

Distribution and Characteristics of the Eastern Filbert Blight Epidemic in Western Oregon

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ABSTRACT

Pinkerton, J. N., Johnson, K. B., Theiling, K. M., and Griesbach, J. A. 1992. Distribution and characteristics of the eastern filbert blight epidemic in western Oregon. *Plant Dis.* 76:1179-1182.

In October of 1986, eastern filbert blight (EFB), caused by *Anisogramma anomala*, was found in a hazelnut (*Corylus avellana*) orchard located in Oregon's Willamette Valley. This was the first detection of EFB within Oregon's principal hazelnut production area. Hazelnut plantings in nine Willamette Valley counties were surveyed in fall and winter during 1986-1990 to determine the prevalence and distribution of the disease. EFB was found at 326 of the 1,207 survey sites. Disease incidence and severity were greatest in the northeastern Willamette Valley. Currently, 30% of Oregon's hazelnut plantings are affected or in proximity to diseased plantings. An apparent focus of disease was centered 25 km southeast of the location where EFB was first found in Washington State in 1970. Affected orchards were found up to 20 km south and 50 km west of the focus, but disease incidence and severity decreased with distance from the focal center. Patterns of disease distribution within orchards indicate that most local spread of disease occurs to the north and northeast, which is the direction of the prevailing winds that accompany spring rains. It is likely that these meteorologic conditions have slowed dispersal of rain-disseminated ascospores to orchards located south of the infected area.

In 1970, eastern filbert blight (EFB), caused by the fungus *Anisogramma anomala* (Peck) E. Müller, was found in a European hazelnut (*Corylus avellana* L.) orchard in southwest Washington State (3,4). This was the first report of the disease west of the Rocky Mountains. By 1979, EFB had spread to 49 Washington orchards (8), most of which have been removed as a result of the disease. In 1986, an orchard severely diseased with eastern filbert blight was found in the northeast corner of Oregon's Willamette Valley (11). This was the first report of the disease within Oregon's hazelnut production area.

Oregon produces more than 98% of domestic European hazelnuts on 11,526 ha in the Willamette Valley (14). The potential threat of eastern filbert blight to this industry was first recognized in 1922 when the Oregon Department of Agriculture established a quarantine to prevent importation of *Corylus* spp. from east of the Rocky Mountains. This quarantine was based on data of disease reactions of European hazelnut grown in New York (1,2,10).

The pathogen apparently is an obligate, biotrophic parasite of only species of *Corylus* (5,6). Ascospores are discharged from perithecia on diseased branches in response to rain from fall through late spring (7,13). Spores transported in rainwater and splash droplets infect young vegetative tissues in the spring (13). Once established, *A. anomala* colonizes the cambial tissue, causing cankers (6). Stromata that contain perithecia develop within cankers 12-26 mo after initial infection (7,13) and form at the margins of cankers in successive years (7). Cankers girdle branches, which causes dieback of tree canopies and death of trees in 5-15 yr (8).

The Oregon Department of Agriculture conducted a survey from 1986 to 1990 to detect and map the distribution of the disease. Objectives were to gather data on which to delimit regulatory disease control areas and to observe the characteristics of the epidemic that could guide research on disease management strategies.

MATERIALS AND METHODS

Survey site selection. Surveys were conducted each fall and winter from October 1986 through April 1990. Hazelnut plantings were identified from directories of growers maintained by the Oregon Filbert Commission and were located by aerial photographs and roadside surveys.

During the winter of 1986-87, the survey concentrated on plantings surrounding the initial detection site in order to collect data required to set the boundaries of a regulatory quarantine area. All known commercial, residential, and abandoned hazelnut plantings in a 400-km² area of Multnomah and northern Clackamas counties were inspected. In addition, 96 orchards in seven other Willamette Valley counties were inspected (Fig. 1).

In the summer of 1987, EFB was discovered in three isolated orchards located in southern Washington and western Clackamas counties, 20-45 km southwest of previously known diseased areas. The survey during the following winter (1987-88) concentrated on plantings located within 10-15 km of these recently discovered diseased orchards. In the 1988-89 and 1989-90 survey seasons, survey crews emphasized inspection of hazelnut plantings located in northern Washington, Marion, and Yamhill counties. In localities where EFB was detected, all surrounding hazelnut plantings were inspected; otherwise, only commercial orchards were surveyed.

