Canker Expansion on Water-Stressed Pin Oaks Colonized by *Endothia gyrosa*

D. N. APPEL, Former Graduate Research Assistant, and R. J. STIPES, Professor, Department of Plant Pathology, Physiology, and Weed Science, Virginia Polytechnic Institute and State University, Blacksburg 24061

ABSTRACT

Appel, D. N., and Stipes, R. J. 1984. Canker expansion on water-stressed pin oaks colonized by *Endothia gyrosa*. Plant Disease 68: 851-853.

The effect of moisture stress on predisposition of 5- to 7-yr-old pin oak (*Quercus palustris*) grown in containers to canker induction by *Endothia gyrosa* was studied. Inoculated trees were subjected to episodes of drought in the greenhouse. Only stressed trees were colonized by the fungus. Colonization was consistently inhibited in regularly watered trees, and a callous ridge formed around the inoculated wound. During drying of the potting media, resistance to colonization diminished before wilting was evident. Cankers elongated most rapidly 2–8 days after a drying period was terminated by watering. A target pattern in cankers resulted from repeated episodes of drought.

Pin oak blight is a canker disease of *Quercus palustris* Muenchh. incited by *Endothia gyrosa* (Schw.) Fr. Since the disease was discovered (19) and the pathogen identified (13,14,19), pin oak blight has damaged and killed pin oaks of all ages throughout cities in eastern Virginia. Several circumstances indicate that environmental stress influences the susceptibility of pin oak to colonization by *E. gyrosa*. Pin oak grows well on wet sites with poorly drained soils (7); soils in the heavily urbanized regions of eastern Virginia have a high sand content with a low capacity for soil moisture retention (8). Also, eastern Virginia is on the periphery of the natural range of pin oak (7), where trees may be more susceptible to disease because of unfavorable environmental conditions (5). Water stress is considered the most common factor contributing to decline of trees in urban environments (15) and is believed to have predisposed pin oak to colonization by *E. gyrosa* (9).

Cankers on trees frequently have been associated with the occurrence of drought (18,20). In some instances, the association between moisture stress and predisposition to fungal infection and/or colonization has been verified experimentally. When sycamore (*Platanus occidentalis* L.) seedlings were water-stressed before inoculation, they became susceptible to infection and colonization by *Lasiodiplodia theobromae* (Pat.) Griff. & Maubl. (12). Young aspen (*Populus tremuloides* Michx.) seedlings were susceptible to colonization by *Hypoxylon mammatum* (Wahl.) Mill. when subjected to water stress after inoculation (4). In both cases, wilting was used as an indicator of water stress in the seedlings. European white birch (*Betula alba* L.) and dogwood (*Cornus stolonifera* Michx.) seedlings were susceptible to cankering by *Botryosphaeria dothidea* (Moug. ex Fr.) Ces. & de Not. when exposed to controlled levels of water stress (17).

Before this report, direct experimental evidence of predisposition of pin oak by water stress to colonization by *E. gyrosa* was lacking. Colonization was reported to be greatest during the driest months of the year, July and August (10). The major infection courts for *E. gyrosa* on landscape pin oaks were branch stubs left after pruning. Hunter (9) studied the water relations of pruned branches but found no evidence that colonization by *E. gyrosa* was controlled by drying in the stubs. In our experiment, the association between water stress and colonization was studied by manipulating the moisture status of young trees growing in containers and observing the results of inoculations made to main stems before and after periods of simulated drought.

MATERIALS AND METHODS

In May 1977, 45 *Q. palustris* whips (5–7 yr old, 1–2 cm in diameter) were planted in containers of three sizes. The three groups of trees (designated I, II, and III) were watered daily until 4 July 1978. Trees to be water-stressed in each group were then allowed to deplete moisture for 5–28 days. Thereafter, selected trees were watered only when unable to regain turgor overnight, a condition we refer to as permanent (sensu Kramer [11]) wilt.

In group I, the 17 trees were grown in 95-L plastic containers in a medium of 1:1 Weblite (expanded shale, Weblite Corp. Roanoke, VA) and soil (Hagerstown silty loam). Three control trees received 4 L of water on alternate days, and the remaining 14 trees were watered after 28 days of drying. Stressed trees were then watered individually when they showed permanent wilt.

