HortScience 40(1):111–113. 2005.

Increased Shade Intensity and Afternoon Irrigation Decrease Anthracnose Severity on Three *Euonymus fortunei* Cultivars

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Additional index words. *Colletotrichum gloeosporioides*, leaf spot, stem lesion, wintercreeper euonymus

***Abstract*. The effectiveness of shade intensity and time of day in which irrigation was applied were tested for control of anthracnose symptoms caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. on container-grown *Euonymus fortunei* (Turcz.) Hand.-Mazz. 'Canadale Gold', 'Emerald 'n Gold', and 'Emerald Gaiety' during the 2002 and 2003 growing seasons. Rooted cuttings in 3.8 L containers were placed in 0% (full sun), 63%, 73%, or 80% shade at Park Hill, Okla., in 2002 and 2003 and at Stillwater, Okla., in 2002. Overhead irrigation was used to irrigate one-half of the plants in each cultivar and shade treatment in the morning and the other one-half during the afternoon. At both sites, disease damage ratings were inversely related to shade intensity throughout each growing season. Disease incidence was usually lower on afternoon irrigated plants than on morning irrigated plants. 'Canadale Gold' typically had the most anthracnose symptoms followed by 'Emerald 'n Gold'. 'Emerald Gaiety' had the least symptoms regardless of shade intensity or irrigation time.**

Euonymus fortunei is an ornamental, perennial landscape plant that is used extensively in the landscape industry (Turner, 1997). Anthracnose on *E. fortunei* has become a significant problem for nursery producers. One eastern Oklahoma nursery estimates losses between $200,000 and $500,000 annually (D. Dunn, personal communication). Leaf and stem lesions, leaf abscission, and stem dieback caused by lesions girdling the stem are the most common symptoms of the disease. Anthracnose on *E. fortunei* is caused by *Colletotrichum gloeosporioides* (Farr et al., 1989) that produces asexual spores called conidia (Agrios, 1997; Alexopoulos et al., 1996). During the growing season, the fungus consists of a mass of hyphae known as mycelium, and its asexual or conidial stage causes infection (Agrios, 1997; Alexopoulos et al., 1996). *Colletotrichum gloeosporioides* can reinfect its host throughout the growing season by producing conidia in acervuli below the cuticle surface of stems and leaves. The cuticle eventually ruptures and releases more conidia, causing the disease to spread to other plants via splashing from rain and overhead irrigation or from wind (Agrios, 1997; Alexopoulos et al., 1996).

New England nurseries first reported anthracnose on *E. fortunei*. The pathogen repeatedly isolated from diseased leaves and stems was identified as *C. gloeosporioides* (Mahoney and Tattar, 1980a, 1980b). *Colletotrichum gloeosporioides* was later observed on *Euonymus* spp. in Florida (Chase, 1983). Effective means for controlling anthracnose on *E. fortunei* have not been found; however, some control of *C. gloeosporioides* on *E. fortunei* has been achieved by altering the growing environment. Ningen et al. (2004) found that plants grown with a 19.3 °C night temperature had fewer disease symptoms than plants grown at 28.6 °C night temperature.

The objective of this study was to determine the effect of shade intensity and time of day in which irrigation is applied on anthracnose severity in *E. fortunei*. Three cultivars were tested to determine cultivar tolerance to *C. gloeosporioides*. No previous research has tested the effect of shade intensity or time of day in which irrigation is applied on anthracnose symptoms.

