8-1992

Effects of light intensity, leaf temperature, and tree aspect on Discula lesion enlargement rates and acervuli production

John M. Parham

To the Graduate Council:

I am submitting herewith a thesis written by John M. Parham entitled "Effects of light intensity, leaf temperature, and tree aspect on Discula lesion enlargement rates and acervuli production." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

Mark T. Windham, Major Professor

We have read this thesis and recommend its acceptance:

Robert Trigiano,Alan Windham, Robert Auge,Jim Hilty

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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James W. Hilty

Alan S. Windham

Accepted for the Council:

Associate Vice Chancellor and Dean of The Graduate School

EFFECTS OF LIGHT INTENSITY, LEAF TEMPERATURE, AND TREE ASPECT ON DISCULA LESION ENLARGEMENT RATES AND ACERVULI PRODUCTION

A Thesis

Presented for the

Master of Science

Degree

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John M. Parham

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ABSTRACT

Field studies were conducted at Lookout Mountain and Knoxville, Tennessee in 1990-91 to determine the effects of light intensity, leaf temperature, and tree aspect on *Discula destructiva* acervuli production, and lesion enlargement rates. Higher leaf temperatures were associated with higher light intensities in both sun and shade. Leaves on the east side of trees had higher leaf temperatures and light intensities in the morning. The diameter of the anthracnose lesions increased faster in the spring for both the sunny and shady plots. Most lesions on foliage in the sun had purple-rims whereas necrotic lesions were more prevalent on foliage in the shady plots. Necrotic lesions were more likely than purple-rimmed lesions to contain acervuli and have *D. destructiva* conidia present when the fungus was allowed to sporulate in moist chambers. The rates of lesion enlargement in shady compared to sunny plots at Lookout Mountain in the second experiment were significantly influenced by light intensity and leaf temperature as determined by covariate analysis.

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1. INTRODUCTION

The flowering dogwood, *Cornus florida* L. is an important ornamental and forest tree. Dogwood berries are included in the diets of 12 species of mammals and 42 species of birds (31). More dogwoods are sold in Tennessee than any other state, and in 1989 wholesale nursery estimates were at 30 million dollars (40). The role of the flowering dogwood as a source of food, beauty, and economic value may be limited by epidemics of dogwood anthracnose in eastern United States (30,31).

Decline and mortality of the flowering dogwood was first observed near Long Island, New York, in the late 1970's (28). Similar symptoms were noticed in New York, Connecticut, and New Jersey on dogwoods and, the disease was termed lower limb dieback (17). Byther and Davidson (12) reported a decline on the Pacific dogwood, *Cornus nuttallii* Aud., in the Pacific Northwest and termed the disease dogwood anthracnose. Salogga (32,33) and Daughtrey et al. (17,18) suggested that a species of *Discula* was the causal agent of dogwood anthracnose. This *Discula* sp. has also been reported on other *Cornus* species (9,10,23) and possibly blackgum (*Nyssa sylvatica* L.) trees (26). Since these early publications, dogwood anthracnose has been reported in nine northeastern states (15,18,21,22,24). In 1988, dogwood anthracnose was reported in the southeastern United States and has been identified in Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia (4,13,36). Redlin (29) described the fungus, Discula destructiva Redlin, sp. Nov. in 1991 as the causal agent of dogwood anthracnose.

Dogwood anthracnose lesions may develop on any part of the leaf (8) and are often characterized by having a red to purple border with a chlorotic halo (17). Purple-rimmed lesions may enlarge slowly and several may coalesce forming a single large necrotic lesion throughout the spring months. Necrotic lesions may enlarge and the leaf may be completely destroyed. Blighted leaves appear scorched and hang on the tree throughout the winter (11). The fungus invades and colonizes the branch through the vascular tissue to eventually infect the trunk of the tree (37,38). Leaf blight and twig death lead to a loss of apical dominance and epicormic shoots may develop. These shoots may serve as new infection courts (6,20). Annual cankers often develop at the base of epicormic shoots. Trees may die within one to five years depending on age, size, vigor and the environment in which it lives (7,11,15,17,18,19,22,25,34). Infected trees are at greater risk to being susceptible to dogwood borer in sunny areas (39), Armillaria root rot (16), and possibly other pathogens that invade stressed trees.

Several factors may influence dogwood anthracnose epidemics. Dogwood anthracnose symptom severity increased as pH of simulated acid rain treatments decreased (1,2,3,5). Fog at high elevations has enhanced dogwood anthracnose epidemics in the southern Appalachian region (41). Proximity to streams is another factor in anthracnose symptom development along the southern Appalachian region which includes Lookout Mountain (41,42).

The objective of this study was to determine the effects of leaf temperature and light intensity on dogwood anthracnose lesion enlargement rates, lesion type, and production and development of acervuli by D. destructiva.

2. MATERIALS AND METHODS

In the summer of 1990, a field study was conducted in Knoxville and Lookout Mountain, Tennessee. *Cornus florida* trees were located in both densely shaded and in full sunlight to compare lighted versus shaded areas. Four trees were used in each of the habitat type at Lookout Mountain, and two trees in similar areas at Knoxville. On each tree, one to three anthracnose lesions on each of five leaves were drawn on paper so that they could be relocated and monitored during the experiment. The lesions were measured once a week from July 19 to August 25 by taking the average of longest diameter of each lesion and a diameter perpendicular to the first. Leaf temperature was measured one day a week for each leaf, approximately every two hours from 8:00 AM to 3:00 PM, with a thermocouple mounted in the sensor head of a portable automatic diffusion porometer (AP3, Delta-T Devices, Cambridge, England). Ambient air temperature was also measured simultaneously in the shade with a thermometer. Light intensity was taken approximately at 1.5-2 hour intervals with a portable sunfleck ceptometer (Decagon Devices, Inc., Pullman, WA. 99163) between 8:00 AM to 3:00 PM at all five leaves on each tree. Daily means of light intensity, leaf temperature, and lesion enlargement increase were calculated. After five weeks, leaves were harvested, returned to the laboratory, and placed in petri dishes with moist filter paper for sporulation of D. destructiva. Lesions that contained D. destructiva acervuli were noted and D. destructiva was isolated. The type of lesion (purple-rimmed or necrotic) on every leaf was also noted.

In 1991, the study was repeated at Lookout Mountain and a different location in Knoxville. At Lookout Mountain, C. florida trees were located in dense shade and direct sunlight as in 1990. However, in Knoxville, trees were located in dense shade and partial sunlight. In both locations, four dogwood trees were used in both the sunny and shady habitats. Six leaves per tree were selected for study. Three leaves were located in the exterior canopy: one each on the east, south, and west side of each tree. The other three leaves were located within the canopy on the north side. One to three anthracnose lesions were drawn on paper as described previously for six leaves per tree. Data were collected at the Lookout Mountain location between May 29 to July 3 (Experiment one), and the experiment was repeated from July 18 to August 20, 1991. At the Knoxville location, data were collected between June 18 to July 26, and the experiment was repeated July 29 to August 31. Data were collected in 1991 as described previously except that leaf and air temperature were taken with a Type T thermocouple attached to a HH-25TC digital thermometer (Omega Engineering, Inc., Stamford, Ct. 06906). At the end of each experiment, leaves were harvested, returned to the laboratory, placed in moist chambers and incubated 48 hours at room temperature. Anthracnose lesions on which acervuli developed were noted, and conidia from acervuli were examined for identification as D. destructiva.

Statistical analyses were performed on data collected at Lookout Mountain and Knoxville. Correlation analyses between leaf temperature and light intensity were performed to observe how closely the two parameters are associated together. Covariable analyses of light intensity and leaf temperature were performed to determine if these parameters influenced dogwood anthracnose lesion enlargement. Analyses were also performed without any covariables to test if diameter of lesions increased at different rates. All analyses were performed using SAS/STAT (SAS Institute Inc. Cary, NC) for personal computers.

3. RESULTS

1990. Dogwood leaf surfaces in sunny plots were warmer than leaf surfaces in shady plots (Fig. 1)*. Leaf temperature did not rise as high on overcast days as it did on clear days, but leaf temperatures increased on each day. On sunny days, leaf temperatures on trees in full sunlight exceeded leaf temperatures on trees in the shade by 2 to 4°C.

Mean light intensities on trees in sunny plots were significantly higher than those on trees in shady plots (Fig. 2). Light intensities fluctuated more on overcast days than on clear days. Leaf temperature readings were highest on days when light intensity levels were highest.

Mean lesion diameters increased in both sunny and shady plots at Knoxville (Fig. 3) and Lookout Mountain (Fig. 4). Diameters of anthracnose lesions continued to increase similarly over the five weeks at both locations (Fig. 3-4).

Acervuli were more often associated on totally necrotic lesions more often than purple-rimmed lesions in both the sunny (Fig. 5) and shady plots (Fig. 5). Necrotic lesions were more likely to form on trees in shady areas, but purple-rimmed lesions were dominant on leaves in the sunlight at Lookout Mountain. Discula destructiva was isolated from acervuli in both sunny and shady plots.

*All figures and tables may be found in Appendices A and B.

1991 At Lookout Mountain and Knoxville, the average light intensity was significantly higher at the canopy surface of trees in sunny locations than at the surface of the canopy in shady locations (Fig. 6-9). Mean light intensities were higher on sunny days at Lookout Mountain (Fig. 6-7) than at the Knoxville location (Fig. 8-9). Light intensities on leaves on the north side of trees were significantly lower than at the other aspects at both Lookout Mountain (Fig. 6-7) and the Knoxville location (Fig. 8-9) in the sunny plots. Trees in shaded plots of the Knoxville location rarely exceeded a mean light intensity of 20 μmol m^{-2} s^{-1} because the trees were beneath an extremely dense canopy of hardwoods and conifers. Light intensities readings at Lookout Mountain and Knoxville were higher in the outer canopy than in the inner canopy and these data were consistent with previous work (14).

Mean leaf temperature was higher in the sunny plot than the shady plot at Lookout Mountain (Fig. 10-11) and Knoxville (Fig. 12-13). However, leaf temperatures were similar on overcast days in full sun and shade in all aspects on days at Lookout Mountain (Fig. 10). Mean daily leaf temperatures on leaves at all aspects were similar in the shady plot at Lookout Mountain (Fig. 10-11) and both sunny and shady plots at Knoxville (Fig. 12-13). At the sunny plot in Lookout Mountain, mean daily leaf temperatures were not always similar.

Light intensity and leaf temperature data were correlated at both Lookout Mountain and Knoxville for all experiments (Table 1). The correlation was greater earlier in the year than later in the season at both Lookout Mountain and Knoxville.

At Lookout Mountain, lesions within the canopy at the northern side of trees increased more rapidly than did lesions on other leaves in the first (Fig. 14) and second experiments (Fig. 15). In the second experiment at Lookout Mountain, lesion enlargement rates did not increase rapidly on any side of the tree in the sunny plot (Fig. 15). Lesions from leaves at the east side of trees developed more slowly at Lookout Mountain (Fig. 14-15). In the shady plot at Lookout Mountain, results were similar as for lesions in full sun in the first experiment (Fig. 14-15). Anthracnose lesion diameters increased more in the first experiment (Fig 14) than the second experiment (Fig. 15) in the shady plot at Lookout Mountain.

In the first experiment in the sunny plot at Knoxville, lesions increased the most on leaves at the south sides of trees (Fig. 16) whereas lesions on leaves on the east side of tree canopies increased the least. In the second experiment at Knoxville, lesions on the west side of trees increased the most whereas south and east sides of trees increased in size the least in the sunny plot (Fig. 17). In the shady plot at Knoxville, lesions on the west and east sides of trees increased the most (Fig. 16) in the first experiment. In the second experiment, trees on the east side of trees increased most whereas lesions on the west side of trees did not increase at all at Knoxville (Fig. 17).

The increase of leaf temperature was associated with increases in light intensity and ambient air temperature. Leaves on the east sides of trees in full sun warmed faster than leaves on the other sides of tree canopies. In the morning, leaves on the east side of canopies dried more quickly than leaves on other sides of canopies when any residual dew, fog, or rain remained from the previous night. In the afternoon, leaves on the west sides of trees were the warmest. Leaf temperature at Lookout Mountain frequently did not increase until 10:00 AM due to hazy overcast conditions or fog. At Knoxville, leaf temperatures did not rise as high as leaf temperature at Lookout Mountain because the trees were in partial or full shade. However, leaf temperatures did increase on cloudy days.

When data were analyzed without light intensity or leaf temperature being covariables, lesion enlargement on leaves in full shade increased significantly (Pr > F 0.0006) more rapidly than did lesions on trees in full sun at Lookout Mountain in both experiments in 1991. Lesion enlargement on leaves in full shade was significantly (Pr > F 0.003) greater than lesion enlargement in partial sun in both experiments at the Knoxville location in 1991.

With light intensity and leaf temperature as covariables, only lesion enlargement growth in the second experiment at Lookout Mountain was significant (Pr > F .004) in the sunny plot versus the shady plot (Fig. 18). With both covariables at Knoxville, lesion enlargement rates were not significant (Fig. 19).

