Association of Climatic Stress with Blight on Chinese Chestnut in the Eastern United States

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ABSTRACT

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In commercial and home plantings of Chinese chestnut in Georgia, North Carolina, Tennessee, Virginia, West Virginia, and New York, 23% of the trees had main stem cankers incited by the chestnut blight fungus, *Endothia parasitica*. The average main stem canker size was 28 × 55 cm. Fifteen percent of the trees had infection over 50% or more of the limb circumferences. Only two blighted trees were killed. In general, main stem canker incidence (13–93%) was higher in plantings of the Appalachian Mountain region than in plantings of the Piedmont region (2–13% incidence). Trees that were damaged most by *E. parasitica* cankers were located in high-wind and cold-winter areas of the Appalachian Mountains.

Chinese chestnut (*Castanea mollissima* Blume) generally is considered resistant to the chestnut blight fungus *Endothia parasitica* (Murr.) And. & And. Some Chinese chestnut cultivars are highly resistant to blight. These grafted cultivars are found in only a few locations, however, and the Chinese chestnut trees in home plantings and the commercial orchards of Georgia are typically of seedling origin. Chinese chestnut trees are obligately cross-pollinated and progeny show variation in blight resistance (10).

Severe to moderate cankering of Chinese chestnut trees by *E. parasitica* has been observed (1,6,9,10). Berry (1) suggested that instances of severe disease may be related in part to early frost. Evidence exists for a similar relationship in Japan for Japanese chestnut (13,15). Presently, quantitative information on the natural incidence and severity of blight on Chinese chestnut trees in the eastern United States exists for only one planting (9), and almost no information is available on the natural killing of Chinese chestnut trees by blight. This investigation was undertaken to determine the incidence of blight on Chinese chestnut in selected areas of the eastern United States.

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MATERIALS AND METHODS

We examined Chinese chestnut trees in Georgia, North Carolina, Tennessee, Virginia, West Virginia, and southern New York. No grafted cultivars were included. The study was done late in the summer of 1976 and during the spring and summer of 1977 and the spring of 1978.

Most of the trees were in small orchards; fewer were around homes. Leaf, bud, twig, and tree characteristics were used to differentiate *C. mollissima* from other species and hybrids of *Castanea*. Trees that were considered to be at least into their fourth growing season were included in this study. Because of the low branching of main stems of Chinese chestnut, diameter of the largest stem at 30 cm height (instead of breast height) was used as an indicator of relative tree size.

All main stems, to a height of about 2.2 m, were visually searched for cankered areas larger than 5 × 15 cm. The number of cankers on each tree was determined, and the width and length of the largest canker were measured.

Although *E. parasitica*-incited cankers are usually distinctive, biopsies were taken from canker margins of 25% of the diseased trees to confirm the presence of *E. parasitica*. Tissue pieces were plated on acidified potato-dextrose agar and incubated at room temperature (28 C).

The topography (ie, frost pockets, exposed ridges) of the general area where trees were located was recorded. Altitude for four sites in Georgia, Virginia, and New York was determined from maps prepared by the U.S. Geological Survey. Altitude for the remaining sites was determined with the aid of an aneroid barometer (G. Luft Metall-barometerfabik GmbH, West Germany).

Table 1. Geographic locations, altitudes, and terrain of sites of Chinese chestnut trees

Site[a]	Altitude (m)	Terrain
GA 1 (Peach)	154[b]	Flat Piedmont farmland
GA 2 (Dekalb)	322[b]	Very gentle slope in a foothill area of the Piedmont
NC 1 (Guilford, Forsyth, and Stokes)	244–366[c]	Generally flat, backyards, Piedmont
NC 2 (Stokes, Surry, and Wilkes)	381–442[c]	Rolling hills, no frost pockets, in foothills, edge of Piedmont
NC 3-TN 1 (Watauga and Carter)	946–1022[c]	Medium-sized mountain slopes, plateaus, and valleys, some partial frost pockets, severe winter weather, protected from wind
VA 1 (Giles and Montgomery)	549–641[b,c]	High rolling foothills, some frost pockets, generally not exposed to wind
VA 2 (Montgomery)	665[c]	Relatively high ridge, somewhat exposed to high winter winds with a small amount of vegetation to reduce wind
VA 3 (Floyd)	747[c]	Small mountain ridge top, exposed to moderately cold temperatures and severe winter winds
WV 1 (Wyoming)	476[c]	Frost pocket with high ridges blocking early morning and late afternoon sun
WV 2 (Raleigh)	763[c]	Plateau, with severe winter cold and wind
WV 3 (Mercer and Raleigh)	732–763[c]	High ridge top and 15 m from the ridge, protective vegetation, and situated to reduce damaging wind
NY 1 (Nassau)	10[b]	Coastal residential area

[a] Names of counties in parentheses.
[b] From U.S. Geological Survey map.
[c] By aneroid barometer.