The 17 trees in group II were planted in 11.4-L plastic containers containing Spasoff's mix (vermiculite, Weblite, and peat moss in a 2:2:1 ratio, supplemented with 28 g of Osmocote 14-14-14 fertilizer and 25 g of Fe Sequestrene 330 per 0.01 m^3). Three control trees were watered on alternate days, and the remaining 14 trees received 2 L of water after 5–7 days of drying. Most of these trees showed permanent wilt before they were rewatered.

In group III, 11 trees were planted in

Present address of first author: Department of Plant Sciences, Texas A&M University, College Station 77843.

Accepted for publication 19 May 1984 (submitted for electronic processing).

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

18.5-L metal containers in the same medium used for group I. Three control trees received 2 L of water on alternate days, and the remaining eight were allowed to dry for 10 days. Thereafter, trees were watered when they showed permanent wilt.

All trees were inoculated with plugs of mycelium removed with a 7-mm-diameter cork borer from a 7-day-old monosporic culture of *E. gyrosa* (isolate E-13) growing on potato-dextrose agar. Trees were wounded with the same cork borer by removing a bark disk from the main stems about 45–60 cm above the soil surface. The mycelial plug was placed in the wound and plastic was wrapped around the stem at the point of inoculation. Trees in group I were inoculated on 10 August, 8 days after the first watering and 9 days before any received a second watering. Those in groups II and III were inoculated on 29 June, before any period of drying. Cankers appearing as dark green, sunken lesions were measured on alternate days.

Table 1. Average lengths (mm) of cankers caused by *Endothia gyrosa* on artificially inoculated, water-stressed or nonstressed pin oaks in groups I, II, and III[y]

Treatment	Group I	Group II	Group III
Stressed	55 a[z]	88 a	128 a
Nonstressed	17 a	26 b	25 b

[y] Cankers on the 14 stressed and 3 nonstressed trees in group I were measured 51 days after inoculation, cankers on the 14 stressed and 3 nonstressed trees in group II were measured 64 days after inoculation, and cankers on the 8 stressed and 3 nonstressed trees in group III were measured 64 days after inoculation.
[z] Values in columns followed by different letters are significantly different ($P = 0.01$).

RESULTS

Trees in group I averaged 22 days between watering and permanent wilting, whereas those in groups II and III averaged 9 and 18 days, respectively. At the first watering, three trees in group II and two in group III were wilted, and none in group I had wilted. Transitory wilting in the stressed trees was frequent and highly variable. Wilting was not observed on any of the regularly watered, inoculated control trees in any group. Several trees in groups II and III died from repeated desiccation and were withdrawn from the experiment after 60 days.

Average canker lengths were greater on the water-stressed trees than on the regularly watered, inoculated control trees in each group (Table 1). In groups II and III, the lengths of 64-day-old cankers on stressed and nonstressed trees were significantly different ($P = 0.01$). Canker elongation on the regularly watered, inoculated trees in each group was consistently inhibited, and a swollen ridge of callus formed at the point of inoculation. This reaction was not observed on any of the water-stressed trees. Cankers on the water-stressed trees in each group ceased to elongate after tree death.

There were wide variations in canker lengths among water-stressed trees in each group (Table 2). Some cankers elongated rapidly, whereas others grew slowly. In Figure 1, canker elongation and watering dates are depicted for one tree in each group. The canker on the tree in group III elongated most rapidly, with a final legnth of 277 mm. This tree was watered twice, on 15 July and 9 August. The canker showed a marked increase in elongation 4 days after the first watering and 3 days after the second. Similar increases in canker elongation occurred 7 days after watering the tree in group II on 8 August and 3 days after watering the tree in group I on 8 September. No cankers formed on any trees in group I until they had been exposed to a second period of drying.