Survey method. Each year, surveys began in mid-November after leaf fall and continued until leaves obscured the branches in early April. Within individual orchards, the choice of trees to inspect depended on the relative susceptibility of the main crop cultivar and pollinizer cultivars (3,8,9). Approximately 90% of inspected orchards were planted to the cultivars Barcelona (main crop) and Daviana (pollinizer), of which Daviana is the more susceptible (3,9). In these plantings, each Daviana tree was inspected, which represented about 10% of the orchard. Amount of time spent inspecting each tree was inversely proportional to the disease severity but typically was about 5 min per tree. Some main crop Barcelona trees also were inspected, but the inspection period was limited to time used by the surveyor to walk to the next pollinizer location (usually 10-20 sec per tree). When EFB was detected in a Daviana tree, the Barcelona trees in proximity were thoroughly inspected. In orchards planted to other main crop cultivars considered

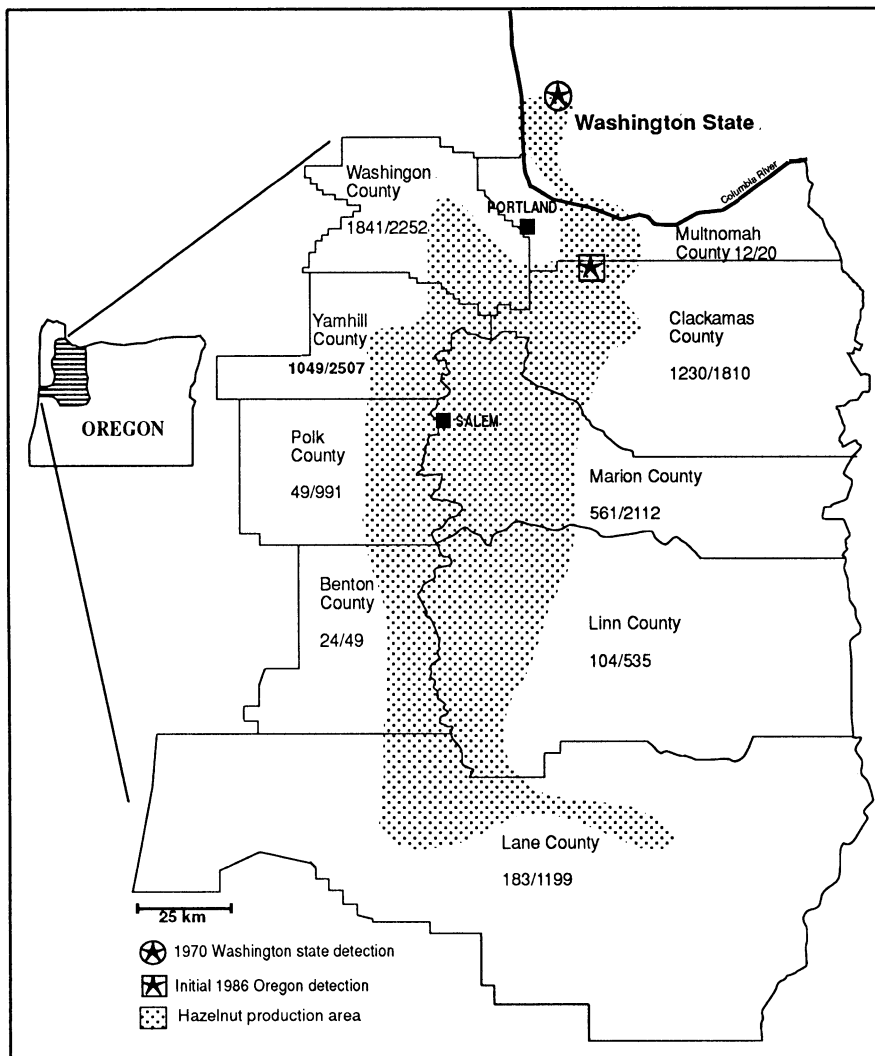


Fig. 1. Map of the commercial hazelnut production area in Oregon's Willamette Valley. The two numbers listed in each county are hectares of hazelnuts surveyed for eastern filbert blight during 1986-1989 followed by total hectares in hazelnut production.