Materials and Methods

Rooted cuttings from presumably anthracnose-infected mother plants of three *E. fortunei* cultivars, 'Emerald Gaiety', 'Emerald 'n Gold', and 'Canadale Gold', were planted in 3.8 L containers with media consisting of 6 pine bark : 1 sand amended with 3 kg·m^{-3} dolomitic lime, 391 g·m^{-3} 0N–20P–0K (triple superphosphate), 215 g·m^{-3} 0N–0P–46K (KCl), 111 g·m^{-3} trace elements (Frit 504 HF, Frit (U.K.) Ltd., Cambridge, U.K.), 889 g·m^{-3} $FeSO_4$, 741 g·m^{-3} 46N–0P–0K (urea), and 1.2 kg·m^{-3} iron oxide (GU-49, Master Builders, Inc., Cleveland, Ohio). Two cuttings with stems about 10 cm in length were planted in each pot. High disease incidence in the field at the time cuttings were taken eliminated the need to further inoculate. Trifluralin (2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine) plus isoxaben (*N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide) (Snapshot, Dow AgroSciences, Indianapolis) was applied to container media at 224 kg·ha^{-1} on 4 June 2002 to control weeds. Containers were hand weeded as needed.

Plants were placed on black plastic covered planting beds in 0% (full sun), 63%, 73%, or 80% shade provided by woven shade fabric (PAK Unlimited, Willacoochee, Ga.) at the Oklahoma State University Nursery Research Station in Stillwater and on gravel beds under the same shade intensities at Greenleaf Nursery Company in Park Hill, Okla. Maximum photosynthetic photon flux (PPF) values were determined using an integrating quantum/radiometer/photometer (LI-188B; LI-COR, Inc., Lincoln, Nebr.) and are noted in Table 1. Plants were irrigated daily with 1.3 cm of water applied in about 30 min using overhead sprinkler irrigation either in the morning (0600 HR at Stillwater and 0700 HR at Park Hill) or in the afternoon (1400 HR at both sites). Plants were sheared on 22 May, 28 June, 5 Aug., and 27 Aug. as standard nursery practice. About 25% of the plant was removed during shearing using nonsterilized hand shears. Shearing tools are often not sterilized at nurseries and disease can be transmitted by shearing. Disease samples were collected from plant leaves and stems throughout the growing season and cultured on potato dextrose agar to verify the causal organism as *C. gloeosporioides*.

Plants were rated monthly for anthracnose symptoms using the Horsfall-Barratt rating system (Horsfall and Cowling, 1978). The rating

Table 1. Maximum photosynthetic photon flux (PPF) at plant height under various shade intensities in Stillwater, Okla. and Park Hill, Okla., for the 2002 growing season and in Park Hill, Okla., for the 2003 growing season.

Location	Shade intensity (%)	PPF (μmol·m^{-2}·s^{-1})
2002		
Stillwater	0	1798
	63	746
	73	562
	80	289
Park Hill	0	1360
	63	533
	73	384
	80	218
2003		
Park Hill	0	1922
	63	624
	73	596
	80	308

Received for publication 12 July 2004. Accepted for publication 8 Aug. 2004. Approved for publication by the director of the Oklahoma Agricultural Experiment Station. This research was supported under project OKL02324. The authors thank Greenleaf Nursery Co., Park Hill, Okla. for providing partial funding, plants, space, and labor to conduct this project.
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Table 2. Average daily high ambient air temperatures between rating dates for anthracnose damage on *Euonymus fortunei* irrigated in the morning or in the afternoon in container shade studies in 2003 at Park Hill, Okla.

		Avg daily high temp (°C) ± SD[z]	
Date	Shade intensity (%)	Morning irrigation	Afternoon irrigation
20 May to 19 June	0	36.3 ± 4.8	36.2 ± 4.6
	63	28.1 ± 3.6	27.7 ± 3.6
	73	28.4 ± 3.8	27.8 ± 3.4
	80	29.6 ± 3.7	28.5 ± 3.6
20 June to 22 July	0	41.1 ± 2.4	42.6 ± 2.9
	63	34.4 ± 2.9	33.6 ± 2.7
	73	34.4 ± 2.9	33.1 ± 2.5
	80	34.1 ± 2.2	33.5 ± 2.2
22 July to 21 Aug.	0	40.2 ± 3.3	41.3 ± 3.2
	63	34.4 ± 3.0	35.1 ± 2.7
	73	35.1 ± 2.8	33.9 ± 2.8
	80	---[y]	33.9 ± 2.7
22 Aug. to 15 Sept.	0	35.2 ± 6.1	35.9 ± 6.1
	63	30.9 ± 5.3	30.3 ± 4.9
	73	30.7 ± 5.1	29.9 ± 4.6
	80	---	30.1 ± 4.7

[z]Average daily high temperatures were calculated by summing the daily high temperatures from the day after the previous rating date through the rating date shown and dividing by the number of days in the interval between rating dates. SD = standard deviation.

