Ash Crown Condition and the Incidence of Ash Yellows and Other Insects and Diseases in Illinois, Iowa, Missouri, and Wisconsin

CHRISTOPHER J. LULEY, Forest Pathologist, Missouri Department of Conservation, Jefferson City 65102; MANFRED E. MIELKE, Plant Pathologist, USDA Forest Service, St. Paul, MN 55108; JOHN D. CASTELLO, Professor, State University of New York, College of Environmental Science and Forestry, Syracuse 13210; JANE CUMMINGS CARLSON, Forest Pathologist, Wisconsin Department of Natural Resources, Madison 53711; JAMES APPLEBY, Entomologist, Illinois Natural History Survey, Champaign 61820; and ROY HATCHER, Forester, Iowa Department of Natural Resources, Ames 50010

ABSTRACT

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Seventy-nine plots in Illinois, Iowa, Missouri, and Wisconsin were surveyed in 1990 for ash yellows (AshY) and other diseases and insects. Twenty-one of 38 white ash and 20 of 41 green ash plots had trees with AshY based on the 4′,6-diamidino-2-phenylindole (DAPI) DNA-staining technique or the presence of witches'-brooms. AshY was widely distributed in all states except Wisconsin, where trees in only two of 20 plots were affected. Other than witches'-brooms, symptoms previously associated with AshY were present on trees in plots that tested both positive and negative for mycoplasmalike organisms. Approximately 50% of the ash trees had greater than 10% crown dieback, and 5% of the trees were dead. Overall, trees representing about 12% (6–7 $m^3 \cdot ha^{-1}$) of the total ash volume had 50% or greater crown dieback. There was no significant difference in mean crown condition rating of the ash trees in AshY-positive and AshY-negative plots. Other disease and insect problems were common but were not considered to be major causes of crown dieback. The primary cause of crown dieback of ash in the Midwest is unknown.

Ash yellows (AshY), caused by mycoplasmalike organisms (MLOs), is associated with slow growth, production of witches'-brooms, crown dieback, and mortality of *Fraxinus* spp. in the Northeast (2,8,12,13). The disease was recently identified in four midwestern states: Iowa, Illinois, Missouri, and Wisconsin (13,14). Several species including black ash (*Fraxinus nigra* Marsh.), blue ash (*F. quadrangulata* Michx.), green ash (*F. pennsylvanica* Marsh.), and white ash (*F. americana* L.) have been reported as hosts (13,14).

Green ash and white ash are the most important ash species in the Midwest, although they represent only approximately 2.8% of the net hardwood volume on commercial forest land. Green ash is found mainly in riparian corridors, and white ash occurs mainly on upland slopes, usually along major streams. The recent discovery of AshY and observations of dying ash in several midwestern states (C. Luley, *unpublished*; R. Hatcher, *unpublished*) suggested that AshY might be important in the Midwest and prompted this survey.

Because the distribution and impact of AshY in the Midwest is unknown, and because dieback and mortality of ash also can occur in the absence of AshY (13), a survey was conducted in Iowa, Illinois, Missouri, and Wisconsin in the summer of 1990 to assess the incidence and distribution of AshY, evaluate the overall crown condition of ash, determine the incidence and importance of other diseases and insects of ash, and estimate the potential timber volume affected by dieback and/or AshY. A preliminary report has been published (7).

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MATERIALS AND METHODS

Location of plots and selection of sample trees. In each of the states of Iowa, Missouri, and Wisconsin, 10 green and 10 white ash stands more than 10 yr of age were selected to ensure representation of ash throughout each state; similarly in Illinois, 11 green and eight white ash stands were selected, for a total of 79 stands. The green ash trees were a component of bottomland forests that were dominated by elm (*Ulmus* spp.) and silver maple (*Acer saccharinum* L.) and also contained pin oak (*Quercus palustris* Muenchh.), cottonwood (*Populus deltoides* Bartr.), boxelder (*Acer negundo* L.), pecan (*Carya illinoinensis* (Wangenh.) K. Koch), hackberry (*Celtis occidentalis* L.), and sycamore (*Platanus occidentalis* L.). Most of the white ash trees surveyed were a component of the oak-hickory forest type, but some were surveyed in northern Wisconsin stands where sugar maple (*Acer saccharum* Marsh.), beech (*Fagus grandifolia* Ehrh.), and northern red oak (*Quercus rubra* L.) predominated.