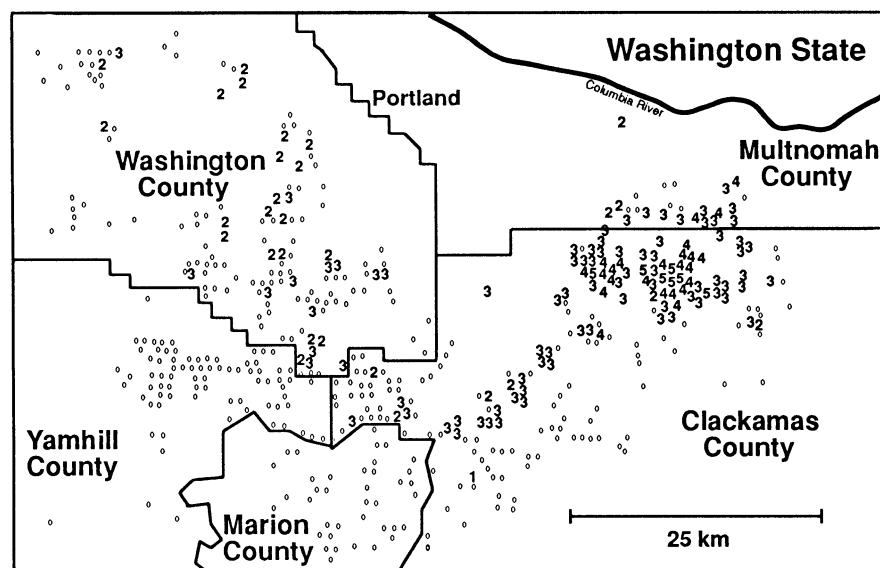


Fig. 2. Distribution of surveyed hazelnut plantings in five northern Willamette Valley counties. Numbers represent mean disease severity values of trees infected with eastern filbert blight within contiguous plantings: 0 = no canker, 1 = single canker, 2 = multiple cankers on single branch, 3 = multiple branches with cankers, 4 = >75% of branches with cankers, and 5 = canopy dead except for basal suckers.

highly susceptible (Ennis, Royal, Nonpareil [3,9]), main crop trees in every third row were inspected. Rows selected were the "pollinizer rows" where two-thirds of the trees were the main crop cultivar and every third tree was the pollinizer cultivar (Butler, Hall's Giant, Daviana, Duchilly).

Twigs and branches were visually examined for dead branches, sunken cankers, stromata, and unabsorbed dead leaves. Binoculars were used to inspect branches in the upper canopy. Branches with questionable symptoms were pruned to permit closer inspection or laboratory verification. Criteria used to verify EFB included canker morphology and the presence of stromata of *A. anomala* (6).

In each orchard, disease incidence was computed as the percentage of pollinizer and main crop trees infected. Trees also were rated for disease severity with the following index: 0 = no detectable EFB cankers, 1 = single canker, 2 = multiple cankers on a single branch, 3 = multiple branches with cankers, 4 = >75% branches with cankers, and 5 = canopy dead except for basal suckers. Age of the oldest canker in a tree was estimated by counting the rows of stromata within perennial cankers. General orchard data for each site also were recorded, including type of planting (commercial, unmanaged, or residential), type and arrangement of cultivars, and latitude and longitude.

Data were processed and summarized with database software (dBase III, Ashton Tate Corp., Torrance, CA). Geographic information software (Atlas Graphics, SPSC Inc., Rockville, MD) was used to plot the distribution of disease incidence and severity for survey sites located in the northern Willamette Valley. On these maps, disease data collected during the 1988-89 season were plotted, except data from Multnomah and northern Clackamas counties, where regulatory quarantine required that diseased plantings be removed before the end of 1988. In these cases, 1987 data were plotted. Data collected from residential sites within the boundaries of former orchards were grouped for analysis.

