

maps for each site. Approximate depth to the water table was determined by calculating the difference in elevation of the site compared with elevation of nearby lakes, ponds, or rivers, because such water bodies were abundant in this region. Surface geology of each site was examined using field quadrangle maps available from the Michigan Geological Survey in Lansing (11).

Using field notes and topographic quadrangle maps, we classified each of the 189 survey sites in the five county area as an upland, wetland, kettle, or depression to determine the relationship between cold pockets and disease incidence. A site was considered upland if it was not a kettle, a depression, or adjacent to a wetland.

While recording elevation values for the five-county survey from topographic maps, we noticed that some of the most severely diseased stands were in very hilly areas. Therefore, soil profiles, surface geology, aspect, drainage class topography, and parent material were investigated at 30 of the survey sites. The 30 sites were selected as follows from sites described in the five-county survey. Ten of these sites were randomly selected from survey locations where >75% of the black walnut trees were infected with *N. galligena*. Another 10 sites were randomly selected from survey locations on flat microrelief and where <6% of the black walnut trees were infected. The final 10 sites were randomly selected from survey locations on rolling microrelief where <6% of the black walnut trees were infected. Microrelief was determined from quadrangle topographic maps.

Soils were characterized at the 30 sites by horizon depth, structure, consistency, color, texture, and the presence of gravel, boulders, clay skins, mottles, and other distinguishing features. Depth to water table was recorded when possible. Qualitative variables were analyzed by a χ^2 contingency test. Quantitative variables were analyzed by a one-way linear regression. In each instance, the surface soil layers were sampled by digging a pit about 0.5 m deep. Subsoil and parent material were sampled as deep as 4.5 m with a 7.6-cm bucket auger. In some instances, subsurface horizons could not be penetrated with a bucket auger because of massive structure or a high density of large cobbles and boulders and therefore were not sampled.

To determine which of the topography and surface geology variables in Table 1 are most important in predicting disease levels, a stepwise addition discriminant analysis procedure (BMDP program 7M) was employed. Disease rating and microrelief were combined to describe three location types (low disease incidence at flat sites, low disease incidence at rolling sites, and abundant disease incidence). Qualitative variables were recoded as a 0 or 1 to meet the requirements of discriminant analysis. Codes were based on the results of χ^2 contingency analyses published elsewhere (15).

RESULTS

The regional and local survey locations and disease incidences are illustrated in Figures 1 and 2. Data collected from the surveys were analyzed in a multiple linear stepwise addition regression. Site wetness, stand dbh, and elevation (186–314 m, $\bar{x}$ = 260 m) were correlated with the percentage of black walnut trees with Nectria canker (r = 0.59, P < 0.0005). Nectria canker was more severe in sites at higher elevations, in wet sites, and/or in mature stands. A stepwise deletion regression resulted in the same regression equation. Depth to water table (2–42 m, $\bar{x}$ = 8 m), stand origin (0 = roadside, 1 = forest or plantation), and basal area (3–32 m^2/ha, $\bar{x}$ = 9 m^2/ha) were not correlated with disease levels (P = 0.05).