[y]Daily high temperatures were not available for the 21 Aug. or 15 Sept. rating dates due to a datalogger malfunction.

scale was from 1 to 12 and corresponded to the following disease incidences: 1 = no diseased tissue, 2 = 1% to 3% diseased tissue, 3 = 4% to 6% diseased tissue, 4 = 7% to 12% diseased tissue, 5 = 13% to 25% diseased tissue, 6 = 26% to 50% diseased tissue, 7 = 26% to 50% disease free tissue, 8 = 13% to 25% disease free tissue, 9 = 7% to 12% disease free tissue, 10 = 4% to 6% disease free tissue, 11 = 1% to 3% disease free tissue, and 12 = no disease free tissue. Plants were rated at both sites 20 May, 25 June, 26 July, and 22 Aug. Final ratings were done 18 Sept. in Stillwater and 4 Sept. in Park Hill.

The study was repeated at Park Hill in 2003 with the following adjustments. Daily high ambient air temperatures were recorded in each shade intensity and irrigation treatment (Table 2). Plants were sheared in 2003 on 2 June, 14 July, and 12 Aug. Plants were rated 22 May (initial), 20 June, 23 July, 22 Aug. and 15 Sept.

A modified split-split-plot design was used at each site with shade as the main plot (four treatments) irrigation as the subplot (morning or afternoon) and cultivar as the sub-subplot (three cultivars). A different person rated each site and year, so data for each site and year were analyzed separately. Treatment combinations contained 20 single plant replications. Data were analyzed using analysis of variance (SAS Institute, Cary, N.C.). Means of significant interactions and main effects were analyzed using trend analysis or separated using a protected least significant difference (LSD) procedure depending on the treatment (related or nonrelated treatments).

Results and Discussion

No three-way interaction existed among cultivar, irrigation time, and shade intensity during June or July 2002 at Park Hill or Stillwater or at any rating date in 2003 at Park Hill (data not presented). Irrigation time interacted with shade intensity (Table 3) and cultivar interacted with shade intensity (Table 4) in June and July 2002 at Park Hill and Stillwater and at all rating dates in 2003 at Park Hill. A three-way interaction occurred among cultivar, irrigation time, and shade intensity during August and September 2002 at Park Hill and Stillwater (Table 5).

At both sites in 2002 and in both years at Park Hill, disease ratings were negatively related to shade intensity throughout the growing season (Tables 3-5). Lower disease ratings with higher shade intensities may be partially attributed to lower ambient air temperatures in the shade than in the sun (Table 2). Ningen et al. (2004) showed that anthracnose disease severity decreased with lower night temperatures. Although media temperatures were not measured in this study, plants growing in high-density polyethylene containers and exposed to direct solar radiation often have media temperatures from 38 to 52 °C that cause root death or heat stress (Davidson et al., 2000). Shading may have reduced heat stress by decreasing root zone temperatures of the plants in this study.

Plant disease ratings of all cultivars in full sun increased throughout the growing season (Tables 4 and 5). By the end of the growing season, few plants of any cultivar in full sun were alive at either site in 2002 or at Park Hill in 2003, and those that survived were not salable quality. In contrast, plants under shade, regardless of light intensity or cultivar, were considered of good quality at Stillwater in 2002 and at Park Hill in 2003 (average rating of 2.6 suggesting that <6% of tissue was diseased) (Tables 4 and 5).