In the Knoxville location, the dominant type of lesion in the sunny plot was the purple rimmed-lesion (Table 2). Fewer acervuli were on purple-rimmed lesions than on necrotic lesions. *D. destructiva* cirri and conidia were observed more often on necrotic lesions than on purple-rimmed lesions. The necrotic lesion was dominant in the shady plot. Acervuli were more likely to form on necrotic lesions than purple rimmed-lesions in either the sunny or shady plot (Table 2). Statistics for the Knoxville lesion data are presented in Table 3. At Lookout Mountain, the dominant lesion in the sun was purple-rimmed whereas the necrotic lesion was dominant in the shade in both experiments (Table 4). Acervuli and conidia of *D. destructiva* were more likely to be observed on necrotic than on purple-rimmed lesions (Table 4). Statistics for the Lookout Mountain lesion data are listed in Table 5.

Other fungi were also observed on leaf surfaces. *Pestalotia* sp. conidia were infrequently observed on leaves from Lookout Mountain. On leaves from Knoxville, sp. of

Asterosporium, Alternaria, Pestalotia, and Botrytis conidia were also observed.

4. DISCUSSION

In our study, higher light intensities were associated with leaf temperatures $\geq$ 28°C, reduced lesion enlargement rates, and lower acervuli production. The observed reduction in symptom severity in full sun agreed with a previous study where full sun exposure deterred symptom development on dogwoods at Long Island in 1986 (18). In vitro studies revealed growth of *D. destructiva* was inhibited by temperatures above 28°C (D. Brown, unpublished). High light intensity had also been associated with decreased symptom development of northern corn leaf blight caused by *Exserohilum turcicum* (Pass.) Leonard and Suggs (35). Maize plants grown under high light intensities were less susceptible to *E. turcicum* than plants grown under low light intensities (35).

Anthracnose lesion enlargement rates on leaves exposed to partial sun and partial shade were affected by location on the tree. In addition, trees in partial sun had fewer symptoms on the side of the canopies that were not shaded by other trees and/or buildings. Leaves on northern sides of trees had greater lesion enlargement rates at both Knoxville and Lookout Mountain in both sunny and shady plots. Thus, we conclude that trees on northern sides of homes in landscape settings would be more susceptible to lesion enlargement.

Purple-rimmed lesions had fewer acervuli and D. destructiva spores than necrotic lesions. Dogwoods in forested areas had larger numbers of necrotic lesions and than dogwoods in full sun. Fewer spores of D. destructiva would be available as inoculum for secondary infections on purple-rimmed lesions. This may explain why dogwood anthracnose had often been more severe in forested areas where epidemics have occurred. The reduction in sporulation could be due to increased leaf temperature or an enhanced plant defense in areas of full sunlight.

In the first experiment at Lookout Mountain and both experiments at Knoxville, covariant analysis using light intensity and leaf temperature partially explained why lesions in sunny versus shady plots did not increase at significantly different rates. At Lookout Mountain, cooler ambient air temperatures in the spring influenced leaves by keeping the sunny and shady plots similar. At Knoxville, light intensity and leaf temperature readings in both sunny and shady plots were similar in both spring and summer for differences in lesion enlargement rates to be noted.

In the second experiment at Lookout Mountain, light intensity and leaf temperature as covariables influenced the enlargement rates of lesion diameters. However, based on the covariant analyses, light intensity and leaf temperature did not totally explain differences in lesion enlargement rates in both plots. Excess moisture may be another variable needed to explain lesion enlargement. Excess moisture on foliage in the first experiment in both sunny and shady plots favored sporulation of the fungus. As warmer conditions became more prevalent, light intensity and leaf temperature as covariables began to explain differences in enlargement rates between the sunny and shady plot because moisture was not as prevalent due to drier conditions. Evaporation of moisture on trees in the shade had been demonstrated to be slower than trees in partial sun (14). Therefore, length of leaf wetness along with leaf temperature and light intensity should be investigated in future studies to determine why dogwood anthracnose is more severe in forested areas.

High light intensities can affect dogwood morphology and D. destructiva. Diseased leaves on trees in full sunlight were most common on lower branches or on the inner canopy of the tree (22). Leaves in the inner canopy of this study received the lowest light intensities throughout the day compared to leaves in the outer canopy of the tree. Cirri on leaves on the outer canopy and upper crown of trees in full sun probably desiccated more quickly due to higher light intensities warming the leaves. Leaf cuticular wax was thicker on dogwoods in full sun compared to trees in shade (E. Graham, unpublished). Thicker cuticular waxes could impede or thwart penetration by fungi. In addition, thick waxy cuticles could cause water to bead on leaf surfaces and affect water evaporation from the leaf surfaces. Therefore, dogwoods planted in partial or full sun may enhance the plants resistance mechanisms.

Light intensity has been demonstrated to affect other plant species. Zollinger and Kells demonstrated that sowthistle had a greater plant height, greater plant weight, greater water transpiration, and a greater rosette diameter in studies conducted at 1015 μmol m-2 s-1 compared to the 580 and 285 μmol m-2 s-1 (43). However, dogwoods grown under 10% or 50% shade had greater tree height than dogwoods grown in full sun (Erbaugh, unpublished). Greater tree height does not seem to be a factor in dogwood anthracnose because trees of all heights seem to be susceptible (22). Scotts pine seedlings were stimulated to have greater lateral bud growth at higher light intensities (27). Diseased dogwoods can develop epicormic shoots in both sunny and shady locations. Leaves growing from epicormic shoots that develop on trees in sunny locations will have thicker cuticular wax patterns. These shoots may not be as susceptible to shoot dieback and the formation of elliptical cankers. Other research concerning the effects of light intensity on dogwoods should continue to determine how it effects the disease process.

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APPENDICES

APPENDIX A

TABLE 1. Correlation analyses of mean light intensity and mean leaf temperature data for experiment 1 (May 29 -July 3, 1991) and experiment 2 (July 18-Aug. 20, 1991) at the Lookout Mountain location and experiment 1 (June 18-July 31,1991) and experiment 2 (July 29-Aug. 31, 1991) at the Knoxville location

	Experiment Locations			
	Lookout Mountain		Knoxville	
Experiment number	**Sunny Plot**	**Shady Plot**	**Sunny Plot**	**Shady Plot**
#1				
Correlation Coefficient	.6865	.5012	.5019	.4641
Prob > R	.0001	.0004	.0001	.0001
#2				
Correlation Coefficient	-.2471	-.1828	.3284	.3684
Prob > R	.0271	.1002	.0227	.0249

Table 2. Dogwood anthracnose lesion type and percentages in both the sunny and shady plots at the Knoxville location for 1991

		Sunny Plot		Shady Plot	
Observations	**Lesion type**	**Experiment** #1[a]	#2[b]	**Experiment** #1	#2
% Anthracnose lesions	Purple	81	63	24	17
	Necrotic	19	37	76	83
% Acervuli formation	Purple	26	26	23	50
	Necrotic	92	96	75	77
% *Discula* spores	Purple	22	1	0	50
	Necrotic	75	70	73	77

[a]Experiment one occurred from June 18-July 26, 1991.
[b]Experiment two occurred from July 29-August 31, 1991.

Table 3. Dogwood anthracnose lesion data for both sunny and shady plots at the Knoxville location for 1991.

Observations	Lesion type	Sunny Plot Experiment #1[a]	Sunny Plot Experiment #2[b]	Shady Plot Experiment #1	Shady Plot Experiment #2
# Anthracnose lesions	Purple	9.8	13[c]	1.5	3.3
	STD[d]	4.6	5.5	3.0	4.0
	Necrotic	5.8	3.0	7.5	10
	STD	6.5	4.0	1.7	4.3
% Acervuli formation	Purple	21.8	33.2	50	40.6
	STD	21	14.1	0.0	52
	Necrotic	88.6	96	73	68.6
	STD	19	6.9	24	25
% *Discula* spores	Purple	6.3	19	50	0.0
	STD	12.5	13	0.0	0.0
	Necrotic	75.3	88.6	73	67.1
	STD	21.5	19	24	23.6

[a]Experiment one occurred from June 18-July 26, 1991.
[b]Experiment two occurred from July 29-August 31, 1991.
[c]Figures are an average of readings from four trees per plot with six leaves per tree.
[d]Standard deviation of the mean lesions per tree, with six leaves per tree with four trees in each plot.

Table 4. Dogwood anthracnose lesion type and percentages in both the sunny and shady plots at the Lookout Mountain location for 1991

Observations	Lesion type	Sunny Plot Experiment #1	Sunny Plot Experiment #2	Shady Plot Experiment #1	Shady Plot Experiment #2
% Anthracnose lesions	Purple	75[a]	84[b]	31	20
	Necrotic	25	16	69	80
% Acervuli formation	Purple	33	46	26	25
	Necrotic	92	91	93	86
% *Discula* spores	Purple	26	38	26	25
	Necrotic	92	91	81	86

[a]Experiment one occurred from May 29-July 3, 1991.
[b]Experiment two occurred from July 18-August 20, 1991.

Table 5. Dogwood anthracnose lesion data for both sunny and shady plots at the Lookout Mountain location for 1991.

Observations	Lesion type	Sunny Plot Experiment #1[a]	Sunny Plot Experiment #2[b]	Shady Plot Experiment #1	Shady Plot Experiment #2
# Anthracnose lesions	Purple	18.5[c]	16	3.5	4.5
	STD[d]	6.8	1.4	4.0	3.6
	Necrotic	6.3	3.0	10.8	12.6
	STD	4.2	2.9	6.4	7.6
% Acervuli formation	Purple	33.2	50.8	1.3	21.6
	STD	15	22	2.5	20
	Necrotic	92	94	90.3	90.5
	STD	6.9	9.8	13	6.5
% *Discula* spores	Purple	27.5	13.2	1.3	21.6
	STD	14.5	10	2.5	20
	Necrotic	92	94	84	90.5
	STD	6.9	9.8	13.4	6.5

[a]Experiment one occurred from May-29-July 3, 1991.
[b]Experiment two occurred from July 18-August 20, 1991.
[c]Figures are an average of readings from four trees per plot with six leaves per tree.
[d]Standard deviation of the mean lesions per tree, with six leaves per tree with four trees in each plot.

APPENDIX B

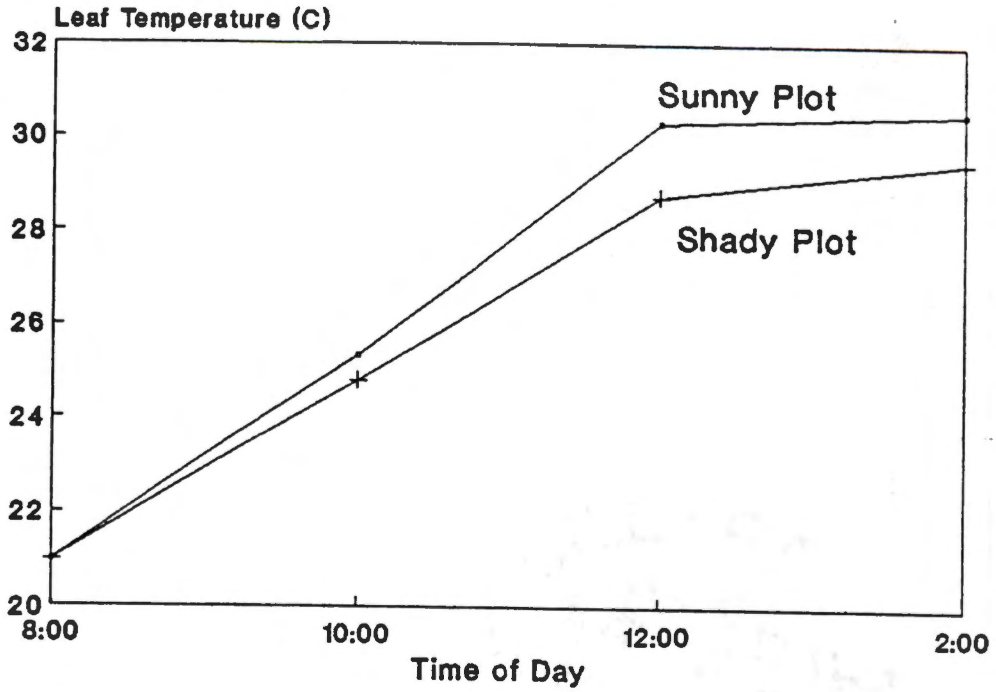


Figure 1. Average leaf temperature of the sunny plot versus the shady plot on a sunny day at the Lookout Mountain location on 7/26/90.