Horizontal line sampling (analogous to strip cruising) (1) was used to select the trees and provide forest inventory estimates. Sampling was initiated 20 m in from the stand edge, along one or more 20-m line segments. All ash trees selected with a 10-BAF (basal area factor) prism, perpendicular to the line segment, were included in the survey. Each line segment was completed until a minimum of 10 ash trees per stand (total of 879 trees) was selected for data collection. Trees of species other than ash that were selected with the prism were counted but were not examined further.

Data collection. Diameter at breast height, crown position (dominant/codominant, intermediate, or suppressed), crown condition (classes 1 = no crown dieback, 2 = 10% crown dieback, 3 = 11–50% crown dieback, class 4 = 51–99% crown dieback, class 5 = dead) (11), and incidence of witches'-brooms, epicormic sprouts, deliquescent branching, chlorosis, basal bark cracks, and basal shoots were recorded for each tree. The incidence of insects and pathogens or their damage that were judged as having a significant effect on tree health were recorded as present or absent: ash flower gall (caused by the mite *Eriophyes fraxinoflora* Felt.), insect defoliators, borers, injury by the plant bug *Tropidosteptes amoenus* Reuter, anthracnose (caused by *Gnomoniella fraxini* Redlin & Stack), rust (*Puccinia sparganioides* Ellis & Barth.), cankers, and basidiocarps and other indicators of decay. Estimates of ash volume (gross cubic meters per hectare), number of ash trees, and ash basal area (square meters per hectare) were calculated from line sampling data from each plot, and the mean was calculated for all plots by species and state.

MLO detection and estimation of growth reduction. In each plot, three ash trees most likely to be infected with MLOs, based on the presence of witches'-brooms or symptoms often associated with AshY (deliquescent branching, epicormic sprouts, basal bark cracks, basal shoots, and crown dieback) were sampled for MLO detection. Single segments of approximately 0.5-cm diameter were cut from two roots per tree, placed in separate glass vials containing 2.5% glutaraldehyde in 0.1 M phosphate buffer, and tested for MLO infection with the 4',6-diamidino-2-phenylindole (DAPI) DNA-staining technique (12). If any root tested positive for MLOs, then no more roots from trees in that plot were tested.

Estimates of growth and incidence of sustained growth reduction were derived from one increment core extracted 1.37 m above ground level from each of the root-sampled trees in each plot. A clear plastic ruler was used to estimate relative ring widths. When there was evidence of slow growth, sustained growth reduction was determined to have begun in the year in which an annual growth ring was less than half the width of the previous year's ring (8). For all cored trees, the number of years elapsed since initiation of growth reduction were averaged to allow plot-to-plot comparisons.

Monthly data for the Palmer hydrologic drought index (PHDI) for each of the 33 climatic divisions in the four states, along with statewide averages, were acquired from the National Climatic Data Center, Asheville, North Carolina. PHDI data for each growing season (April–September) from 1975 to 1990 were compared with growth increments.

Statistical analyses. Differences between MLO incidence in green and white ash plots were tested by chi-square analysis. Mean differences between plots that were affected or unaffected by AshY symptoms and growth reduction were analyzed by a *t* test. Crown condition of ash, incidence of other pests, and forest inventory estimates were addressed with summary statistics by SAS (10).