The relationship of disease abundance

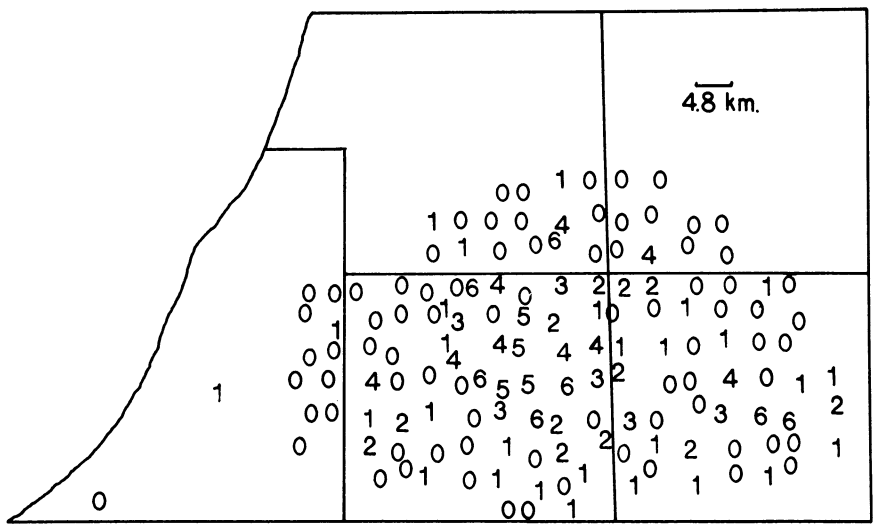

Fig. 1. Locations of the regional survey sites for Nectria canker on black walnuts in southwestern Michigan. Each value represents one stand of black walnut and indicates percentage of black walnut trees in the stand that were infected: 0 = none, 1 = 1–5%, 2 = 6–15%, 3 = 16–25%, 4 = 26–50%, 5 = 51–75%, and 6 = >75%. Solid lines represent boundaries of Kalamazoo, Cass, St. Joseph, Van Buren, and Berien counties.

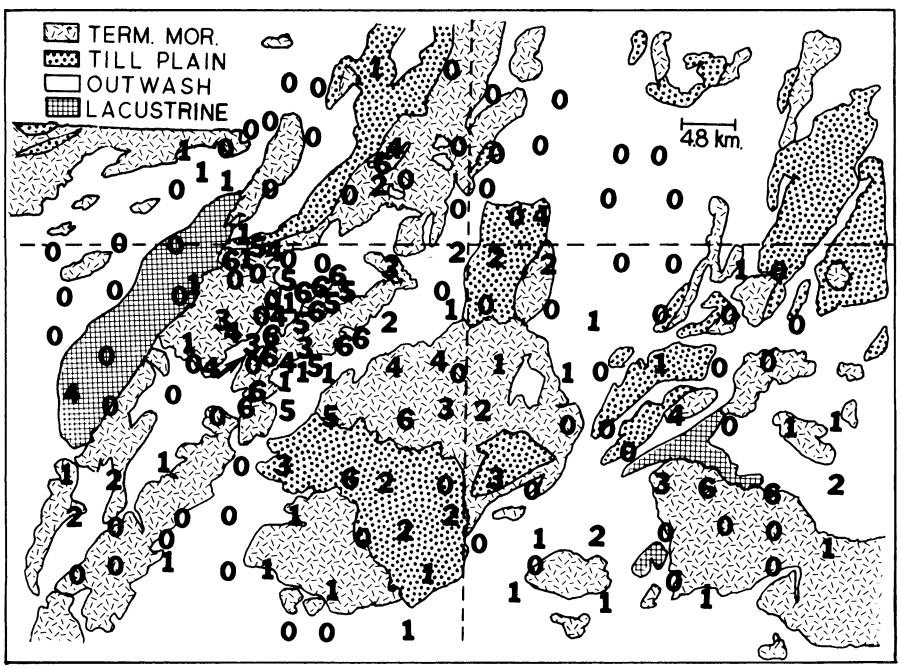

Fig. 2. Relationship of Nectria canker on black walnut to surface geology of Kalamazoo, Van Buren, Cass, and St. Joseph counties in southwestern Michigan. Each value represents one stand of black walnut and indicates percentage of black walnut trees in the stand that were infected: 0 = none, 1 = 1–5%, 2 = 6–15%, 3 = 16–25%, 4 = 26–50%, 5 = 51–75%, and 6 = >75%. Map is adapted from field notes of Martin (11). Arrow indicates Russ Forest location. Dashed lines represent county boundaries.

(percent black walnut infected) to surface geology is shown in Figure 2. Sites with >5% of the black walnut trees infected (abnormal disease levels) were more likely to occur on glacial till (till plain or terminal moraine) than on outwash or lacustrine material according to a χ^2 contingency test ($P = 0.05$). However, not all sites on till had severe disease. Black walnut had greater disease levels when growing on sites adjacent to wetlands, in kettles, or depressions according to a χ^2 contingency test (Table 2, $P < 0.0005$). Not all uplands had low levels of disease.

Soil properties and topographic features were compared for the 30 sites. Drainage class, soil type (sandy, clayey, rocky, or loamy), soil series (taxonomy), depth of rooting, and depth to gleying, to saturation, to the least permeable layer, and to mottles had no apparent relationship with disease rating. The textures of the least permeable layer. A horizon and B horizon showed no apparent relationship to stand percent infection rating. Modal descriptions of soils were listed elsewhere (15). If the C horizon was gravelly, the site was more likely to have severe disease than if it was sandy ($P = 0.02$).