Table 2. Incidence and size of cankers incited by *Endothia parasitica* on Chinese chestnut trees at 12 locations in the eastern United States

Site	Trees (no.)	Cankered trees (%)	Cankers per tree	Mean canker area (cm^2)[a]	Mean stem diameter (cm)[b]
GA 1	90	13.3	1.92	400	36
GA 2	65	1.5	1.00	432	30
NC 1	43	9.3	1.25	969	29
NC 2	48	12.5	1.83	555	27
NC 3–TN 1	168	28.6	1.71	1485	30
VA 1	23	13.0	1.00	639	22
VA 2	48	25.0	1.83	3066	26
VA 3	15	93.3	3.71	3672	30
WV 1	10	70.0	1.43	1150	35
WV 2	28	50.0	1.93	1104	24
WV 3	27	40.7	2.09	1078	16
NY 1	9	0.0	0.0	0	32

[a] Approximated by multiplying canker width by canker length. Based on measurements of the largest canker on each tree.
[b] Measured at 30-cm height.

RESULTS

Canker incidence. Of the 574 Chinese chestnut trees examined 10–1,022 m above sea level, 68% had one main stem, 31% had two to four main stems, and the remainder had five to nine main stems. The average diameter of the largest main stem of each tree was 29 cm. Twenty-three percent of the trees had one or more stem cankers larger than 5 × 15 cm. Smaller cankers were not considered to affect tree health significantly. Average canker size was 28 × 55 cm. The largest canker was 96 × 225 cm. Some cankers were very damaging, sometimes surrounding the main stem, but only two dead trees were found. An average of 1 to 3.7 stem cankers per infected tree was found at the various sites. All canker tissue biopsies yielded *E. parasitica*.

The lowest incidence of stem cankers, among the locations with large samples, was 1.5% in DeKalb County in the Piedmont region of Georgia at an altitude of 322 m (Tables 1 and 2). In general, canker incidence was higher on Chinese chestnut trees at higher altitudes, colder environments, or in frost pockets. Trees that were exposed to strong winter winds had a high incidence of canker. For example, between 549 and 641 m (VA 1), the canker incidence was 13% for trees protected from wind; at 665 m (VA 2), the incidence was 25% for trees on a semi-protected ridge line; but at 747 m (VA 3), unprotected trees on a ridge line had a 93% canker incidence (Tables 1 and 2). At 763 m (WV 2), trees on the predominately windward side of the planting had a higher incidence of

cankers and larger cankers than did trees on the leeward side of the planting. Among locations, there did not appear to be a direct relation between canker incidence and canker size, although sites with higher canker incidences tended to have larger cankers (Table 2).

Of the trees examined, 79% did not have significant branch cankering (none to small cankers or 0 to 24% of the branch circumference cankered). Six percent of the trees had medium branch cankers (25–49% circumference cankered), with 1.9 cankers per branch; 9% had medium to large cankers (50–74% circumference cankered), at a frequency of 2.5 cankers per branch; and 6% had large cankers (75–100% circumference cankered), with 1.9 large cankers per tree.

Cold-hardiness of stem tissues. In view of our findings and the suggestions of Berry (1) and others (13,15) that frost or cold injury may be a factor in blight development on Oriental chestnut trees, two types of freezing tests were done to ascertain how hardy dormant *C. mollissima* tissue is to temperatures varying from −10 to −50 C, according to the procedures of George and Burke (2,3,7; M. F. George, *personal communication*). These tests were performed on terminal portions of 1-yr-old branchlets (15-cm sections) of a Chinese chestnut and an American chestnut. Both trees were growing in Blacksburg, VA. Samples were collected on 26 January 1978.

