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Light Intensity and Drought Stress as Predisposition Factors for Dogwood Anthracnose[1]

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Abstract

Light and drought stress were studied as predisposition factors for dogwood anthracnose. Disease progression was recorded as a percentage of leaves with lesions in two-year-old potted dogwood trees (*Cornus florida* L.) that had been inoculated with dogwood anthracnose (*Discula destructiva* Redlin sp. nov.) and subjected to four light (100%, 50%, 10% and 2% ambient light) and two drought treatments. Natural vs. artificial inoculation methods were compared and found to have similar effects on disease severity. Shade increased disease severity; maximum disease progression values for trees in thoroughly watered treatments were about 5% at 100% light and 50% light, 35% at 10% light, and 26% at 2% light. Drought increased disease severity on all shaded trees, where disease progression increased 625% in 50% light, 43% in 10% light and 31% in 2% light, compared to 100% light. Drought had no effect on disease severity of unshaded trees.

Index words: *Cornus florida, Discula destructiva,* flowering dogwood.

Significance to the Nursery Industry

The flowering dogwood, *Cornus florida* L., is a valuable landscape tree, and dogwood anthracnose is threatening this economic resource of commercial nurseries. Because therapeutic control measures are not available at this time, growers need to be aware of cultural practices, such as watering properly and choosing planting sites within optimal light ranges, that inhibit pathogenesis. For years, growers, homeowners and scientists have exchanged anecdotal and largely untested and unpublished ideas about the effects of shade and soil moisture on severity and spread of dogwood anthracnose. Here, we show that drought and low light can each increase the severity of the disease.

Introduction

The flowering dogwood, *Cornus florida* L., is a native, understory tree throughout the eastern United States (19). In addition to being a valuable source of food for forty-two species of birds and twelve species of mammals, it is a prized landscape tree because of its beautiful pink or white bracts. Wholesale dogwood sales were estimated at 30 million dollars in Tennessee in 1989 (22).

The role of the flowering dogwood as an important ecological and economic resource has been threatened in recent years by dogwood anthracnose *(Discula destructiva* Redlin sp. nov.) (11, 17). The disease was first reported in 1978 in New York (16) and since has decimated populations of native and urban dogwoods in several eastern states. Symptoms associated with dogwood anthracnose include necrotic lesions on foliage (11), twig and branch dieback (8), epicormic shoots, trunk cankers, and tree death (11, 23).

Light intensity has been implicated as a determining factor in development of dogwood anthracnose. Foliar lesion enlargement rates have been reported to be higher in shaded versus nonshaded leaves (15), and trees in northeast-facing plots have had significantly more foliar symptoms of dogwood anthracnose than trees in southwest-facing plots receiving more light (7). The USDA Forest Service recommends weekly watering of dogwoods during drought in order to maintain healthy trees where dogwood anthracnose may be present (2). This recommendation is supported by research showing that dogwoods inoculated with *Lasiodiplodia theobromae* (Pat.) Griffon & Maubl. developed larger cankers on drought-stressed trees than on nondrought-stressed trees (14). The objectives of our study were to determine how light and drought affect pathogenesis of potted flowering dogwood seedlings by *D. destructiva*, and to compare two methods of disease inoculation.

Materials and Methods

Plant material. In December, 1990, 144 bare-root, 17-month-old dogwood trees (*Cornus florida* L.) approximately 1.5 m (4.9 ft) tall were received from Commercial Nursery Co. (Decherd, TN) and potted in 100% pine bark in 5 gal black plastic pots (12 in dia. × 11.5 in tall, Phoenix 2000, Zarn, Reidsville, NC). Fertilizer amendments to pine bark included dolomitic limestone [1.7 kg/m^3 (3.8 lb/yd^3)], triple superphosphate 0–46–0 [1 kg/m^3 (2.2 lb/yd^3)], gypsum [1.1 kg/m^3 (2.4 lb/yd^3)], Micromax [0.7 kg/m^3 (1.6 lb/yd^3)] (Grace Sierra Micronutrients, Milpitas, CA) and epsom salts [1 kg/m^3 (2.2 lb/yd^3)]. Trees were kept in a cold frame until May 1990 when they were placed in the field.

Light treatments. Trees were placed out of doors in light treatments of 100%, 50%, 10% or 2% ambient light on July 17, 1991. Trees in 100% ambient light were unshaded, and those in other light treatments were placed in tents con-

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structed of 50%, 10%, and 2% light transmission shade cloth (DeWitt Company, Inc., Sikeston, MO). Tents (2.4 m wide × 2.4 m long × 2.2 m high, 7 ft 8 in wide × 7 ft 9 in long × 7 ft 2 in high) were constructed so the bottom 0.3 m (1 ft) on all sides was uncovered to facilitate air movement and minimize differences in diurnal air temperatures among the light treatments. The outer surface of pots was painted white to minimize differences in root temperatures among the light treatments. Each light treatment was blocked three times with 12 trees per block for a total of 144 trees. For protection against low winter temperatures, defoliated trees were transported to a cold frame on December 17, 1991, and returned to their respective light treatments on March 17, 1992, before leaves emerged.