Black walnut stands on hilly sites (steeper microrelief, greater macrorelief index and higher elevation) had greater Nectria canker incidence (Table 1, $P < 0.05$). Trees on steep microrelief always had >75% of the black walnuts infected. Also. if sites were in low flat areas, kettle bottoms, or adjacent to wetlands, they were more likely to have greater disease incidence. Sites were considered to be adjacent to wetlands if they were within 200 m of at least 0.4 ha of standing or slowly moving water and at similar elevations (±3 m). Of the 10 stands that had disease ratings of 6 (>75% black walnut infected), none were on south slopes or on high flat positions (Table 1). All of the intensively sampled stands that were in kettles or on moraine material had >75% of the black walnut infected.

Of the variables in Table 1 as well as elevation and aspect, macrorelief index was the only variable selected in the discriminant analysis to distinguish between flat sites with low disease incidence (0–5%), rolling sites with low disease incidence, and sites with abundant disease incidence (>75%, $P = 0.05$, F to remove = 5.24, df = 2/27). The F statistic to remove is a measure of the importance of the variable in the discriminant function. A larger F value reflects greater importance. Macrorelief index alone predicted the site type correctly for 80% of the flat sites with low disease incidence, 20% of the rolling sites with low disease incidence, and 50% of the sites with abundant disease incidence.

In a second discriminant analysis, sites with low disease incidence (0–5%) on black walnut were pooled. Topographic position and elevation were the only variables selected to discriminate between low and abundant (>75%) levels of disease ($P = 0.05$). F to remove was 11.41 for topographic position and 9.34 for elevation (df = 1/27). These two variables predicted the location type correctly for 65% of the low disease incidence sites and 100% of the abundant disease incidence sites.

DISCUSSION

Nectria canker was more severe on sites at higher elevations or on wetter soils. However, these two factors explained only 35% of the variability in Nectria canker severity on black walnut. The topography of Michigan was caused by glaciation during the Wisconsin age of the Pleistocene Epoch (10). Sites at higher elevation in southwestern Michigan were usually on glacial till material (terminal moraines and till plains [5]). Glacial till material was more hilly. Hilly terrain was more likely to have cold pockets resulting from depressions and kettles. The glacial till plains and terminal moraines also had stands on hilltops that constituted upland situations. Black walnut growing in depressions or kettles was much more likely to have severe Nectria canker than black walnut growing on uplands. This could explain why not all sites on till material or at high elevations had high disease levels.

A similar situation existed for black walnut on outwash material. Most outwash sites were wetlands or uplands. Wetlands had high disease levels, uplands did not. Therefore, some black walnut on outwash sites had severe disease and some did not. Kettles, depressions, and wetlands are all cold pockets (areas where cooler air accumulates). Because the factors causing low spots in hilly areas are different from those causing wet spots on flat land, it was not surprising that site factors such as glacial material, soil type, and water table were only weakly correlated with Nectria canker severity.

Environmental factors were observed to be associated with severe Nectria canker in other studies. Nectria canker on apple was associated with fog and high precipitation, moderate temperatures, and a shorter growing season (4). Sites on terminal moraines (8), hilly or rugged areas (2), or higher elevation (3,6) also were associated with severe Nectria canker. However, there was no association with aspect of the site (6,9). Nectria canker was associated with wet soils (3,9), lakes (1,17), and cold pockets (2,3). Spaulding et al (14) reported that Nectria canker was severe in dense forests but not in open areas. Our results are consistent with these studies and indicate that Nectria canker severity may be site-related.

Table 2. Summary of the relationship between topography and stand percent infection rating of 189 Nectria canker survey sites for black walnut in southwestern Michigan[a]

Stand percent infection	No. of sites observed			
	Uplands[b]	Wetlands[c]	Kettles	Depressions
0	86	4	0	4
1–5	21	7	1	8
6–15	2	4	1	6
16–25	0	4	1	5
26–50	1	5	0	6
51–75	0	5	0	5
>75	1	6	5	1
Subtotal	111	35	8	35

[a] Topography is significantly related to percent infection according to a χ^2 contingency test ($P < 0.0005$).

[b] Sites were considered uplands if they were not a wetland, kettle, or depression.

[c] Sites were considered wetlands if they were within 200 m of at least 0.4 ha of standing or slowly moving water and at elevations similar (±3m) to that water.

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