Afternoon irrigated plants tended to have lower disease ratings than morning irrigated plants (Tables 3 and 5). Generally morning irrigation is recommended rather than irrigation in the evening to reduce disease incidence. Foliage dries quickly when irrigated in the morning compared to irrigation in the late evening, reducing the opportunity for pathogen infection. In this study, morning irrigation occurred at 0600 HR in Stillwater or 0700 HR in Park Hill when air temperatures were relatively cool and wind was generally minimal. In contrast, afternoon irrigation was at 1400 HR at both sites when air temperatures were higher and it was typically more windy. Higher air temperatures and wind speeds during the afternoon would dry the foliage more quickly than during the morning, making environmental conditions for disease development less favorable. Also, the cooling effect of afternoon irrigation may have reduced plant stress thus reducing their disease susceptibility.

Symptoms of anthracnose were apparent on

Table 3. Effect of time of day for irrigation and shade intensity on anthracnose disease ratings on *Euonymus fortunei* in Park Hill, Okla., and Stillwater, Okla., in 2002 and in Park Hill, Okla., in 2003; n = 60.

		Disease rating[z]							
		2002				2003			
Irrigation	Shade	Park Hill		Stillwater		Park Hill			
time	intensity (%)	June	July	June	July	June	July	Aug.	Sept.
AM	0	6.7	11.6	3.8	8.2	2.8	4.8	9.5	11.6
	63	1.8	6.7	2.6	3.0	2.2	2.3	2.7	3.7
	73	2.0	5.4	2.5	2.5	2.1	2.7	2.6	3.3
	80	1.9	4.9	2.5	2.4	2.0	1.8	1.8	2.0
Linear		***	***	**	***	***	***	***	***
Quadratic		***	NS	NS	**	NS	NS	**	NS
Cubic		NS	NS	NS	NS	NS	**	**	**
PM	0	5.9	11.6	3.0	5.3	2.5	4.5	7.6	10.7
	63	2.0	5.5	2.7	2.6	1.9	2.5	3.0	3.6
	73	2.0	5.5	2.4	2.4	1.9	2.2	2.2	2.4
	80	2.0	2.7	2.4	2.4	1.8	2.1	2.0	1.8
Linear		***	***	***	***	***	***	***	***
Qudratic		***	***	NS	NS	NS	NS	NS	NS
Cubic		NS	***	NS	NS	NS	NS	NS	NS

[z]Anthracnose damage ratings based on the Horsfall-Barratt rating system (see text).

NS,**,***Nonsignificant or significant at $P < 0.01$ or 0.001, respectively.

Table 4. Effect of cultivar and shade intensity on anthracnose disease ratings on *Euonymus fortunei* in Park Hill, Okla. and Stillwater, Okla., during 2002 and in Park Hill, Okla., in 2003; n = 40.

Cultivar	Shade intensity (%)	Disease rating[z] 2002 Park Hill June	July	Stillwater June	July	2003 Park Hill June	July	Aug.	Sept.
Canadale Gold	0	8.2	12.0	4.0	8.8	2.0	5.2	10.7	11.6
	63	2.0	6.2	2.8	3.0	1.8	2.3	3.0	3.7
	73	2.0	4.7	2.5	2.6	1.6	2.1	2.2	2.9
	80	2.0	3.3	2.6	2.6	1.4	1.5	1.7	1.8
Linear		***	***	***	***	***	***	***	***
Quadratic		***	***	NS	***	NS	NS	**	NS
Cubic		NS	NS	NS	NS	NS	NS	NS	NS
Emerald 'n Gold	0	5.4	11.4	3.3	6.6	3.2	4.9	8.6	11.4
	63	2.0	5.8	2.5	2.8	2.1	2.4	3.0	3.2
	73	2.0	5.7	2.6	2.6	2.0	2.0	1.9	1.8
	80	1.9	3.3	2.2	2.3	2.0	2.0	1.9	1.8
Linear		***	***	***	***	***	***	***	***
Quadratic		**	**	NS	NS	NS	NS	NS	*
Cubic		NS	***	NS	NS	NS	NS	NS	NS
Emerald Gaiety	0	5.4	11.4	2.9	4.8	2.8	3.8	6.4	10.4
	63	1.7	6.2	2.5	2.6	2.3	2.4	2.6	4.0
	73	1.9	5.9	2.3	2.3	2.2	2.6	2.5	2.9
	80	1.9	4.1	2.4	2.3	2.3	2.4	2.0	2.0
Linear		***	***	*	***	***	***	***	***
Quadratic		***	*	NS	NS	NS	NS	NS	NS
Cubic		NS	**	NS	NS	NS	NS	NS	NS