Inoculation treatments. On June 6, 1992, 6 trees from each block of each light treatment (18 trees per light treatment, 72 trees total) were transported to a forest near Ozone, TN, and placed under dogwood trees naturally infected with *D. destructiva*. To supplement canopy wetting by rainfall, the naturally infected tree canopies were sprayed with water every other evening so that inoculum of *D. destructiva* would drip onto the experimental trees. When foliar lesions were detected, the trees were returned to the appropriate light treatment (July 1).

Three other trees selected from each block (36 trees total) were transported to Asheville, NC, on June 15, 1992, and artificially inoculated with *D. destructiva*. Trees were placed under a plastic grid which held detached branches of *C. florida* leaves infected by *D. destructiva*. Water was misted above the plastic grid from dawn to dusk so that inocula would drip onto the trees. A 50% shade cloth tent was constructed above the water mister. The trees were also inoculated by spraying once until wet with a distilled water suspension of *D. destructiva* conidia [20,000 conidia/ml (666,666 conidia/oz)]. All trees were replaced to the appropriate light treatment on June 30 when foliar lesions were detected.

Drought treatment. Water was withheld from six naturally inoculated trees in each of the four light treatments (two plants per block, 24 trees total) beginning July 18. Soil drying was monitored as described previously (3) with soil matric potential (Ψ_τ) heat dissipation sensors (Soiltronics, Burlington, WA), connected to a datalogger (CR10, Campbell Scientific, Logan, UT). To improve sensor contact with the bark medium in each pot, each sensor was coated with a kaolinite slurry and buried 9 cm (3.5 in) deep in a pocket [about 270 cm^3 (106 in^3)] of autoclaved loamy soil 4–6 cm (1.6–2.4 in) from the side of the pot. Soil Ψ_τ of each drying pot was measured every morning and plants were rewatered when Ψ_τ dropped to –0.02 MPa or below. This treatment represented a moderate level of drought, causing many plants to wilt during the first drought cycle but few plants to wilt in subsequent cycles. Drying cycles were repeated until the end of the experiment. The mean number of drying cycles ± standard error was 3.0 ± 0.9 for plants in the 100% light treatment, 3.7 ± 0.5 for 50% light, 3.8 ± 0.8 for 10% light and 1.7 ± 0.8 for 2% light.

A period of frequent rain necessitated mounting white plastic rain shields above the bark medium on tree trunks in all treatments on August 11. Shields allowed ample ventilation and remained until termination of the experiment.

Environmental characterization of the light treatments. To characterize light treatments, photosynthetic photon flux density (PPFD, 400 to 700 nm), air temperature, and soil temperature of one pot per replicate were monitored for each light treatment for 24 hours, 10 am September 1 to 10 am September 2, 1992. September 1 and 2 were sunny, cloudless days. PPFD was measured every second, and integrated every 10 minutes, with quantum sensors (LI-COR, Lincoln, NE) mounted level on poles 1.5 m (4.9 ft) above the ground, unshaded by foliage. Air temperature was measured every 10 minutes with thermocouples mounted 7 cm (2.8 in) below the quantum sensors and shaded with aluminum foil cones. Soil temperature was measured with the thermocouple in the heat dissipation sensors described above. Readings from all sensors were recorded with a datalogger. On July 2, 1992, a Livingston atmometer (C&M Meteorological Supply, Riverside, CA) was mounted on a pole 1.5 m (4.9 ft) above ground level, unshaded by foliage, in the middle of one replicate per light treatment. Atmometers were weighed weekly with a field balance to determine evaporative potential of the surrounding foliage during the period that data on disease progression were recorded.

Disease assessment. Following inoculation and return of trees to shade tents, disease progression was estimated every fourth day on each tree by determining the percentage of leaves per tree with lesions. Horsfall-Barrett disease rating scores were converted to estimate mean percentages of disease severity (18).

Chlorophyll analysis. Leaves from the three remaining noninoculated trees of each block were sampled and analyzed for chlorophyll content. One expanded, unshaded terminal leaf was collected from each tree between 2:15 and 3:15 PM, placed on ice in plastic bags containing distilled water to immerse the petioles, and rehydrated (brought to ~100% relative water content) to standardize water contents and hence fresh weights among samples. Leaf samples were fractioned and assayed for chlorophyll (1, 12).