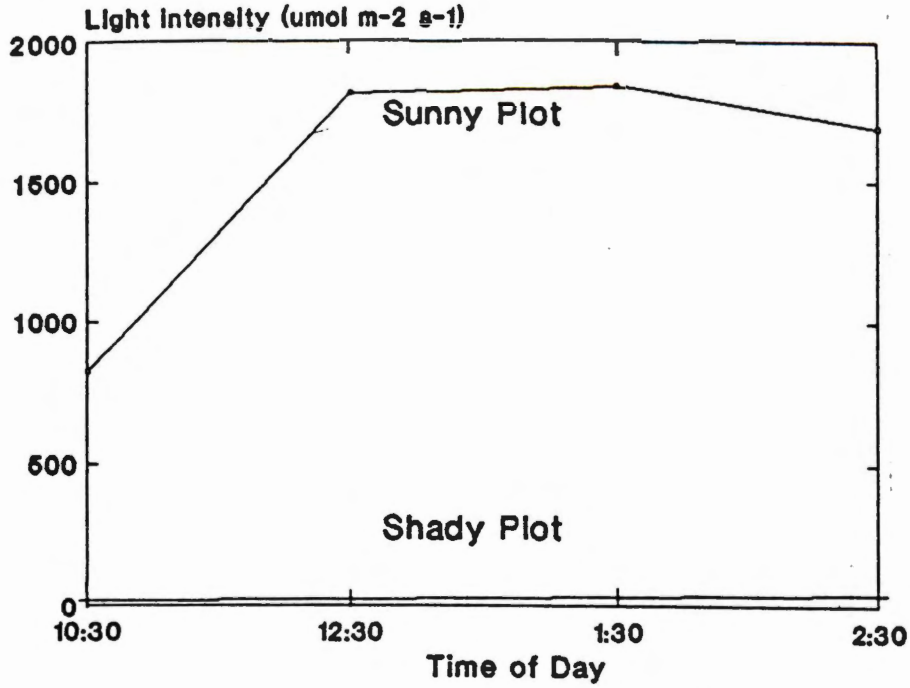
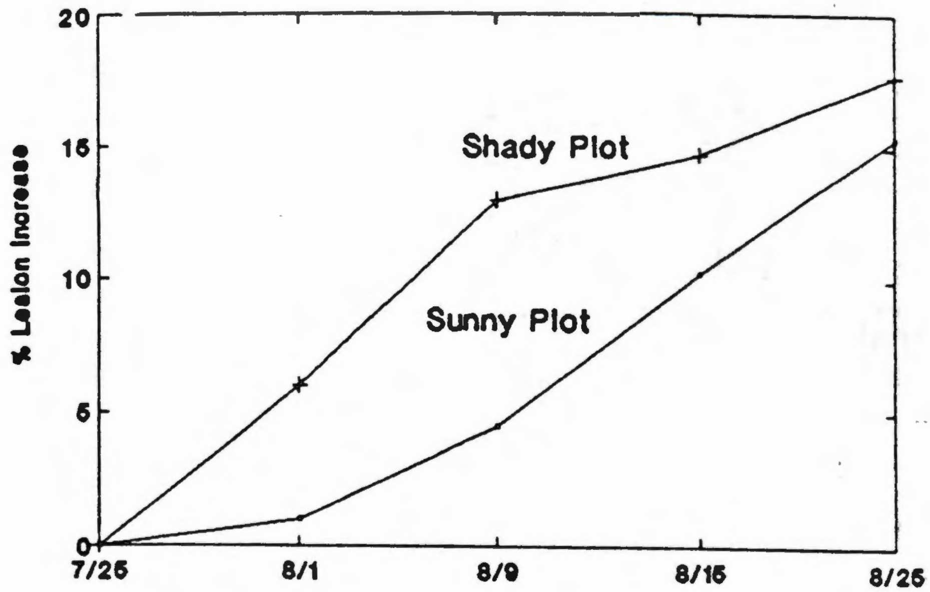
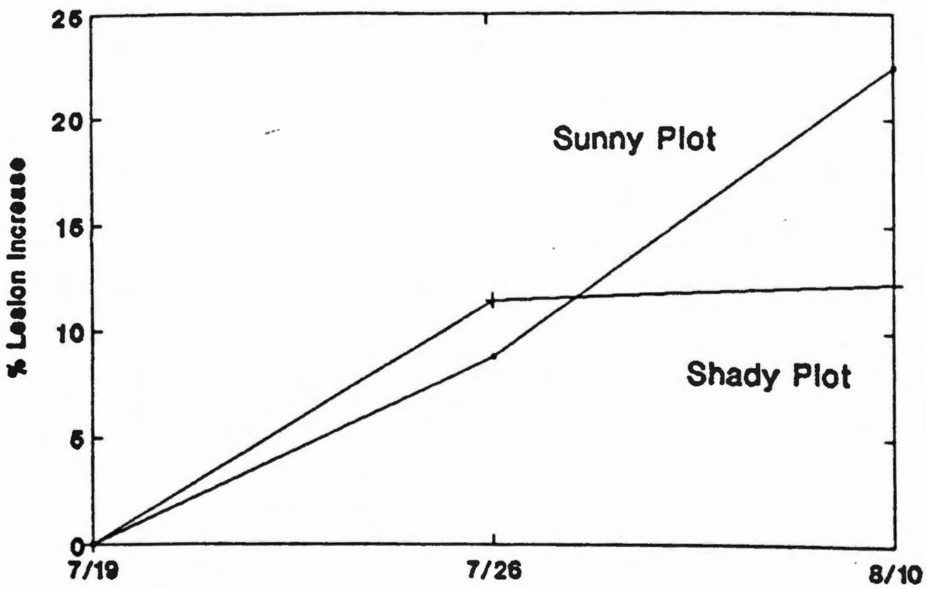


Figure 2. Average light intensity on a sunny day of the sunny plot versus the shady plot at Lookout Mountain on 8/10/90.



	7/25	8/1	8/9	8/15	8/25
Average Daily <u>Leaf Temperature</u>					
Sunny Plot	30.9	26.6	29.4	27.9	27.2
Shady Plot	30.4	25.2	26.9	26.9	25
Average Daily <u>Light Intensity</u>					
Sunny Plot	1403	822	818	549	857
Shady Plot	14	10	19	22	18

Figure 3. Percent anthracnose lesion increase of the sunny plot versus the shady plot at the Knoxville location between July 25 and August 25, 1990 (Top figure) with the average daily leaf temperatures and light intensities.



	7/19	7/26	8/10
Average Daily <u>Leaf Temperature</u>			
Sunny Plot	25.6	26.8	25.1
Shady Plot	25.6	26.2	22.9
Average Daily <u>Light Intensity</u>			
Sunny Plot	1112	920	1542
Shady Plot	44	26	30

Figure 4. Percent anthracnose lesion increase of the sunny plot versus the shady plot at the Lookout Mountain location between July 19 and August 10, 1990 (Top figure) with the average daily leaf temperatures and light intensities.

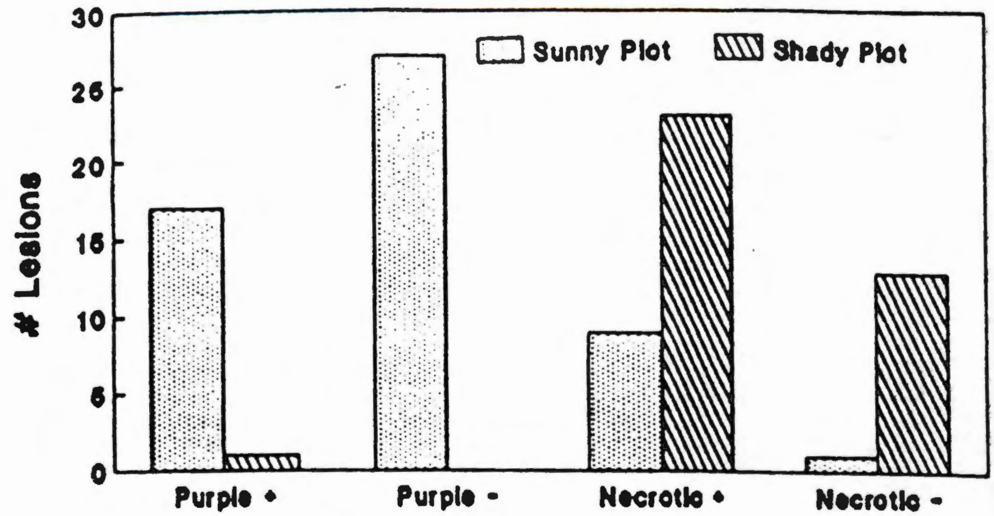


Figure 5. Number and type of dogwood anthracnose lesions that did (+) or did not (-) develop acervuli on the leaves in the sunny and shady plots at Lookout Mountain in August of 1990.

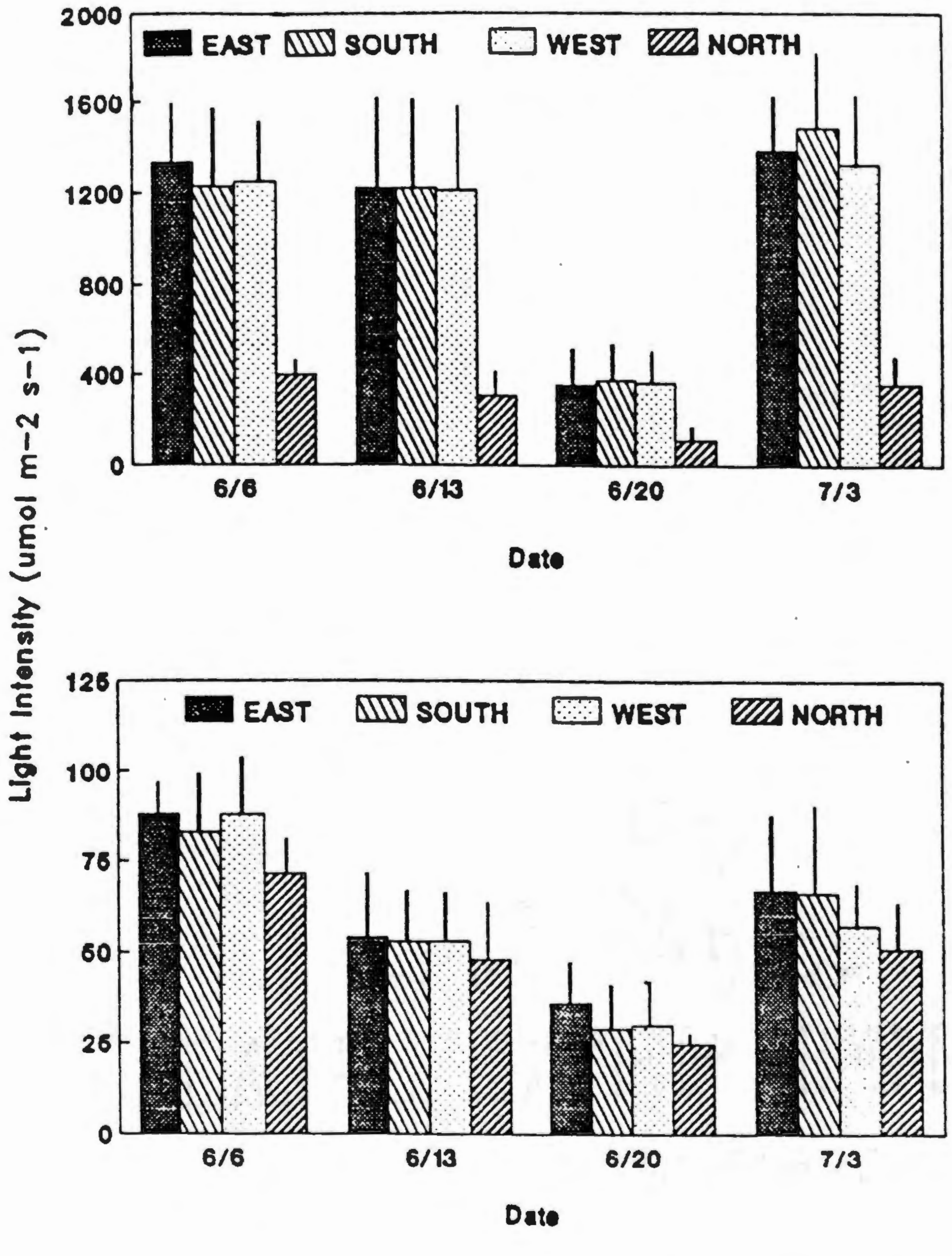


Figure 6. Mean light intensity data collected on the sunny (top graph) and the shady plots (bottom graph) at the Lookout Mountain location (June 6-July 3, 1991). Bars represent the standard error of the mean.