[z]Anthracnose damage ratings based on the Horsfall-Barratt rating system (see text).
NS,*,***Nonsignificant or significant at $P < 0.05$ or 0.001, respectively.

Table 5. Effect of cultivar, irrigation time, and shade intensity during Summer 2002 on intensity of anthracnose on *Euonymus fortunei* in Park Hill, Okla., and Stillwater, Okla.; n = 20.

Cultivar	Irrigation time	Shade intensity (%)	Disease rating[z] Park Hill August	September	Stillwater August	September
Canadale Gold	AM	0	12.0	12.0	11.9	12.0
		63	8.6	8.7	4.1	4.3
		73	4.6	3.6	2.4	2.7
		80	6.0	4.5	2.2	2.2
Linear			**	**	**	**
Quadratic			**	**	NS	NS
Cubic			**	**	NS	NS
	PM	0	12.0	12.0	11.1	12.0
		63	5.7	5.6	2.2	2.8
		73	5.6	4.9	2.1	2.1
		80	2.4	2.4	2.2	2.6
Linear			**	**	**	**
Quadratic			**	**	**	**
Cubic			**	**	NS	NS
Emerald 'n Gold	AM	0	12.0	12.0	11.3	12.0
		63	6.9	8.1	3.4	3.9
		73	5.9	5.9	2.3	2.5
		80	5.4	4.9	2.6	2.6
Linear			**	**	**	**
Quadratic			NS	**	*	*
Cubic			NS	NS	NS	NS
	PM	0	12.0	12.0	8.4	10.7
		63	5.2	5.1	2.7	2.9
		73	5.2	4.6	2.4	2.3
		80	2.3	2.3	2.1	2.2
Linear			**	**	**	**
Quadratic			*	NS	NS	**
Cubic			**	**	NS	NS
Emerald Gaiety	AM	0	12.0	12.0	9.9	12.0
		63	6.5	8.3	2.5	2.5
		73	6.9	5.8	2.0	2.9
		80	5.8	3.6	2.0	2.0
Linear			**	**	**	**
Quadratic			NS	**	**	**
Cubic			*	NS	NS	*
	PM	0	11.7	11.9	5.2	7.2
		63	5.5	6.4	2.2	2.6
		73	5.6	4.9	2.1	2.2
		80	2.5	2.4	2.0	2.3
Linear			**	**	**	**
Quadratic			**	**	NS	*
Cubic			**	*	NS	NS

[z]Anthracnose damage ratings based on the Horsfall-Barratt rating system (see text).
NS,*,**Nonsignificant or significant at $P < 0.05$ or 0.01%.

all cultivars tested; however, 'Canadale Gold' had the highest and 'Emerald Gaiety' had the lowest disease ratings regardless of treatment and rating time (Tables 4 and 5). Our results agree with those of previous research that noted greater disease severity on 'Emerald 'n Gold' than 'Emerald Gaiety' (Mahoney and Tattar, 1980b; LaMondia, 2001), and that disease ratings did not increase as quickly on 'Emerald Gaiety' as on 'Canadale Gold' or 'Emerald 'n Gold' throughout the study period (Ningen et al., 2004).

From this study, we recommend growing *Euonymus fortunei* under shade with afternoon irrigation. Of the cultivars tested, 'Emerald Gaiety' appears least susceptible to anthracnose followed by 'Emerald 'n Gold' and then 'Canadale Gold'.

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