Statistical analysis. Each light treatment was uniquely assigned to three blocks. Within each tent, three combinations of water and method of inoculation were evaluated: 1) nondroughted, natural inoculation, 2) nondroughted, artificial inoculation, and 3) droughted, natural inoculation. The number of trees allocated to each combination within each shade cloth tent were 4, 3, and 2, respectively. All inoculated trees within each tent were evaluated for lesion development on 13 dates. The effects of shade cloth tents and all interactions involving tents were deemed to be random variables with all other factors deemed to be fixed classes of effects in preliminary statistical analysis of the data. Thus, a mixed model analysis was completed via General Linear Mixed Models (4). Only two random variable components were different from zero. The final model used to analyze the data contained (method of inoculation) *tent* (water treatment)/light treatment and residual as random components with light treatment, method of inoculation, water treatment, and date, and their two and three-way interactions deemed to be fixed. To more closely approximate the assumption of homogenous subgroup variances, the response variable (percentage of leaves with lesions) was transformed via a logarithmic transformation.

Table 1. Analysis of variance, using General Linear Mixed Models (4), of the percentage of leaves with lesions (A) from July 5 through July 17, 1992, before drought was imposed, and (B) from July 18 through August 22, 1992, during the drought treatment.

Effect	f	df	Alpha
	(A) Before drought		
Light	51.51	3	**0.00**
Inoculation	8.87	1	**0.00**
Date	12.09	3	**0.00**
Light x Inoculation	6.07	3	**0.00**
Date x Light	0.52	9	0.85
Date x Inoculation	3.68	3	**0.01**
	(B) During drought		
Light	15.84	3	**0.00**
Inoculation	0.48	1	0.49
Water	2.64	1	0.12
Date	26.44	8	**0.00**
Light x Inoculation	1.64	3	0.20
Light x Water	0.72	3	0.55
Date x Light	2.47	24	**0.00**
Date x Inoculation	0.14	8	0.99
Date x Water	3.20	8	**0.00**
Date x Light x Water	0.79	24	0.75
Inoculation x Date x Water x Light	0.30	24	1.00

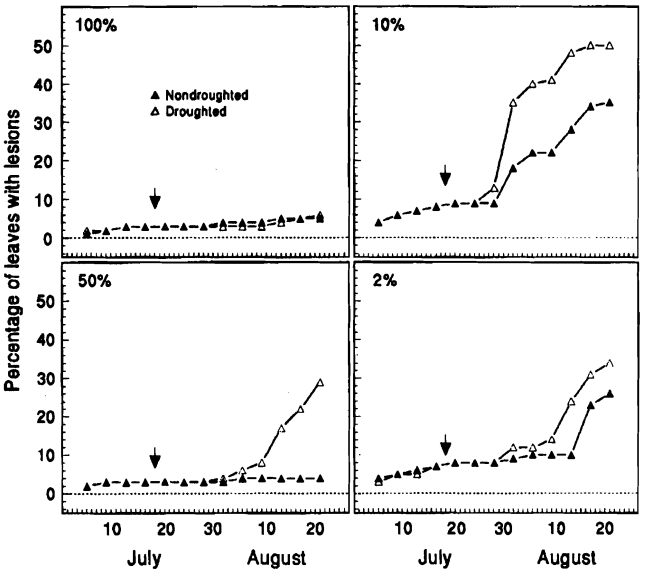

Fig. 1. Effect of drought and light treatments (100%, 50%, 10% and 2% of ambient light) on progression of dogwood anthracnose in 1992 in trees that were inoculated naturally at Ozone, TN. Symbols represent means of six (droughted) or twelve (nondroughted) trees. Arrows indicate date that drought treatments were begun.

Results and Discussion

Disease progression among the light and drought treatments. Initial differences in disease severity between inoculation methods (natural and artificial) were significant, probably because natural inoculation began 9 days earlier than artificial inoculation (Table 1). Differences in disease development between inoculation methods were not significant after July 17. Light intensity had a significant effect on disease severity, with increased shade allowing more lesions to develop (Fig. 1). The rate of disease progression in nondroughted trees was highest in 10% ambient light and lowest in 100% ambient light (Fig. 1). These findings agreed with the negative correlation between light intensity and disease progression previously reported by Chellemi *et al.* (7) and Parham (15). Light quality and intensity have previously been shown to affect pathogen physiology and development (5). For instance, many fungi require specific light intensities and wavelengths for development of reproductive structures (20), and low light intensity can increase susceptibility to pathogens (24).