In the first test (2,3,7), differential thermal analysis (DTA) was performed on sample twigs to determine if deep supercooling occurs in the xylem of *C. mollissima* and *C. dentata*. Hardy xylem of many deciduous forest species supercools or fails to freeze at temperatures approaching −40 C, which prevents frost damage to the tissue (2,3,7,11). The DTA indicated that Chinese chestnut xylem did not freeze until −37 C and that the xylem tissue of the American chestnut did not freeze until −39 C.

The second test was a freezing test to rate visually the freezing damage to bark, cambium, and xylem. Sample twigs were cooled to −10, −20, −30, −40, and −50 C. Each sample of twigs was sectioned and evaluated microscopically by comparing it with control samples that were not frozen. This histopathological examination revealed that the cambial tissue of *C. mollissima* exhibited browning injury by a temperature of −20 C and severe browning by −30 C. The bark tissue began to show some browning injury around −30 C and severe browning between −30 and −40 C. Browning in the xylem was severe between −30 and −40 C, indicating death in this range. The xylem results are in agreement with the results of the DTA.

DISCUSSION

In general, the information gathered in this study indicates that Chinese chestnut trees in Appalachian Mountain sites have a higher incidence of blight than trees in the Piedmont region of the Southeast. Possibly, this higher incidence of blight is related in part to frost or cold injury at these mountain sites. Other factors, such as genetic differences of the Chinese chestnut trees and the virulence and amount of *E. parasitica* inoculum in the respective areas, also may account for some of the differences. Blight-susceptible American chestnut (*C. dentata*) trees are near the mountain sites and blight-susceptible eastern chinquapin (*C. pumila*) is found in both areas; both species are potential sources of inoculum. Griffin et al (8) found that isolates of *E. parasitica* from Chinese chestnut trees are more pathogenic than those from American chestnut trees, and our results indicate that all Piedmont and mountain sites contained potential sources of inoculum on Chinese chestnut trees.

Nishikado et al (13) observed higher incidences of blight on Japanese chestnut trees growing in areas of Japan with lower minimum winter temperatures. Uchida (15) reported that Japanese chestnut trees affected by frost were severely infected by *E. parasitica*, and Berry (1) found that Chinese chestnut trees with cracks from an early frost in 1950 were infected with the blight fungus. Early (1) or late freezes in frost pockets, when tissues may not be resistant to cold, may cause injury of Chinese chestnut trees at inland mountain sites such as WV 1 (Table 1). Such a late frost caused twig dieback on almost all Chinese chestnut trees near Blacksburg, VA, in the spring of 1977 when other hardwood species appeared relatively unaffected (G. J. Griffin, *personal observation*). A few Chinese chestnut trees in coastal New York had no blight, although blight on American chestnut is common in this area.

Only the Chinese chestnut trees in Floyd County, VA (VA 3), and Raleigh County, WV (WV 2), seemed to be affected by the cankers to the point that the trees were noticeably weakened. One tree at the VA 3 and one tree at WV 2 had died. The major difference between these two sites and the other Appalachian sites was their exposure to severe winds, due to the absence of a windbreak. Winds might cause a small reduction of available water in an area of tissue on the main stem through high negative vapor pressure. If the amount of water were reduced in tissue below a critical level, the ability of the tissue to resist the combined effects of wind desiccation and freezing, at very low temperatures, could be reduced (14).

In the low temperature tests, Chinese chestnut cambial tissue was sensitive to freeze damage at around −20 C, bark tissue at about −30 C, with xylem tissue hardy down to −37 C. Thus, cambium or bark tissue could be injured at some of the mountain study areas, such as NC 3-TN 1, the West Virginia sites and some Virginia sites that may have winter temperatures below −20 C (12). Before or after this possible injury, an opening (infection court) could develop in the chestnut bark, and the exposed stressed tissue might be more susceptible to *E. parasitica*. In peach, cold-damaged cambial tissue has been observed to reestablish itself (4,5).

During the growing season, many Chinese chestnut trees in this study seemed to recover slowly from blight. This was evidenced by successive ridges of callus around cankers that developed over a number of years. These were observed on dead trees and indicate that they did not die quickly. Headland et al (9) made similar observations on callus formation for blighted Chinese chestnut trees.

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