Table 2. Canker elongation on water-stressed[w] trees inoculated with *Endothia gyrosa*

Date	Group I[x] Av. length (mm)	Group I[x] *SD*[z]	Group II[y] Av. length (mm)	Group II[y] *SD*	Group III Av. length (mm)	Group III *SD*
July						
5	...	...	0	0	0	0
14	...	...	15	4	12	5
23	...	...	30	13	37	12
August						
1	...	...	45	24	47	13
10	...	...	56	26	70	19
19	9	6	75	42	101	31
29	14	11	83	47	122	52
September						
6	26	17	88	50	137	44
15	37	26	...	...	...	...
24	50	36	...	...	...	...
October						
3	56	40	...	...	...	...

[w] Cankers were measured on 14 water-stressed trees in group I, 14 in group II, and 8 in group III. Water-stressed trees received water when unable to regain turgor overnight.
[x] Group I trees were inoculated on 10 August, 1 wk after the end of a 28-day period of drying.
[y] Trees in groups II and III were inoculated on 29 June, before any drying.
[z] Standard deviation in canker lengths.

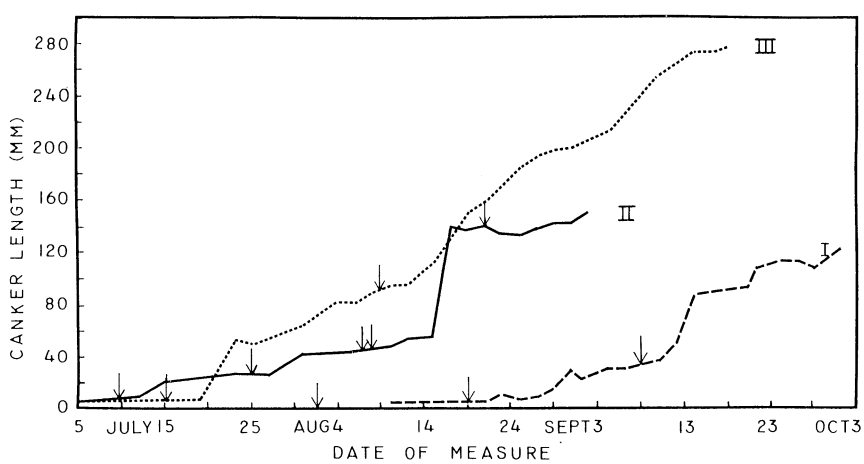

Fig. 1. Watering dates (arrows) and elongation of cankers caused by *Endothia gyrosa* on representative pin oaks from three water-stress regimes.

DISCUSSION

Water stress increased the susceptibility of pin oak to colonization by *E. gyrosa* in all three groups of trees. Regularly watered, inoculated trees were able to initiate wound closure and inhibit colonization by the pathogen. Therefore, supplemental water might be an effective management tool for pin oak blight in eastern Virginia, where the risk of infection by *E. gyrosa* is high (1,13). For this to be effective, pin oaks should be watered regularly during periods of high moisture stress. In the eastern Virginia region, where water is a diminishing resource, only trees of highest value will merit such treatment.

On the average, canker elongation on water-stressed trees continued steadily throughout the experiment (Table 2). Individual cankers often expanded in increments so that a target pattern could be seen on the canker surface. During rapid expansion, canker elongation sometimes exceeded 20 mm/day (2) and usually occurred 2–8 days after drought was terminated by watering (Fig. 1). These rates are many times faster than

any reported for cankers caused by other facultatively parasitic fungi (3,4,6).

Drying rates among individual trees in each of the three groups were variable. When wilting was used as an indicator of desiccation, the large soil volume with a high capacity for moisture retention used in group I appeared to allow trees to deplete moisture slowly; trees in group II depleted moisture rapidly. The 28 days of depletion had no apparent effect on subsequent resistance to colonization in group I. There was no relationship found between frequency of wilting and canker elongation in any group. Wilting, however, is not a sensitive indicator of physiological stress. Further studies would be required to determine the levels of stress necessary to predispose pin oak to increased susceptibility to colonization by *E. gyrosa*, as has been done with other canker-inducing, facultative fungi (6,16,17).

ACKNOWLEDGMENT

We thank Langley Air Force Base for grant-in-aid support for a portion of this work.