For individual orchards, location and severity index of diseased trees were mapped. In three of these orchards, the tree initially infected was determined by estimating canker age and severity indices of infected trees within the orchard. To investigate disease distribution, we calculated disease incidence among these orchards in 30° sectors (north = 0°) that extended outward from the most severely diseased tree at the vertex. The radius of each sector was the distance to the farthest infected tree in an orchard, such that sectors were of equal area. The spatial relationship between the initial diseased tree and other diseased trees in these orchards indicated potential patterns of disease

spread. Weather data (15) were therefore analyzed to determine the relationship between disease patterns and wind direction and precipitation for the period from 1 March to 31 May, when spores are likely to be discharged (12) and when trees are considered susceptible (13).

RESULTS AND DISCUSSION

The survey involved 1,207 hazelnut plantings in nine Willamette Valley counties. Of the 11,526 ha of commercial hazelnut orchards in Oregon, 5,784 ha were examined (Fig. 1). EFB was found at 326 sites, all within Washington, Multnomah, and Clackamas counties (Fig. 2). Seventy-two of the sites were commercial orchards occupying 678 ha, or 5.9% of all commercial hectareage in the state.

The original 1986 detection site of EFB in the Willamette Valley was located in northern Clackamas County (Fig. 1). Within 10 km of this site, the 1986–87 survey found infected trees in 37 commercial orchards, 217 residential plantings, and 36 unmanaged plantings, representing 100, 82, and 70% of each class of planting. Northern Clackamas County is located 20–25 km south-southeast of Clark County, Washington State, where EFB destroyed most commercial hazelnut orchards during the 1970s (8). It is likely that EFB spread into northern Clackamas County from Washington State and developed undetected for 6–8 yr in the many subdivided residential and unmanaged plantings in this area. By the winter of 1988, two-thirds of the 289 plantings surveyed in northern Clackamas County had severity index ratings of 4 or greater and 100% of the trees diseased (Figs. 2 and 3). By 1991, all commercial orchards had become unproductive and most had been removed.

During the winters of 1988 and 1989, surveyors found affected orchards up to 35 km to the south and 65 km to the west of the most intensely diseased area in northern Clackamas County (Figs. 2

and 3). In 98% of the newly discovered affected orchards, EFB was first detected and most severe in highly susceptible pollinizer cultivars. Most of these orchards had less than 1.0% of the trees diseased and severity indices of 3 or less. Of the 31 affected orchards found in Washington County, 27 had fewer than four infected trees, and cankers were confined to a single branch in 77% of trees in which disease was observed. During the 1989–90 survey season, EFB was not found in orchards farther west or south of areas where it was previously detected.

Four affected orchards were found in southern Washington and western Clackamas counties during the summer of 1987. Within three of these orchards, the disease focus was determined as a single tree more severely diseased (severity index ratings of 4, canker age 4–5 yr) than other infected trees within the orchard (severity index ratings ranging from 1 to 3, canker age 1–3 yr). The location of the focus was near the south or west edge of the group of infected trees in each orchard. These data indicate that secondary spread of disease occurs to the north-northeast. While mean disease incidence in the four sectors between north-northwest (331°) and east (90°) ranged from 10.5 to 24.1% (Table 1), infected trees were rarely found in the south and west sectors. Subsequently, these observations were supported by an experiment in which 80 and 3% of 2-yr-old hazelnut trees placed north and south of a severely diseased orchard, respectively, showed symptoms of eastern filbert blight 15 mo after exposure to rain-dispersed ascospores (J. Pinkerton, unpublished).

Examination of National Weather Service records for Portland and Salem, Oregon, during 1982–1990 revealed a correlation between precipitation events that promote ascospore discharge (7) and wind direction (12). During periods when infection is likely to occur (March–May) (13), resultant daily wind vectors from

the south and southwest with precipitation were recorded on an average of 12 days per month. On these days, rainfall amounts exceeded 2.5 mm on 9 days and 12.7 mm on 5 days. Winds from the east, north, and/or west with precipitation averaged 1 day per month, and rainfall amounts were usually less than 1.3 mm per day. For March–May in the period from 1982 to 1990, the correlation coefficient between occurrence of precipitation on a day and the quadrant of the resultant daily wind vector was 0.775 ($P < 0.001$). The weather data and disease distribution observed in orchards support the hypothesis that spores are predominantly rain-splash dispersed (7,12). Ascospores of *A. anomala* are easily trapped in rain that has passed through a diseased canopy (12), but placement of an aspirated Burkard spore sampler in an orchard with EFB did not detect ascospores of the pathogen in air (7).