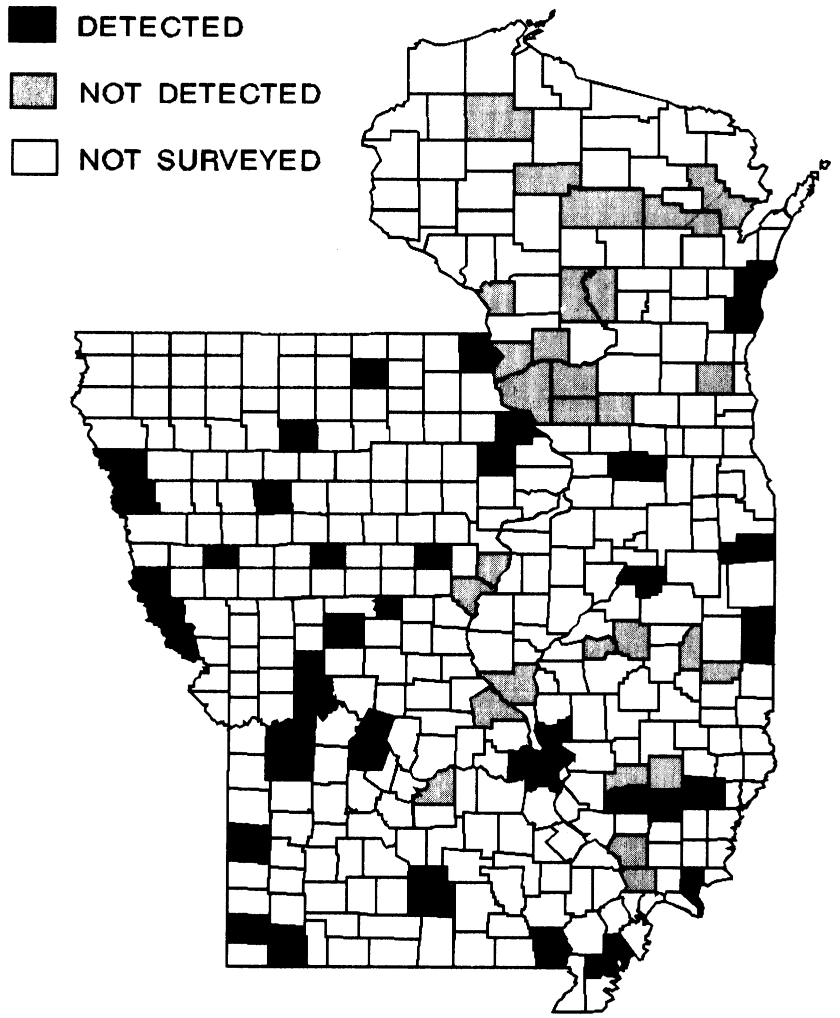

Fig. 1. Distribution of counties with survey plots and incidence of ash yellows in Iowa, Illinois, Missouri, and Wisconsin. Incidence was determined from results of 4',6-diamidino-2-phenylindole (DAPI) tests on root samples from one to three trees per plot or from the presence of witches'-brooms.

Table 1. Mean percentage of green and white ash trees with various symptoms in plots classified as positive or negative for mycoplasmalike organisms (MLOs)

	Green ash		White ash	
Symptom	**MLO-pos**	**MLO-neg**	**MLO-pos**	**MLO-neg**
Epicormic branches	54	68	60	63
Deliquescent branching	30	36	46*[a]	24*
Chlorosis	33*	13*	30	38
Leaf cupping	21	22	33	26
Witches'-broom	2	0	4	0
Basal bark crack	5	5	5	7
Basal shoots	5	9	6	5

[a] *Means are significantly different at $P < 0.05$.

RESULTS

Of 79 ash plots surveyed for the presence of AshY, 39 (49%) were classified as positive for the disease by DAPI analysis of root samples. There was no significant difference ($P > 0.05$) in AshY incidence between green (20 of 41) and white (21 of 38) ash plots. AshY occurred in 17, 13, and two of 20 plots in Missouri, Iowa, and Wisconsin, respectively, and nine of 19 plots in Illinois. AshY was widespread in all states except Wisconsin (Fig. 1).

Except for witches'-brooms, symptoms commonly associated with AshY were present in plots classified both as positive and negative for MLOs (Table 1). Witches'-brooms were found on a low percentage of MLO-infected green ash (1%) and white ash (2%) trees and in only 10 of 39 stands classified as MLO positive by the DAPI technique. The DAPI test corroborated MLO infection on eight of the 10 plots where brooms were found.

Except for foliar chlorosis of green ash in AshY-affected plots and deliquescent branching of white ash in AshY-affected plots, there were no significant differences ($P \geq 0.05$) in symptoms between affected and unaffected plots. Sustained growth reduction began in ash in all plots approximately during 1982–1983. Differences in the time of onset of growth reduction between green and white ash were not statistically significant.

About 5% of all ash trees surveyed (45 of 879) were dead. Mortality by individual state ranged from 1% (green ash in Illinois) to 11% (white ash in Illinois) (Fig. 2). Seventy-two percent of the green ash and 69% of the white ash were classified as dominant or codominant. Of these, 4% (13 of 327 and 12 of 297, respectively) were dead. Intermediate and suppressed trees together accounted for 28% of the green ash and 31% of the white ash surveyed, of which a respective 8% (10 of 129) and 10% (13 of 126) were dead. Thus, mortality was distributed across all crown classes, but intermediate and suppressed trees were twice as likely to be dead as dominant and codominant trees.

Forty-four percent of the green ash and 48% of the white ash surveyed were rated in crown classes 3, 4, or 5 (>10% of crown dead) (Fig. 2). Mean crown condition ratings did not differ significantly ($P \geq 0.05$) between green ash and white ash plots, or between plots affected and not affected by AshY. The frequency distribution of trees across crown condition classes was not related to the presence of MLOs ($P > 0.35$).