LITERATURE CITED

1. Appel, D. N. 1980. The influence of selected urban site factors, host nutrition and water stress on the decline and blight of pin oak (*Quercus palustris*) incited by *Endothia gyrosa*. Ph.D. thesis. Virginia Polytechnic Institute and State University, Blacksburg. 187 pp. Diss. Abstr. 41:4327.
2. Appel, D. N., Stipes, R. J., and Brown, S. S. 1979. Influence of water stress on *Endothia gyrosa* canker development in containerized pin oaks. (Abstr.) Phytopathology 69:534.
3. Bagga, D. K., and Smalley, E. B. 1969. Factors affecting canker development on *Populus tremuloides* artificially inoculated with *Hypoxylon pruinatum*. Can. J. Bot. 47:907-914.
4. Bagga, D. K., and Smalley, E. B. 1974. The development of Hypoxylon canker of *Populus tremuloides*: Role of interacting environmental factors. Phytopathology 64:658-662.
5. Boyce, J. S. 1961. Forest Pathology. 3rd ed. McGraw-Hill, New York. 572 pp.
6. Crist, C. R., and Schoeneweiss, D. F. 1975. The influence of controlled stress on susceptibility of European white birch stems to attack by *Botryosphaeria dothidea*. Phytopathology 65:364-373.
7. Fowells, H. A. 1965. Silvics of Forest Trees of the United States. U.S. Dep. Agric. Handb. 271. 762 pp.
8. Hanna, W. J., and Obenshain, S. S. 1957. The Middle Atlantic Coastal Plain. Pages 620-627 in: Soil, the 1957 Yearbook of Agriculture. U.S. Dep. Agric., Washington, DC. 784 pp.
9. Hunter, P. P. 1977. The blight and canker of pin oak (*Quercus palustris* Muenchh.) incited by *Endothia gyrosa* (Schw.) Fr.: Some factors affecting disease development. Ph.D. thesis. Virginia Polytechnic Institute and State University, Blacksburg. 109 pp. Diss. Abstr. 38:896.
10. Hunter, P. P., and Stipes, R. J. 1978. The effect of month of inoculation with *Endothia gyrosa* on development of pruned branch cankers of pin oak (*Quercus palustris*). Plant Dis. Rep. 62:940-944.
11. Kramer, P. J. 1969. Plant and Soil Water Relationships. A Modern Synthesis. McGraw-Hill, New York. 482 pp.
12. Lewis, R. 1978. Influence of infection court, host vigor and culture filtrates on canker production by *Botryodiploida theobromae* conidia in sycamore. Plant Dis. Rep. 62:934-937.
13. Phipps, P. M., Stipes, R. J., and Miller, O. K. 1972. *Endothia gyrosa*, a fungus associated with a destructive canker of pin oak. W. Va. J. Sci. 44:23-24.
14. Roane, M. K., Stipes, R. J., Phipps, P. M., and Miller, O. K. 1974. *Endothia gyrosa*, causal pathogen of pin oak blight. Mycologia 66:1041-1047.
15. Roberts, B. R. 1977. The physiology of trees in or near human settlements. Pages 293-308 in: Proc. IUFRO World For. Conf. 10th. 417 pp.
16. Schoeneweiss, D. F. 1975. Predisposition, stress, and plant disease. Annu. Rev. Phytopathol. 13:193-293.
17. Schoeneweiss, D. F. 1978. Water stress as a predisposing factor in plant disease. Pages 61-69 in: Water Deficits and Plant Growth. Vol. 5. T. T. Kozlowski, ed. Academic Press, New York.
18. Schoeneweiss, D. F. 1981. The role of environmental stress in disease of woody plants. Plant Dis. 65:308-314.
19. Stipes, R. J., and Phipps, P. M. 1971. A species of *Endothia* associated with a canker disease of pin oak (*Quercus palustris*) in Virginia. Plant Dis. Rep. 55:467-469.
20. True, R. P., and Tryon, E. H.1956. Oak stem cankers initiated in the drought year 1953. Phytopathology 46:617-622.