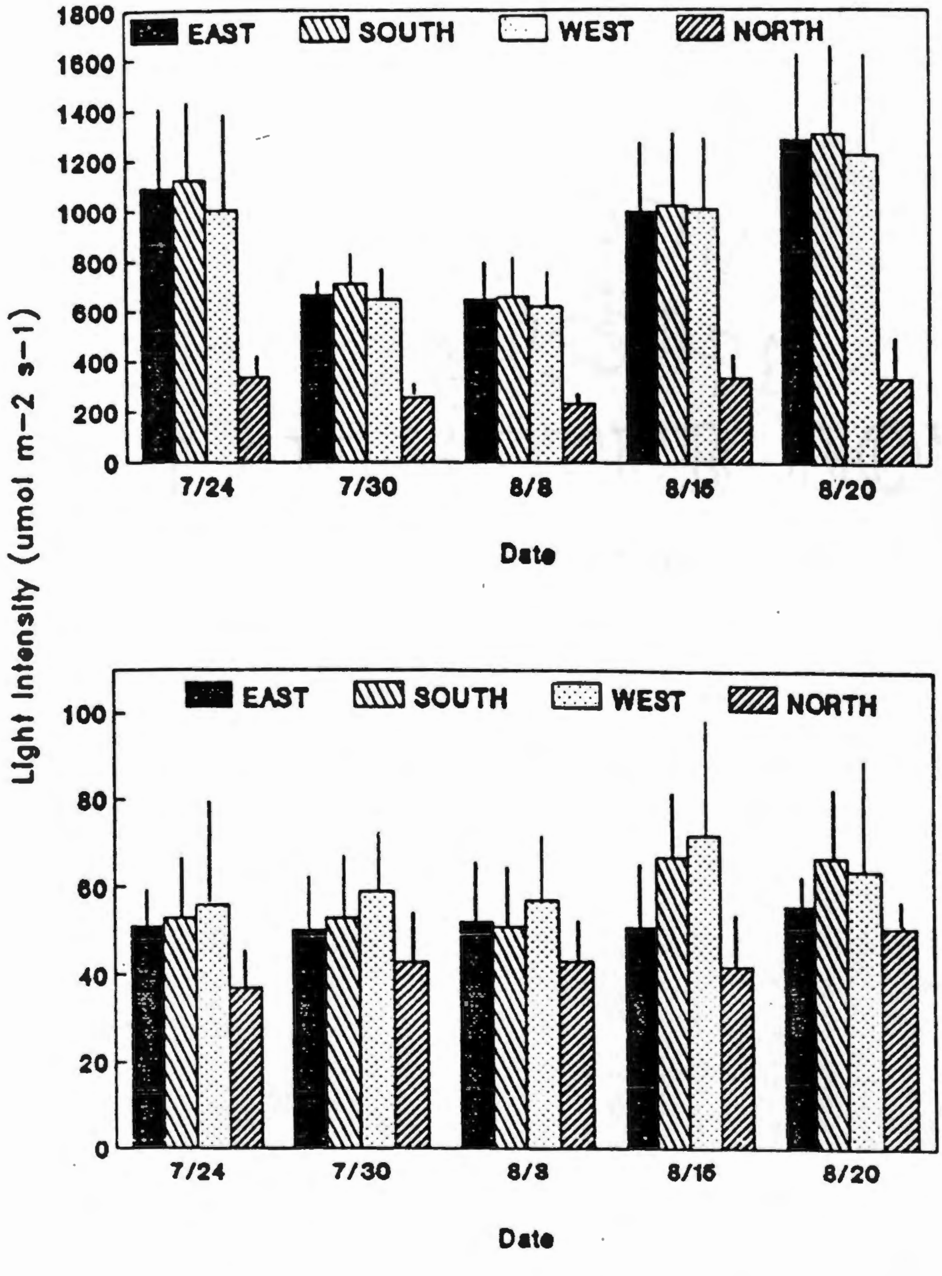


Figure 7. Mean light intensity data collected on the sunny (top graph) and the shady plots (bottom graph) at the Lookout Mountain location (July 24-Aug. 20, 1991). Bars represent the standard error of the mean.

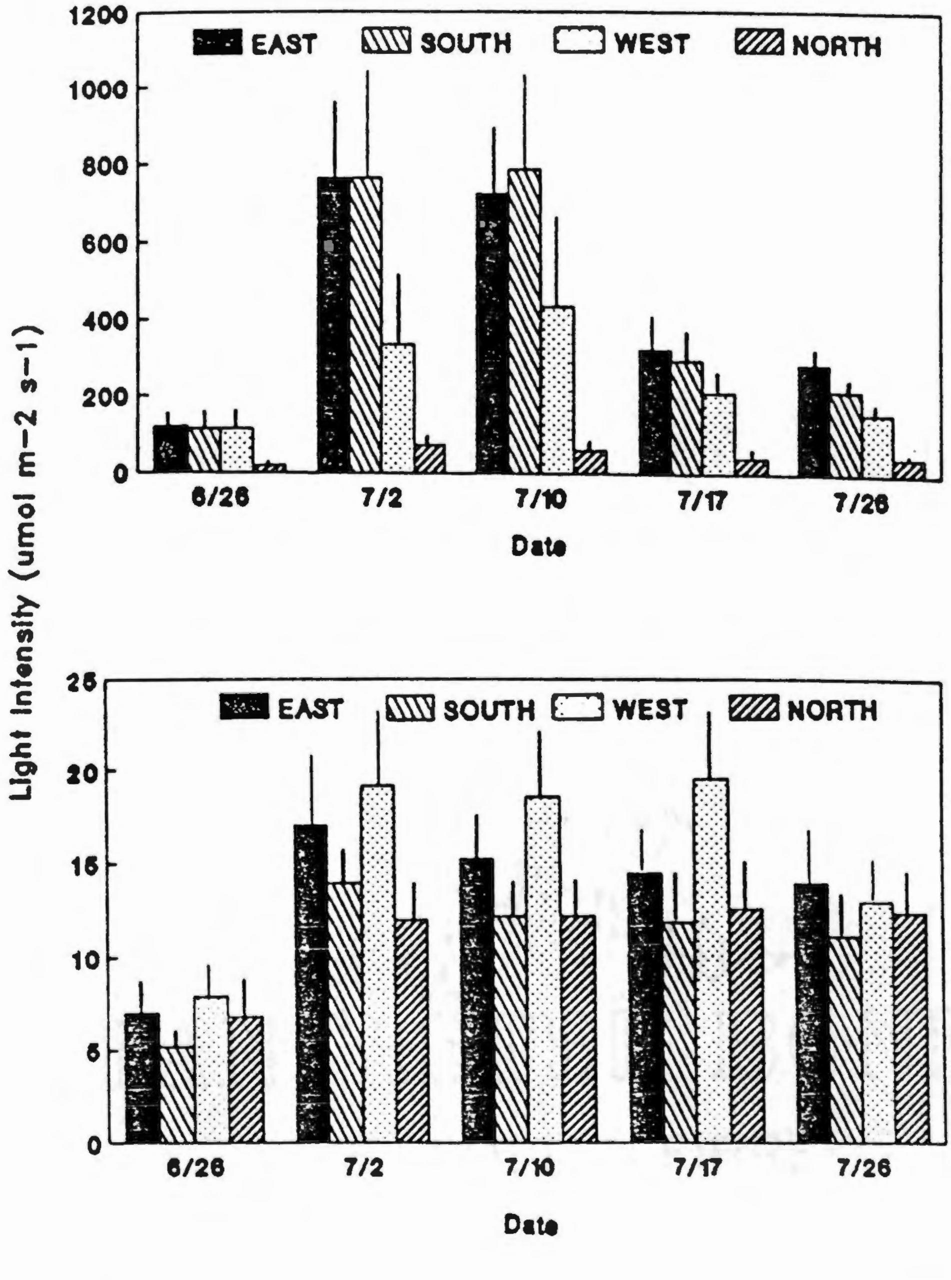


Figure 8. Mean light intensity data collected on the sunny (top graph) and the shady plots (bottom graph) at the Knoxville location (June 26-July 26, 1991). Bars represent the standard error of the mean.

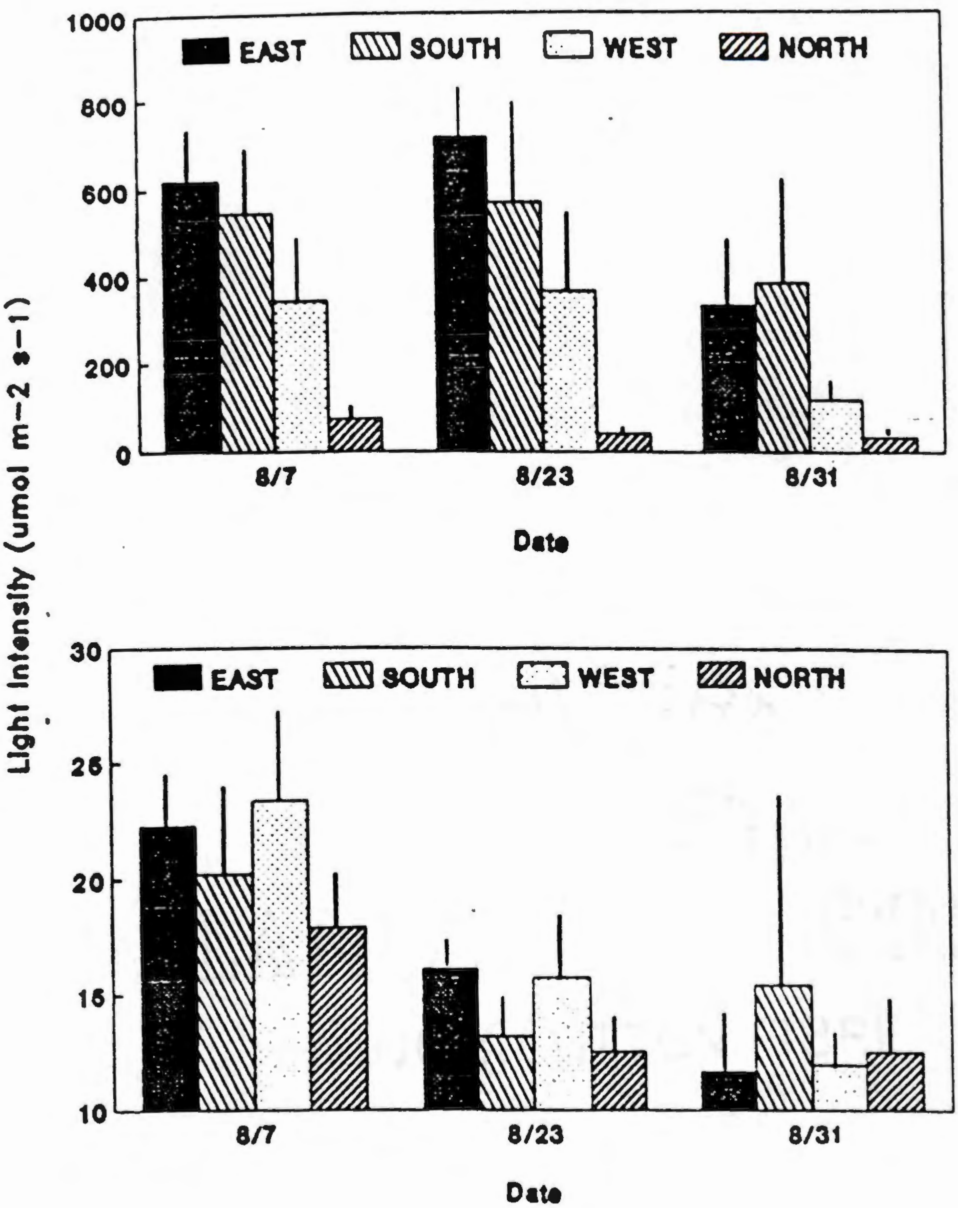


Figure 9. Mean light intensity data collected on the sunny (top graph) and the shady plots (bottom graph) at the Knoxville location (Aug. 7-Aug. 31, 1991). Bars represent the standard error of the mean.

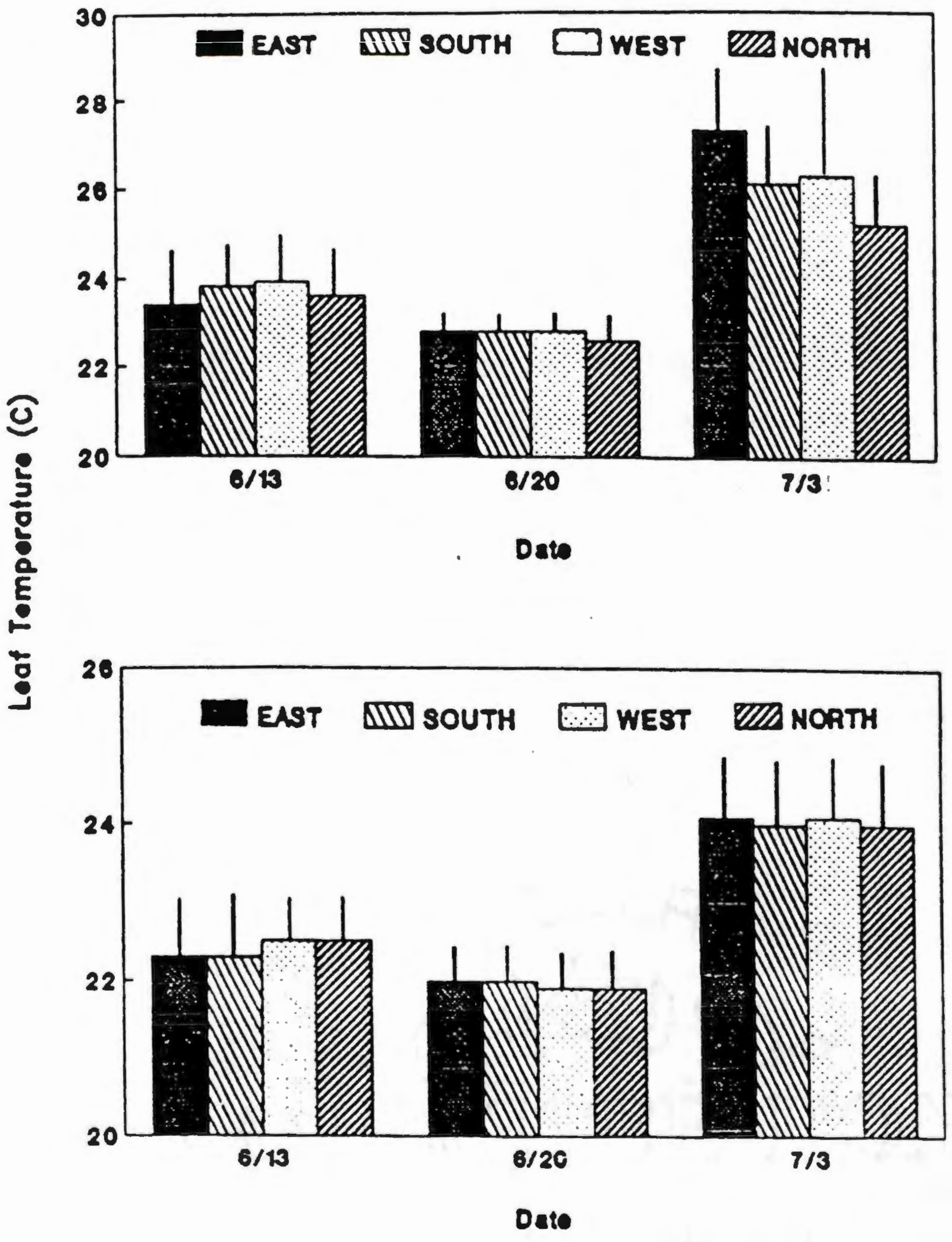


Figure 10. Mean leaf temperature data collected on the sunny (top graph) and the shady plots (bottom graph) at the Lookout Mountain location (June 13-July 3, 1991). Bars represent the standard error of the mean.