The directional patterns of disease observed within individual orchards indicate that movement of the pathogen from its original site of establishment in Washington southward into Oregon may have been slowed by the prevailing meteorologic conditions in the Pacific Northwest that affect release and dispersal of *A. anomala* ascospores. Moreover, given a northeasterly direction of disease spread, the establishment of EFB anywhere farther south in the Willamette Valley would likely allow for more rapid spread of disease back to north and northeast on the prevailing winds. On the basis of these data, the Oregon Department of Agriculture has enacted quarantines to limit the movement of hazelnut plant material within Oregon.

Eradication of EFB in Oregon was attempted in the early years of the epidemic, but this strategy was abandoned after the size of the affected area became apparent. The survey revealed that an

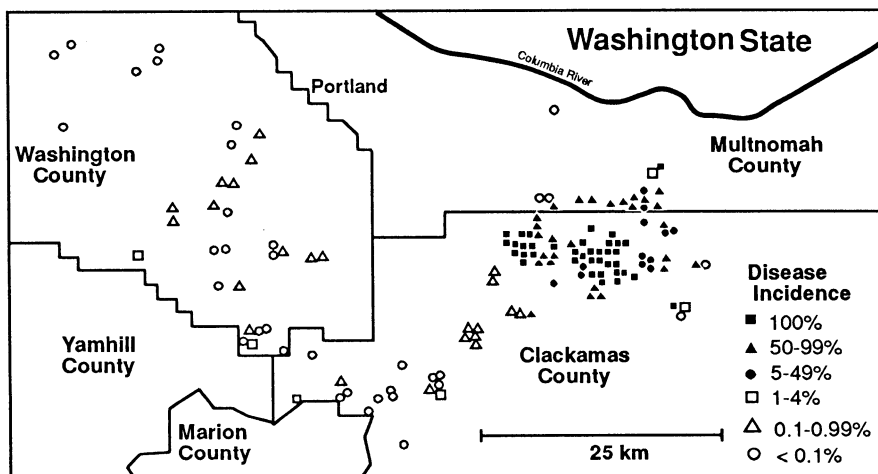


Fig. 3. Incidence of eastern filbert blight in surveyed hazelnut orchards located in the five northernmost counties of Oregon's Willamette Valley.

Table 1. Mean incidence of eastern filbert blight in directional sectors projecting outward from the most severely diseased tree in three Willamette Valley hazelnut orchards^a

Sector (degrees)	Mean disease incidence ^b ± SE
0–30	18.5 ± 12.1
31–60	24.1 ± 9.5
61–90	13.4 ± 7.4
91–120	0.4 ± 0.4 ^c
121–150	0.1 ± 0.1 ^c
151–180	0.0 ± 0.0 ^c
181–210	0.0 ± 0.0 ^c
211–240	0.1 ± 0.1 ^c
241–270	0.0 ± 0.0 ^c
271–300	0.3 ± 0.3
301–330	3.2 ± 2.6
331–360	10.5 ± 7.4

^a Each sector was a 30° arc with the most severely infected tree as vertex and the radius defined as the distance to the farthest infected tree in the orchard. North equals 0°.

^b Percentage of trees infected in a sector.

^c Mean based on two samples.

unmanageable reservoir of *A. anomala* had become associated with volunteer trees growing in woodlands of affected areas. Awareness of the distribution of eastern filbert blight has motivated growers in the northern Willamette Valley to routinely apply fungicide and destroy diseased wood when it is found. Also, growers are now using the survey methods described in this study to scout their orchards for disease.

Survey data confirmed the relative degree of susceptibility of common cultivars and the extreme susceptibility of the pollinizer cultivar *Daviana*. In addition, within severely diseased plantings, several trees of minor cultivars and open-pollinated seedlings were identified that showed apparent resistance to eastern filbert blight. These trees have been incorporated into the Oregon State University hazelnut breeding program.

ACKNOWLEDGMENTS

We thank Ken Falk, Wayne Esterbrook, and the Oregon Department of Agriculture pest and disease survey crews for inspecting the orchards. The Oregon

Department of Agriculture employed the first author during the survey period.

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