The influence of drought in increasing disease severity first became evident in the 10% light treatment, where disease severity in droughted trees was about twice that in nondroughted plants 15 days after withholding water (Fig. 1). After 27 days of drought, disease severity had increased to 425% and 240% of respective nondroughted controls in the 50% and 2% light treatments, respectively. By the experiment's end, drought stress had increased disease severity by 625%, 43%, and 31% in the 50%, 10%, and 2% ambient light treatments, respectively. Drought did not affect disease severity of trees receiving 100% light. As observed before (6, 7, 15), high light intensity and/or high evaporative potential in 100% light-treated plants apparently suppressed disease progression despite exposure to drought. Water deficits have previously been shown to predispose plants to disease (9, 10, 13, 21).

Environmental characterization of the light treatments. Cumulative PPFD, and maximum and minimum air and soil temperatures are listed in Table 2. The cumulative PPFD within the shade cloth tents (46%, 10%, and 3% light transmission) agreed with the manufacturer specifications (50%, 10%, and 2% light transmission). Maximum and minimum air and soil temperatures did not differ greatly among the light treatments.

In mid July, evaporative potentials in the 100% light treatment were nearly 40% greater than those in the 50% light

Table 2. Irradiance, air, and potting medium temperatures within shade cloth tents of each light treatment on September 1–2, 1992.

Nominal light treatment (% ambient light)	Cumulative PPFD (mol m^{-2} day^{-1})	Measured light treatment (% ambient light)	Air temp. (C)		Soil temp. (C)	
			max.	min.	max	min.
100	38.0	100	32.0	17.9	31.3	16.1
50	17.4	46	29.8	18.1	28.6	15.0
10	3.8	10	30.4	17.9	28.6	14.3
2	1.2	3	30.6	18.1	28.6	14.2

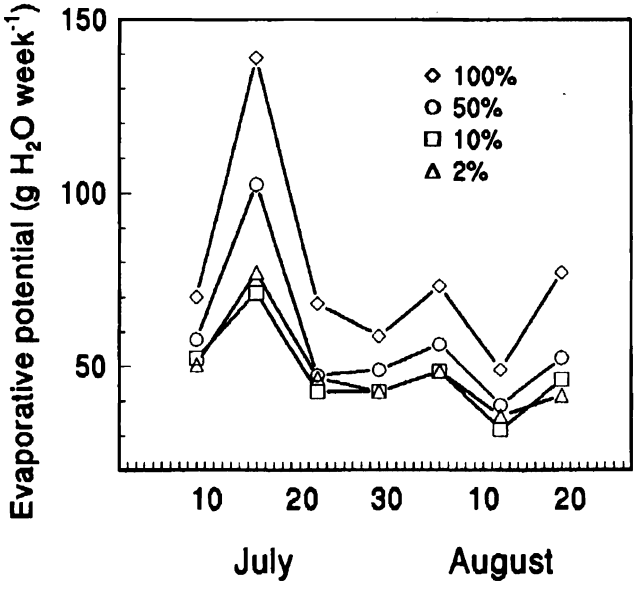

Fig. 2. Evaporative potential, measured with atmometers, of each light treatment (100%, 50%, 10%, 2%) during the disease assessment period in 1992. Each symbol represents water loss from one atmometer.

treatment and nearly 100% greater than those in the 10% and 2% ambient light treatments (Fig. 2). During the last week of July and the first three weeks of August, evaporative potentials as compared to July 16 values were about 50% less among the 100% and 50% light treatments and about 40% less among the 10% and 2% light treatments. Evaporative potentials in the 100% ambient light treatment remained about 25% greater than the 50% light treatment and about 50% greater than the 10% and 2% light treatments. The previously reported (6) negative correlation between evaporative potential and disease severity (percentage of leaf area with anthracnose lesions) is supported by our findings. Disease progression rates increased significantly after July 29 in shaded treatments (Fig. 1), when evaporative potential dropped to about 40 g (1.4 oz) of water per week in the 10% and 2% light treatments.

To characterize the influence of the light treatments on the host plant, we measured leaf chlorophyll concentrations and found that they increased 300% as ambient light decreased from the highest to the lowest light treatments. Average (n = 9) chlorophyll concentrations (in mg/g fresh weight) for each light treatment were 1.1 ± 0.04 at 100%, 1.5 ± 0.1 at 50%, 2.7 ± 0.1 at 10% and 3.2 ± 0.2 at 2% light.

Further work is necessary to determine if environmental factors affecting the degree of disease severity are related to the effects on the tree, the pathogen, or both. Our findings do suggest that dogwoods subjected to low light intensity and drought are more vulnerable to the rapid progression of dogwood anthracnose. Planting dogwoods in full sun light and keeping them thoroughly watered should help to control this disease.

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