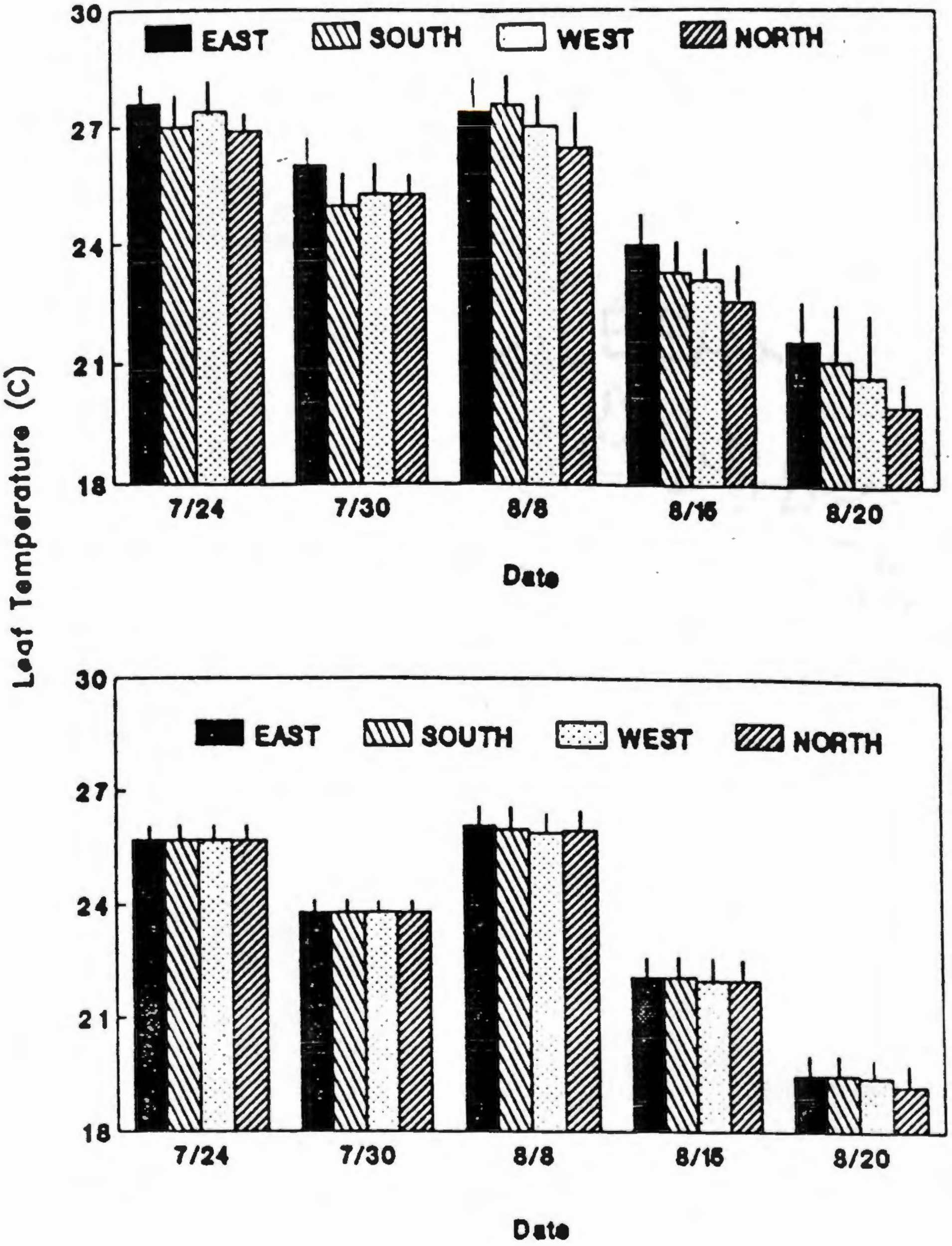


Figure 11. Mean leaf temperature data collected on the sunny (top graph) and the shady plots (bottom graph) at the Lookout Mountain location (July 24-Aug. 20, 1991). Bars represent the standard error of the mean.

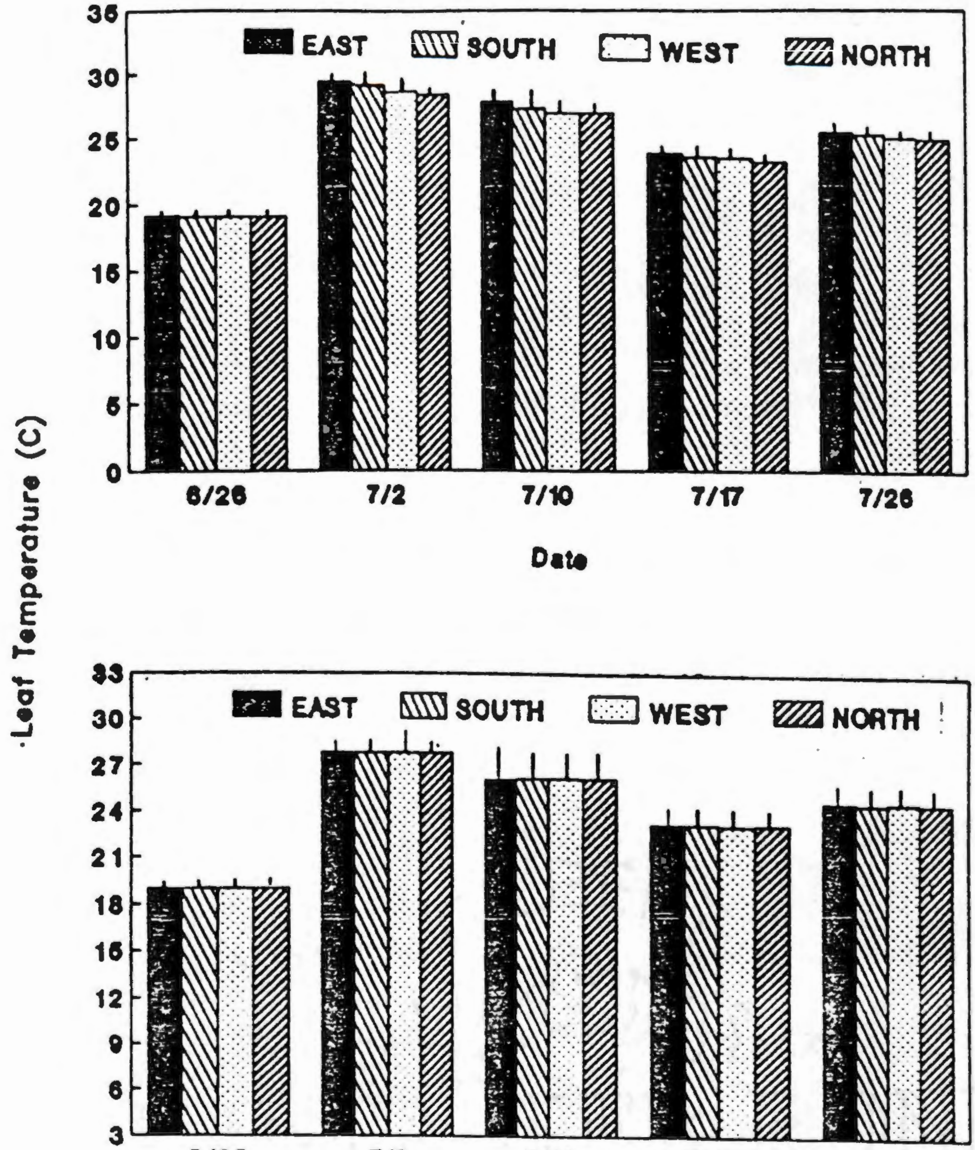


Figure 12. Mean leaf temperature data collected on the sunny (top graph) and the shady plots (bottom graph) at the Knoxville location (July 26-July 26, 1991). Bars represent the standard error of the mean.

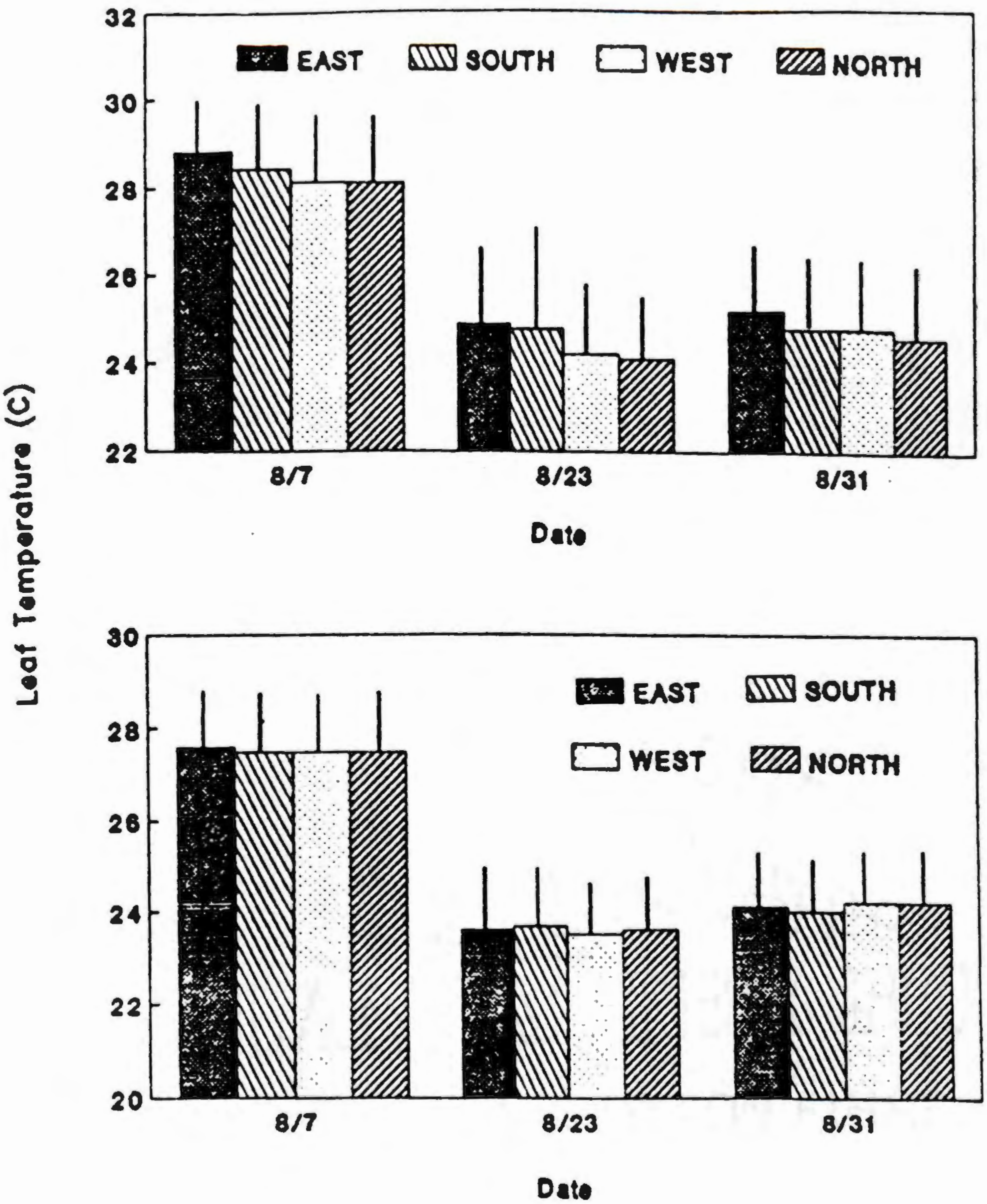


Figure 13. Mean leaf temperature data collected on the sunny (top graph) and the shady plots (bottom graph) at the Knoxville location (Aug. 7-Aug. 31, 1991). Bars represent the standard error of the mean.