Overall, approximately 11% of the green ash volume (6 $m^3 \cdot ha^{-1}$) and 14% of the white ash volume (7 $m^3 \cdot ha^{-1}$) (5) consisted of trees with greater than 50% crown dieback (crown condition classes 4 and 5 combined). In order of frequency, the most common ash health problems other than AshY and undiagnosed dieback were insect defoliation, anthracnose, and trunk decay (Table 2). Cankers, borer damage, plant bug damage, and flower gall mite occurred less frequently (Table 2). No ash rust was observed.

PHDI values (1975–1990) revealed drought conditions ranging from moderate, in all four states in 1980, to extreme, in Missouri in 1981. Only Wisconsin returned to near normal precipitation in 1981. In 1988 and 1989, the entire region again experienced moderate to extreme drought.

DISCUSSION

AshY is widely distributed in both green and white ash in Iowa, Illinois, and Missouri, but its distribution in Wisconsin is limited (Fig. 1). The incidence of AshY ranged from 17 of 20 plots in Missouri to two of 20 in Wisconsin. However, our results are conservative,

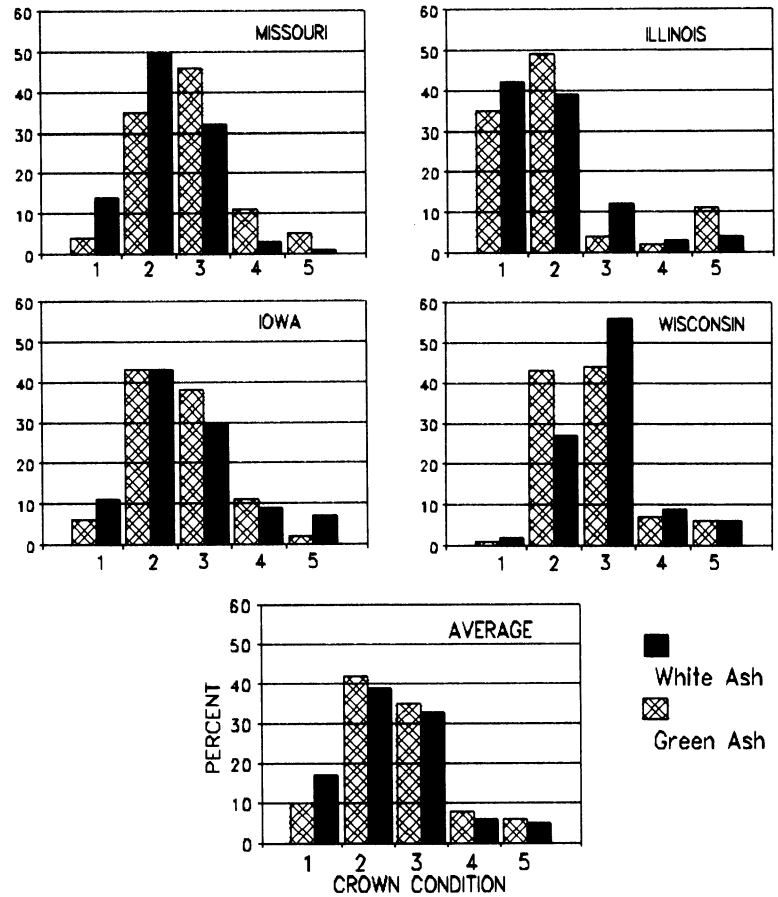

Fig. 2. Percentage of green and white ash trees in each crown condition class in Iowa, Illinois, Missouri, and Wisconsin. Crown condition classes of Silverborg and Ross (11) were used: 1 = no crown dieback; 2 = 10% crown dieback; 3 = 11–50% crown dieback; 4 = 51–99% of the crown dead, and 5 = dead.