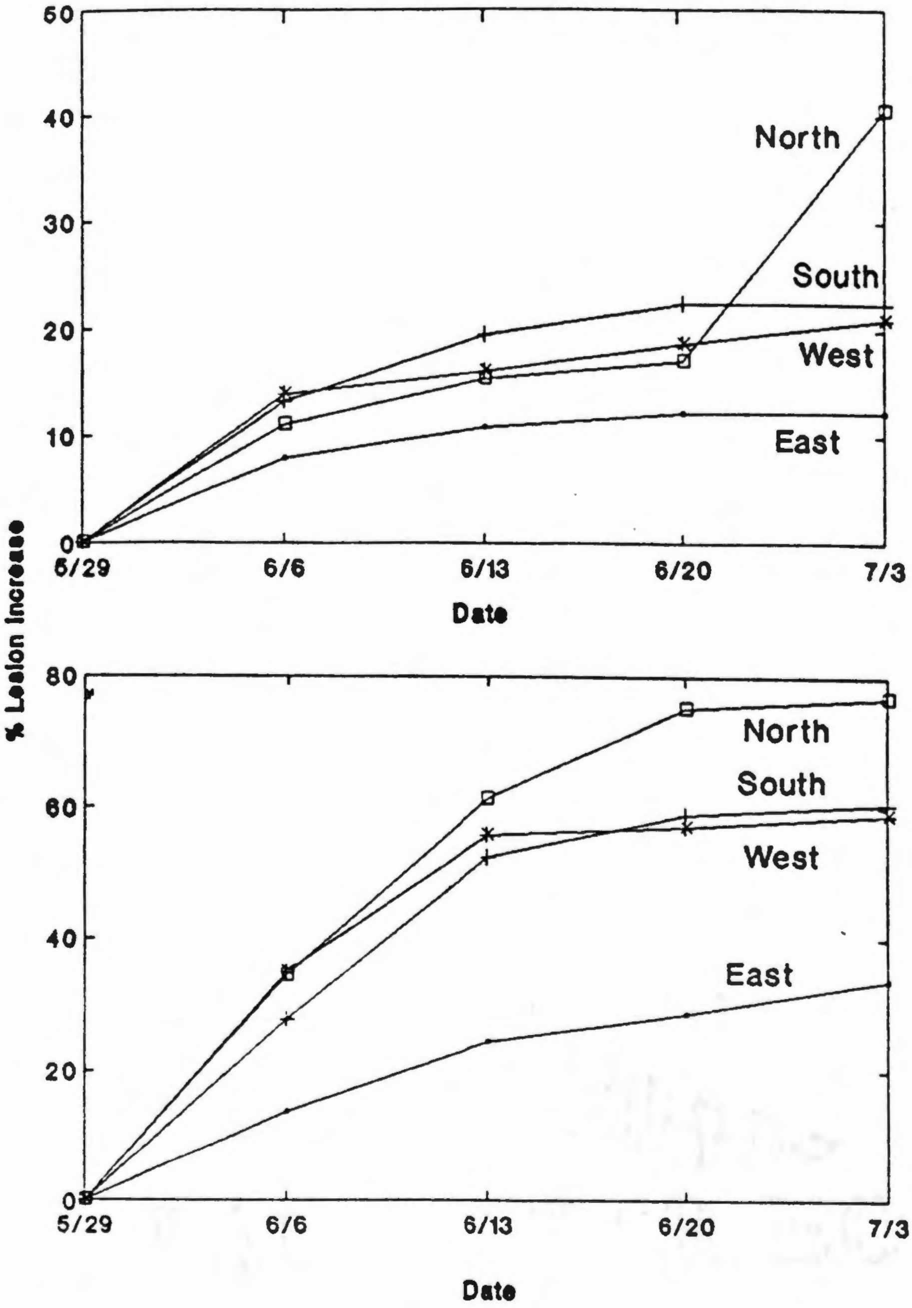


Figure 14. Effects of foliage location on rate of increase of dogwood anthracnose lesion size in sunny (top graph) and shady (bottom graph) plots at Lookout Mountain (May 29-July 3, 1991).

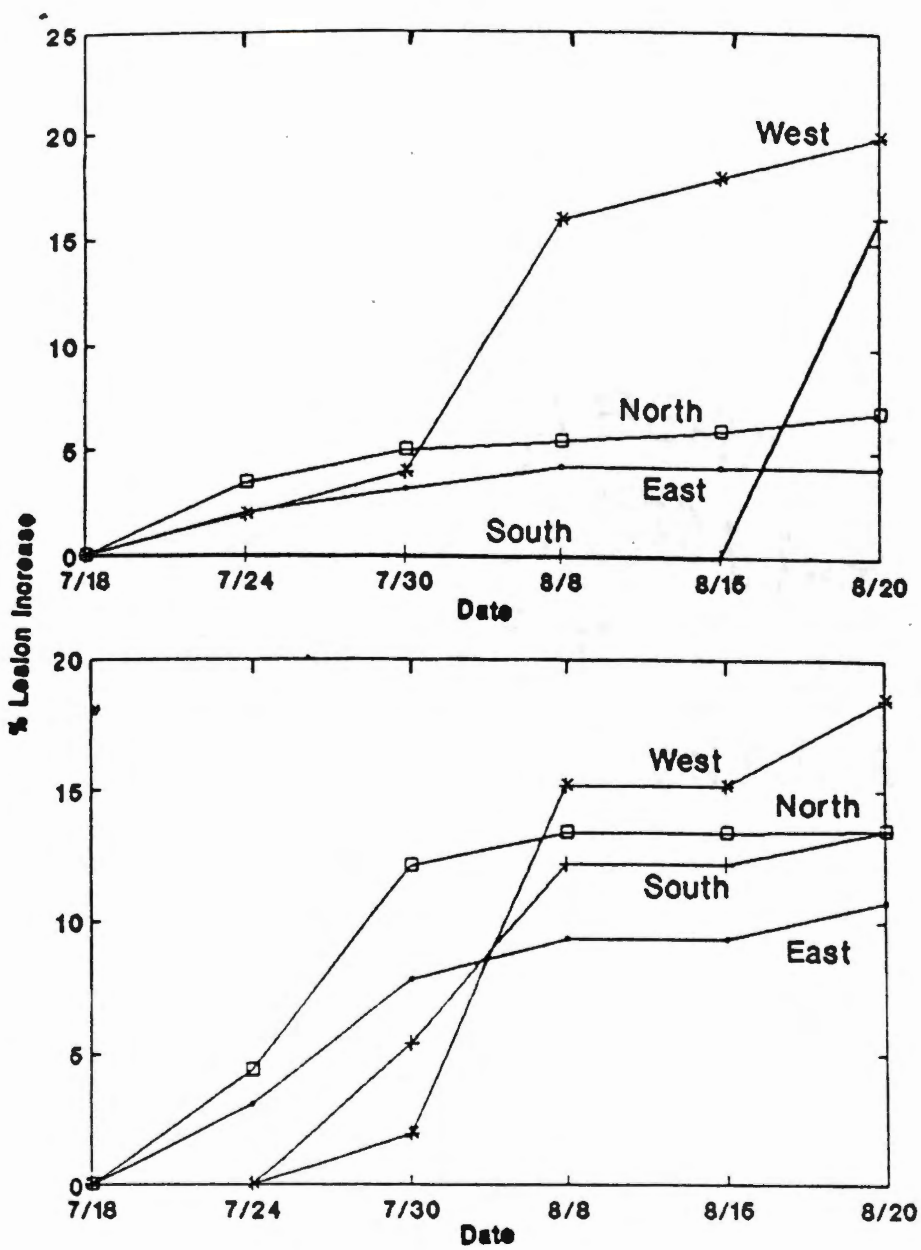


Figure 15. Effects of foliage location on rate of increase of dogwood anthracnose lesion size in sunny (top graph) and shady (bottom graph) plots at Lookout Mountain (July 18-Aug. 20, 1991).

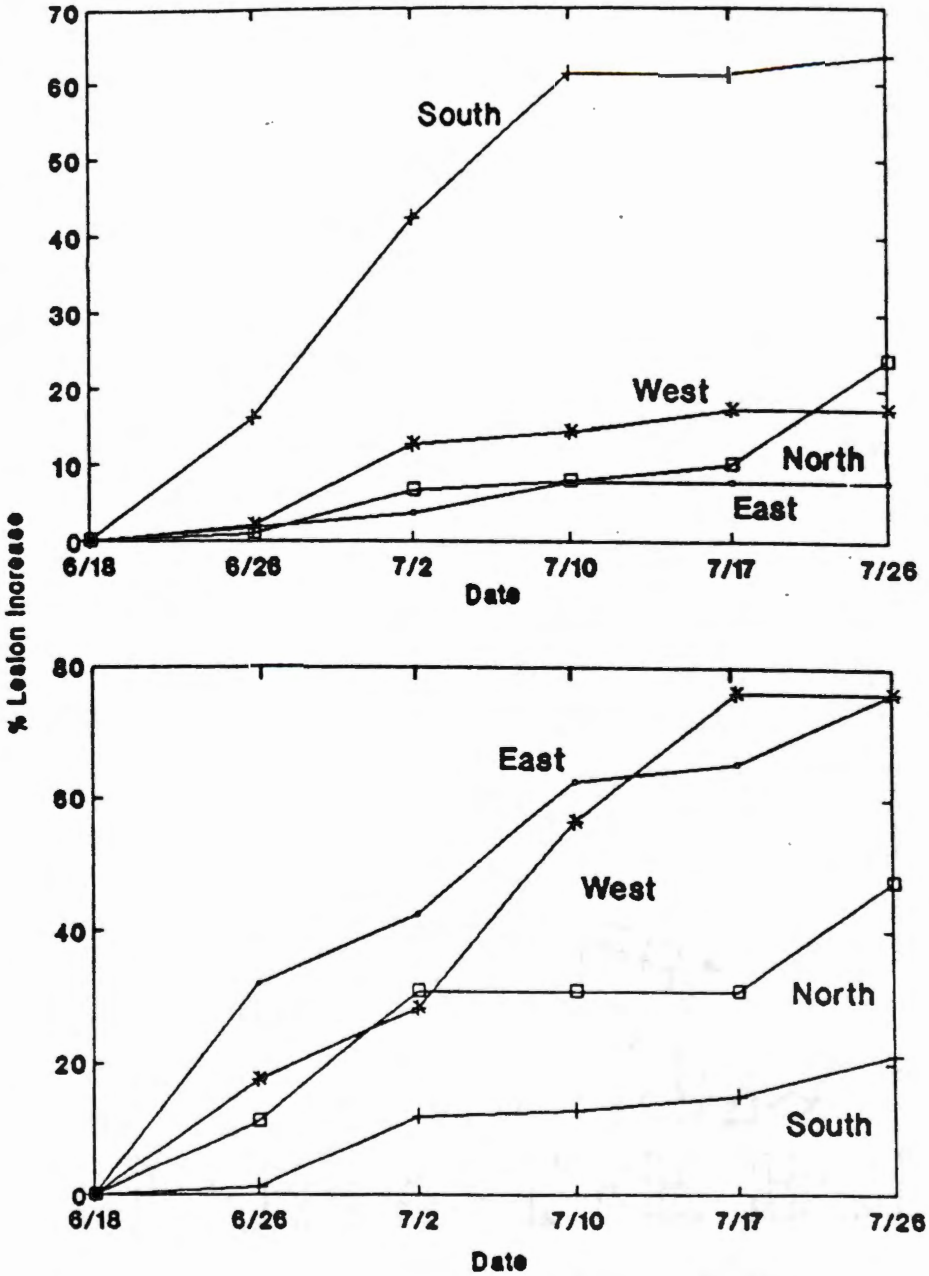


Figure 16. Effects of foliage location on rate of increase of dogwood anthracnose lesion size in sunny (top graph) and shady (bottom graph) plots at Knoxville (June 18-July 26, 1991).

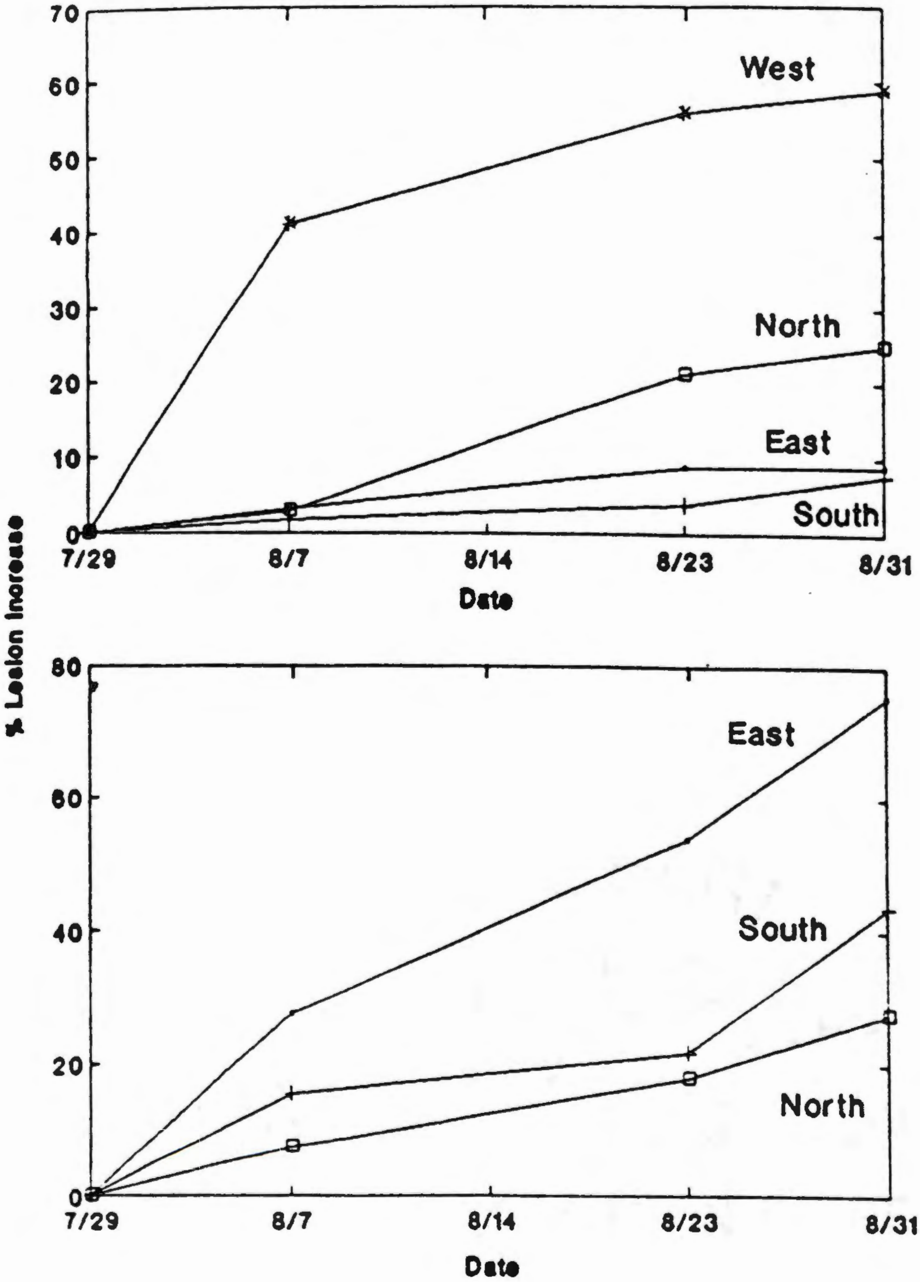


Figure 17. Effects of foliage location on rate of increase of dogwood anthracnose lesion size in sunny (top graph) and shady (bottom graph) plots at Knoxville (July 29-Aug. 31, 1991).

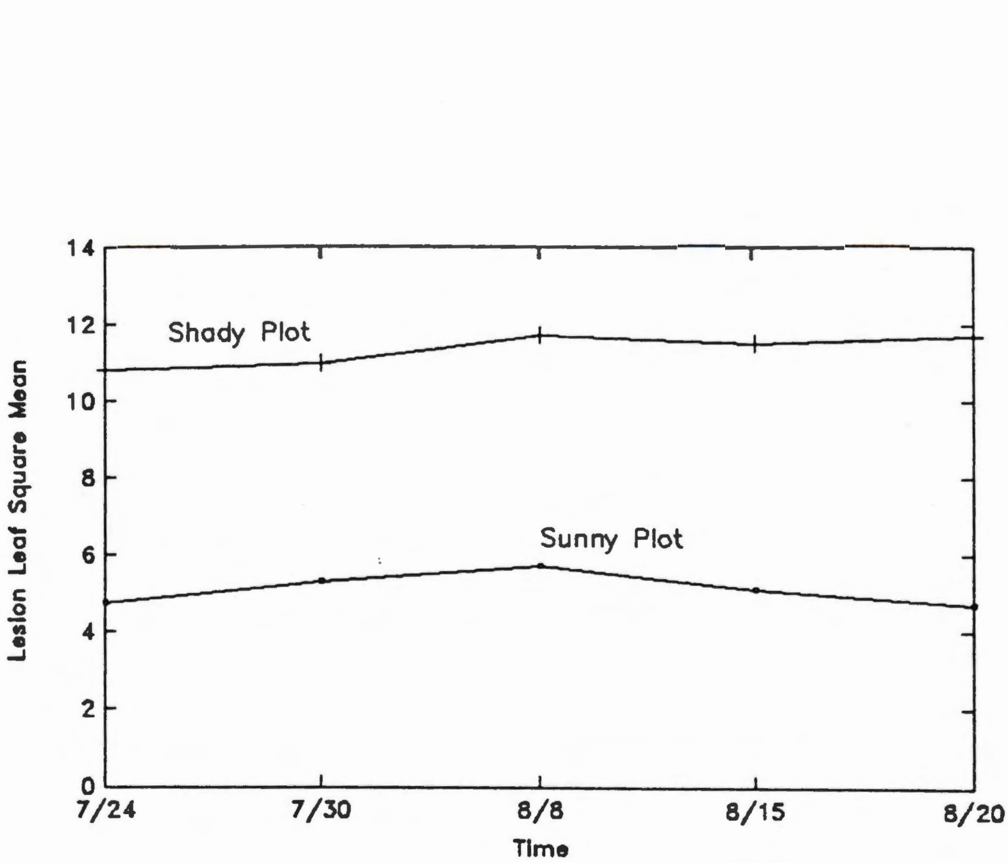


Figure 18. The lesion leaf square means of anthracnose lesions in the sunny versus the shady plot at Lookout Mountain during the second experiment with light intensity and leaf temperature as covariables (F=2.3 with Pr>0.087)

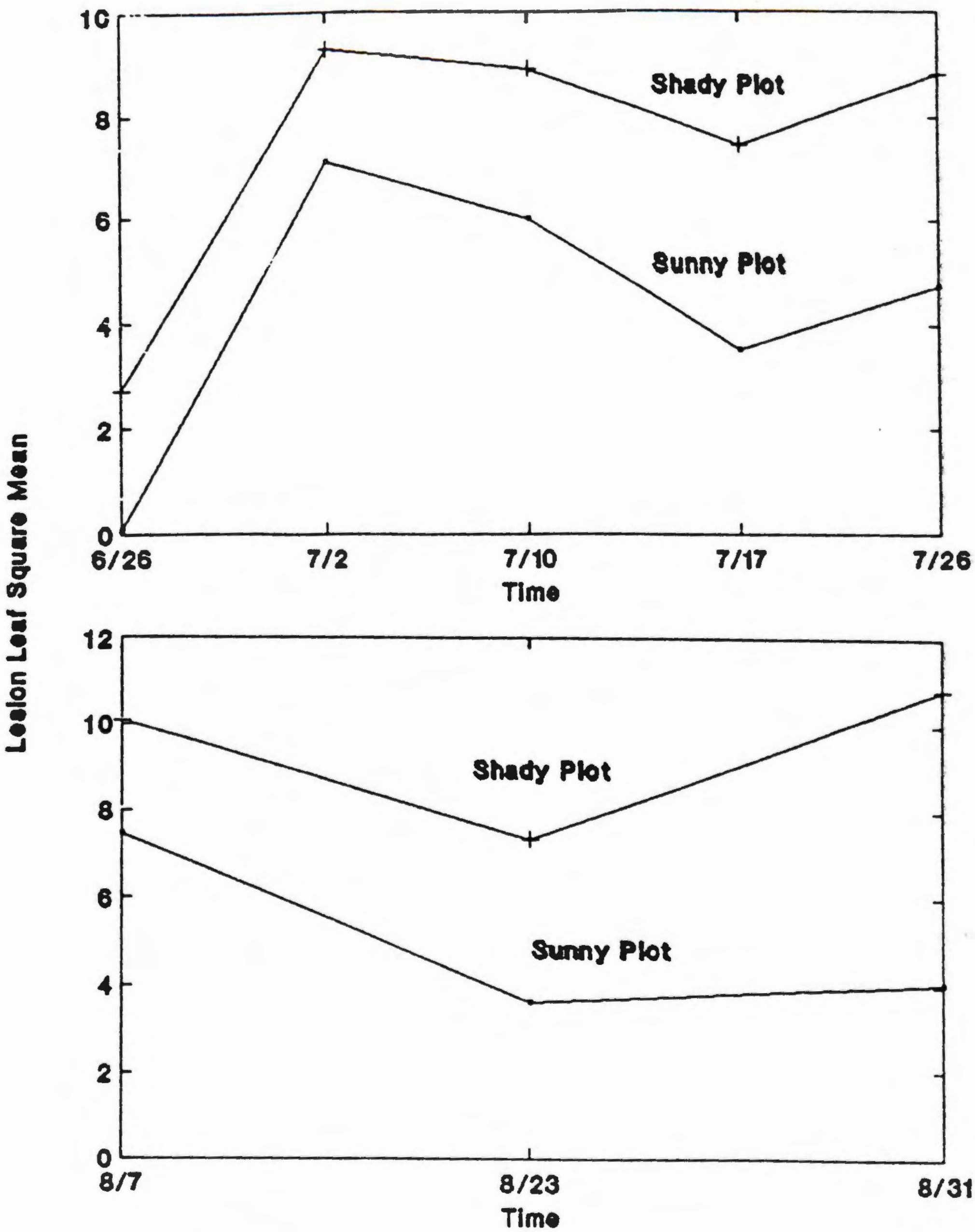


Figure 19. The lesion leaf square means of anthracnose lesions in the sunny versus the shady plot at Knoxville during the first experiment (F=0.92 with Pr>0.46) (top graph) and the second experiment(F=2.02 with Pr>0.17) (bottom graph) with light intensity and leaf temperature as covariables.

APPENDIX C

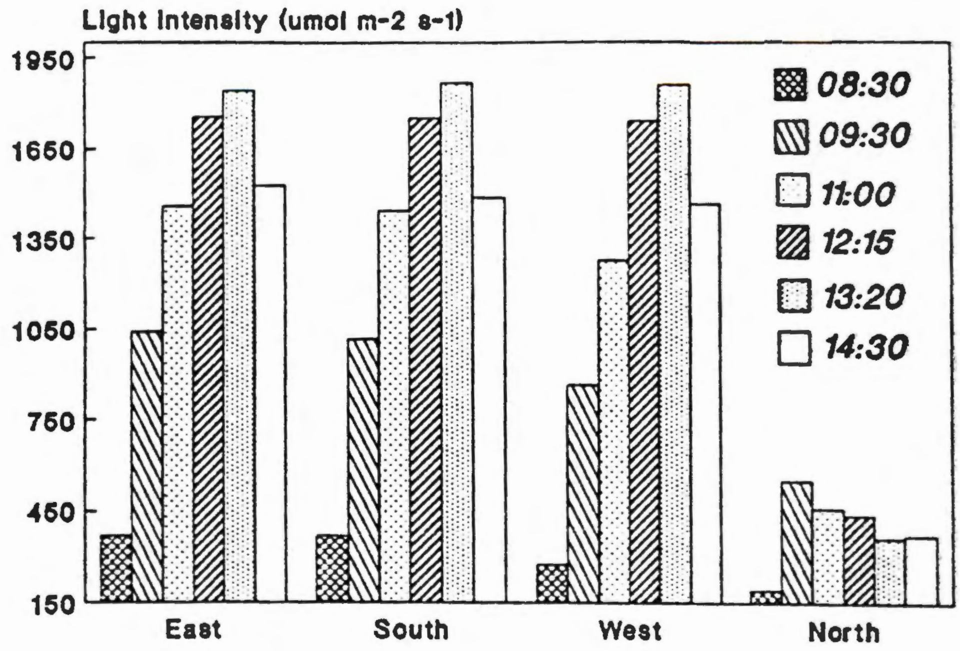


Figure 1. Comparison of light intensities from all aspects in the sunny plot at Lookout Mountain on June 6, 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

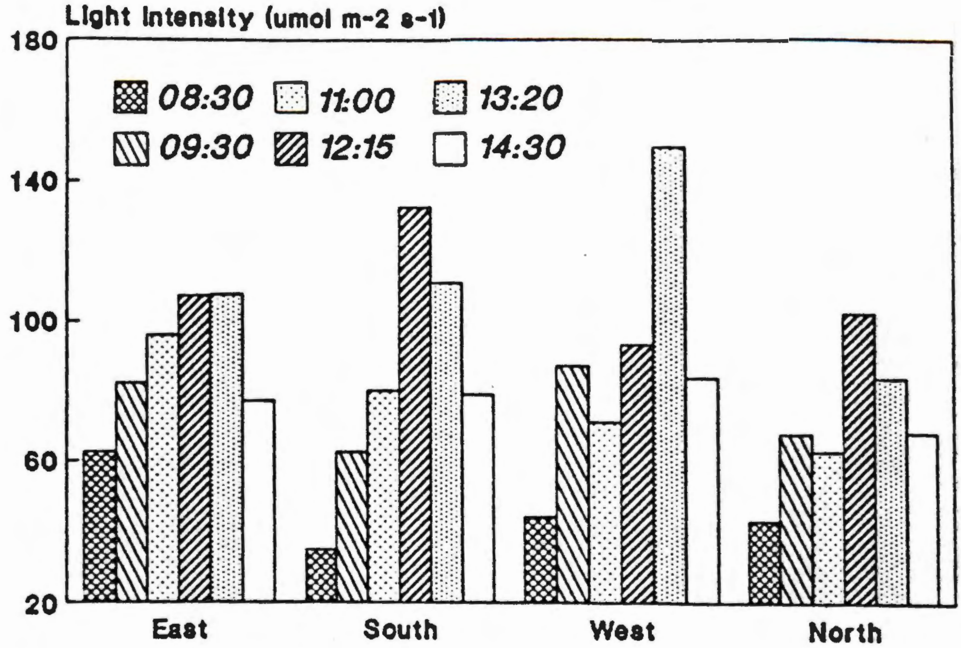


Figure 2. Comparison of light intensities all aspects in the shady plot at Lookout Mountain on June 6, 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