Table 2. Percentage of ash trees with insect and disease problems other than ash yellows and undiagnosed dieback in green and white ash plots in Iowa, Illinois, Missouri, and Wisconsin in 1990

Symptom	Iowa	Illinois	Missouri	Wisconsin	Mean
Defoliation[a]					
Green	40	1	58	90	46
White	24	0	81	90	51
Anthracnose[b]					
Green	45	33	16	66	40
White	42	27	42	43	39
Decay[c]					
Green	12	8	23	39	21
White	10	9	45	27	23
Cankers[d]					
Green	0	0	11	2	3
White	3	0	22	2	7
Borers[e]					
Green	10	0	0	0	3
White	9	0	0	0	2
Flower gall[f]					
Green	3	0	0	1	1
White	2	0	0	2	1
Plant bug[g]					
Green	8	0	0	0	2
White	1	0	2	0	1

[a] By unknown insects.
[b] Anthracnose caused by *Gnomoniella fraxini* Redlin and Stack.
[c] Determined from indicators such as basidiocarps, broken branch stubs, open wounds, or cavities.
[d] Undiagnosed cankers.
[e] Insect borer holes.
[f] Caused by *Eriophyes fraxinoflora* Felt.
[g] Damage caused by the plant bug *Tropidosteptes amoenus* Reuter.

because infected trees may have been present in plots in which DAPI analysis was equivocal (degenerate or crushed sieve tube cells and missing or lost root samples, made DAPI analysis difficult or impossible in four plots), or even in plots scored negative for AshY because only three trees per plot were tested for MLOs. Also, stand edges were not surveyed. AshY is more prevalent along forest edges (15). In addition, we did not score root samples with autoflourescent sieve tube cells as positive for MLO, because this symptom is indicative but not diagnostic of MLO infection (12).

The detection of MLO was determined from two root samples from each of three trees in a plot. There is a less than 1% chance of failing to detect MLOs with the DAPI test when two roots per tree are sampled (12). Despite this, MLOs were not detected in two plots where trees with witches'-brooms were sampled.

Witches'-brooms, the only diagnostic symptom of AshY, were rare. We found witches'-brooms in 23% of plots where MLOs were detected by the DAPI test, compared with 93% in studies conducted by Sinclair et al in four eastern states and Ontario (13). Symptoms other than witches'-brooms usually associated with AshY, but not necessarily diagnostic (12), also were common in plots regardless of MLO presence as detected by the DAPI test. However, chlorosis of green ash foliage and deliquescent branching of white ash were significantly higher in AshY-affected plots.

Although the most symptomatic trees were tested for MLOs, infection apparently was independent of crown condition. These results do not support the reports of Matteoni and Sinclair (8) and Sinclair et al (13) of a close correspondence between MLO infection and the incidence of crown dieback. There are several possible explanations: 1) the incidence of MLO infection was underestimated, 2) MLO infection may have been too recent to cause the production of crown symptoms, 3) crown dieback of white ash may be caused by an interaction of MLO infection and stresses associated either with forest edges or tree competition, 4) dieback associated with other causes (e.g., drought stress) may have been sufficient to mask differences between plots affected and unaffected by AshY, and 5) MLO infection is not responsible for crown dieback of ash in the Upper Midwest. In Wisconsin, only two plots were classified as AshY-affected, yet 64% of the ash surveyed showed more than 10% crown dieback (Table 2). Green ash was more prevalent than white ash in the Wisconsin plots and is more tolerant than white ash of MLO infection (3,15). Regionwide, 48% of all ash trees had more than 10% of their crowns dead.

Crown dieback and mortality in the midwestern ash plots that we surveyed was less than that reported in the Northeast in the early to mid 1960s (11,16). Eleven percent of the green ash volume and 14% of the white ash volume consisted of trees in crown classes 4 (51–99% of the crown dead) and 5 (dead).

Widespread growth reduction and dieback of ash in the Midwest are apparently independent of MLO infection. Other disease and insect problems, such as anthracnose, insect defoliation, and decay were common on both green and white ash but, like AshY, were independent of crown class. Cankers, which are common on declining trees in the Northeast (9,11), have been reported on ash in the Midwest (4), but they were rarely observed on ash in this survey. Drought may have contributed to slow growth and dieback, perhaps in interaction either with MLO infection or tree competition (6). The onset of sustained growth reduction occurred subsequent to a regionwide drought in 1980 and 1981. The moderate to extreme drought in 1988 and 1989 further aggravated growing conditions throughout the region. Drought stress alone can cause growth reduction, and severe drought was associated with the dieback of white ash in northeastern states in the 1950s and 1960s (6). Growth increment was evaluated only for those trees that were sampled for MLO detection, which were also the most symptomatic trees. Because only about half of the sampled trees tested positive for MLOs, it is likely that drought alone played a major role in growth reduction and crown dieback. More extensive root sampling and growth analysis are needed to elucidate the precise relationship between drought, MLO infection, tree competition, and ash crown dieback in the Midwest.

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