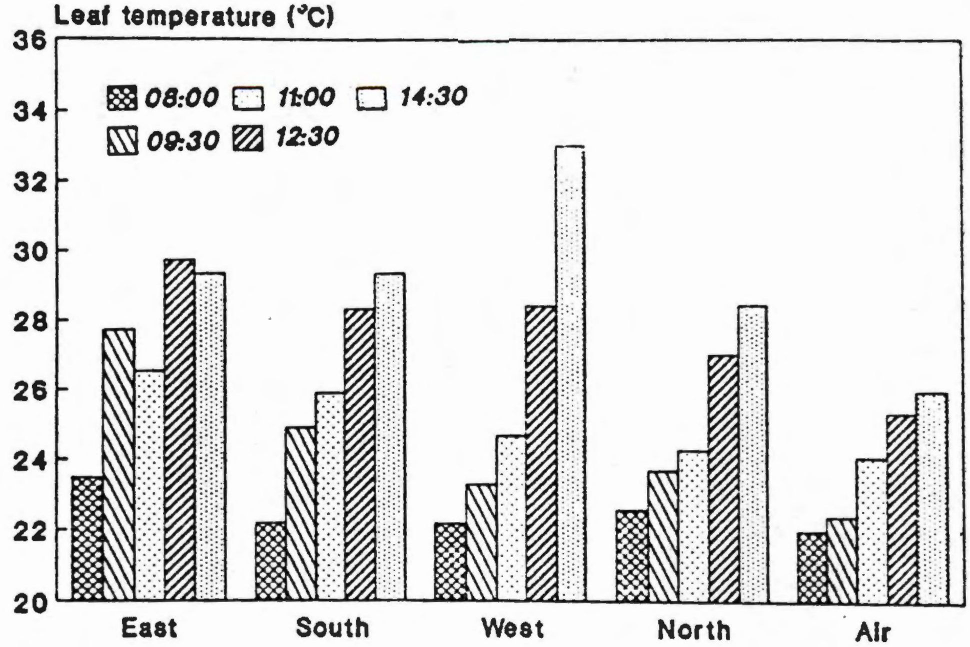


Figure 3. Comparison of leaf temperature with the ambient air temperature from all aspects in the sunny plot at Lookout Mountain on July 3, 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

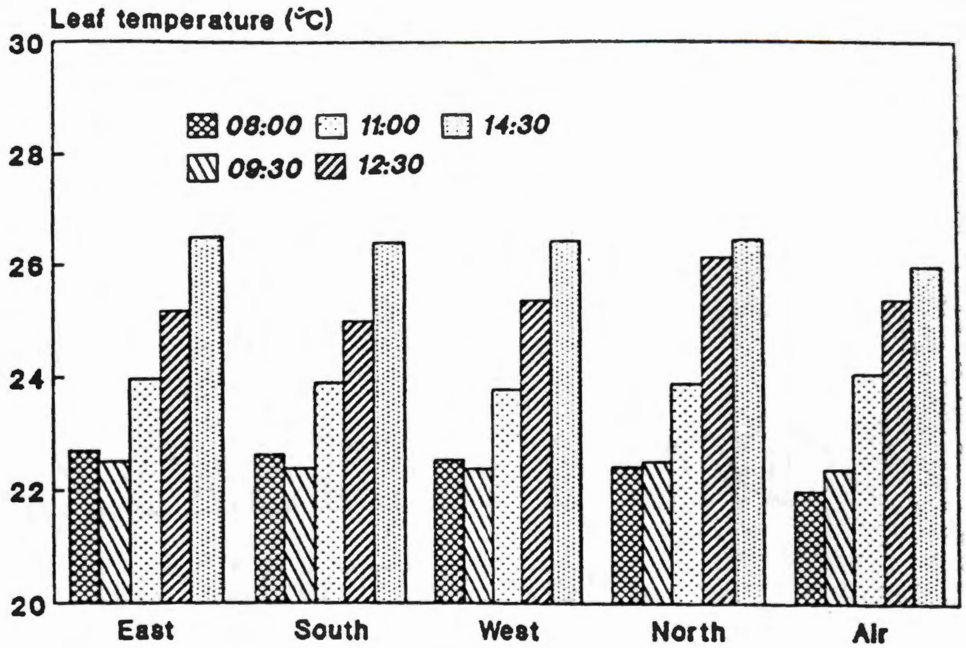


Figure 4. Comparison of leaf temperature with the ambient air temperature from all aspects in the shady plot at Lookout Mountain on July 3, 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

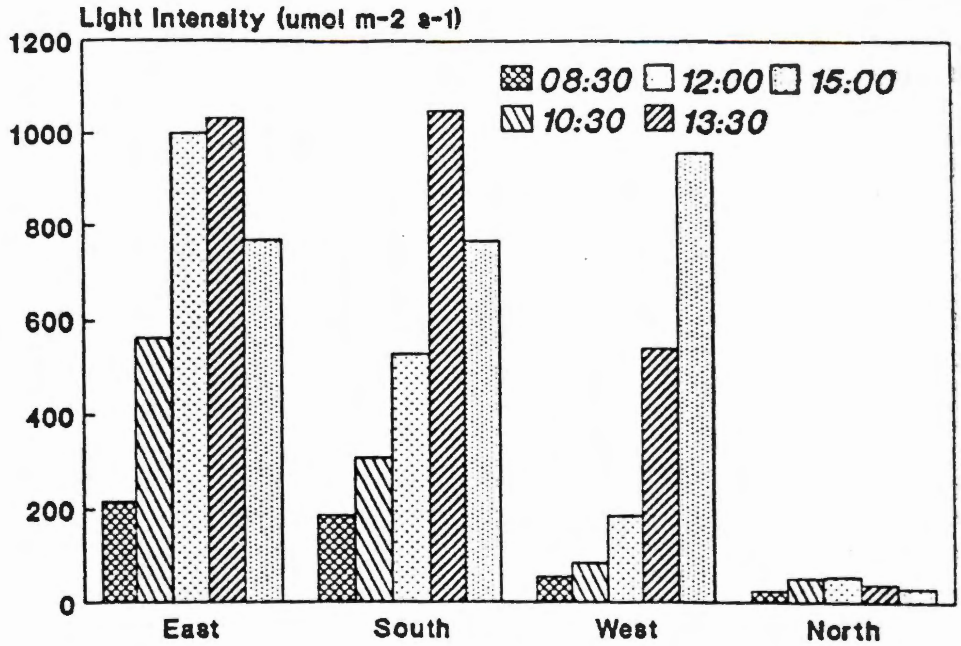


Figure 5. Comparison of light intensities from all aspects in the sunny plot at Knoxville on Aug. 23, 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

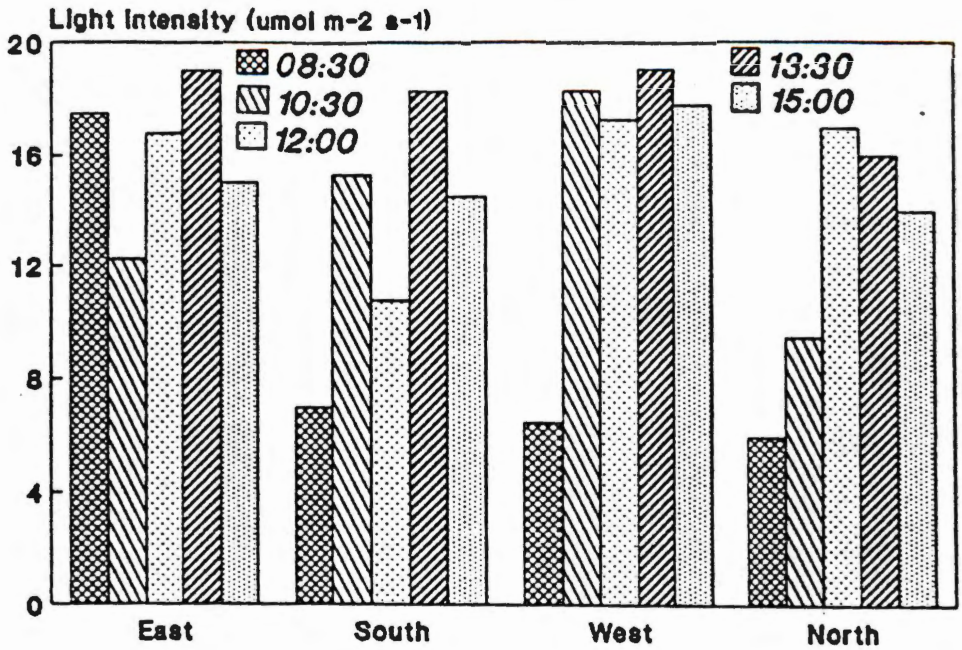


Figure 6. Comparison of light intensities from all aspects in the shady plot at ~~Knoxville on Aug. 23,~~ 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

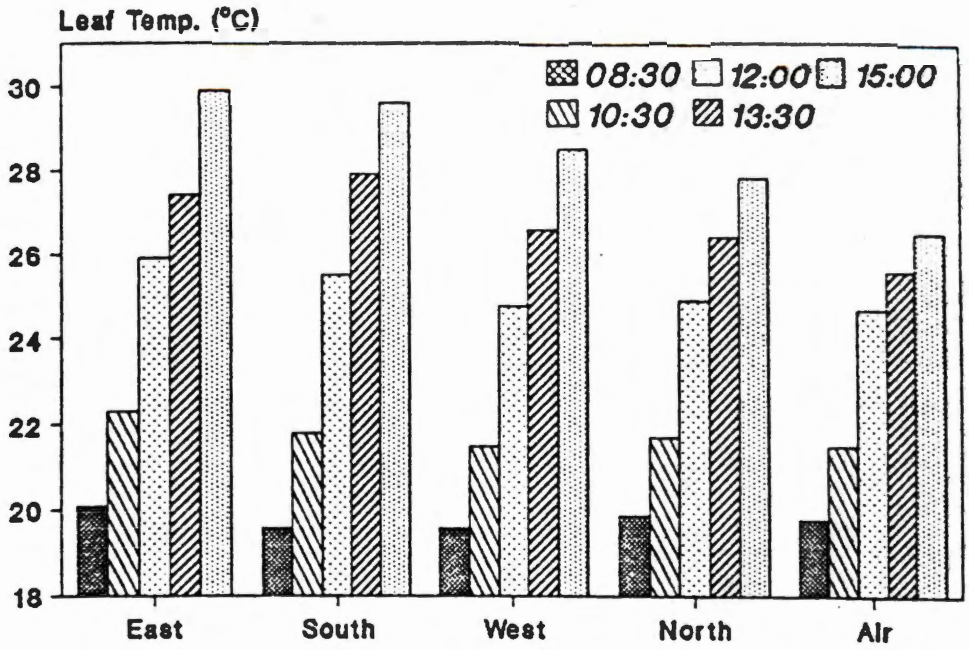


Figure 7. Comparison of leaf temperatures and the ambient air temperature from all aspects in the sunny plot at Knoxville on Aug. 23, 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

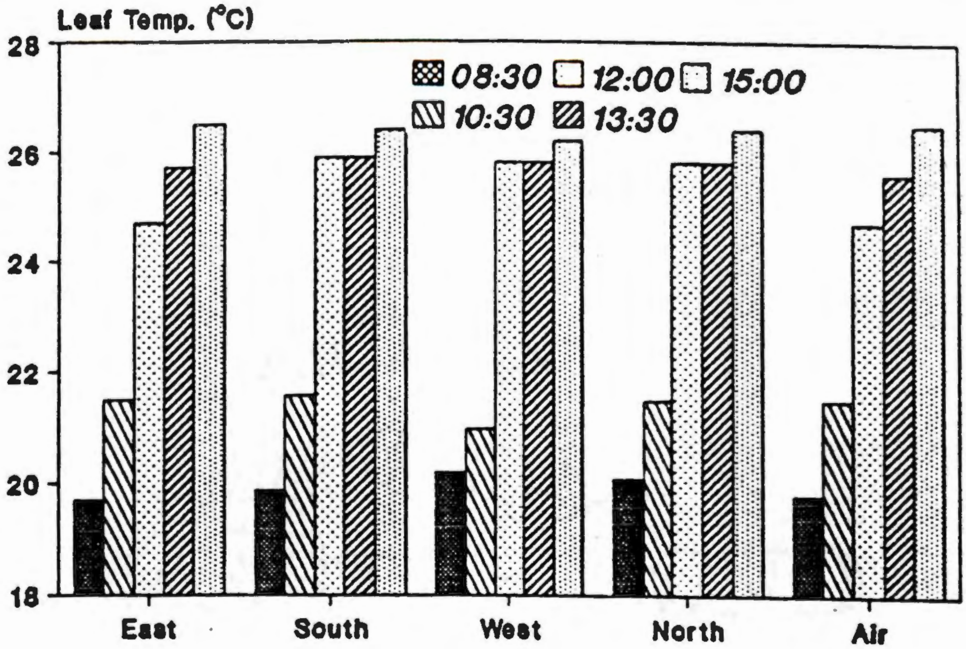


Figure 8. Comparison of leaf temperatures and the ambient air temperature from all aspects in the shady plot at Knoxville on Aug. 23, 1991. For each aspect, bars from left to right represent increasing time from 8:00 AM to 3:00 PM.

VITA

John Malcolm Parham was born on April 2, 1968 in Nashville, Tennessee. He attended David Lipscomb High School and graduated in May of 1986. He attended David Lipscomb University and received his B. S. degree in Biology in May of 1990. Three weeks later, he accepted a graduate research assistantship at the University of Tennessee, Knoxville and began working toward a Masters of Science in Plant Pathology. He married Sheila Craft on May 4, 1991 in Nashville, Tennessee. He graduated with his M. S. in Plant Pathology in 1992.

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