The Effects of Sun, Shade, and Predation on Azalea Lace Bug Populations in Containerized Azaleas

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SUMMARY. The effects of sun and shade in a small monocultural nursery-like environment and the effect of natural enemies on the population density of azalea lace bugs (*Stephanitis pyrioides* Scott) on azaleas (*Rhododendron* L.) in the nursery environment were assessed. A comparison of sun and shade treatments for total number of azalea lace bug eggs collected and eclosed revealed no significant ($P < 0.05$) differences. Stippling damage did not differ significantly between sun and shade treatments. Therefore, lace bug oviposition or eclosion were not affected by sun or shade. Arthropods collected from 5 weeks of beat samples were divided into four feeding guilds: predator-parasitoid (eight families), chelicerates (six families), chewing herbivores (two families), and piercing-sucking herbivores (nine families). Guilds were not significantly different between sun and shade treatments. In the small monocultures designed for this experiment, the 4 guilds do not appear to show preference for sun or shade habitats. No significant differences in azalea lace bug populations between caged and uncaged azalea cuttings in the nursery environment

indicate there were no consequential effects of predation or parasitism on egg eclosion or subsequent instars in the first generation.

Previous research indicates azaleas growing in full-day or afternoon sun are more than twice as likely to be infested with azalea lace bugs and subsequent aesthetic damage is more severe (Raupp, 1984; Trumbule et al., 1995). However, lace bugs prefer feeding and ovipositing on azaleas grown in 50% and 75% shade when predators are excluded (Trumbule and Denno, 1995). Higher arthropod predation causes lace bug survivorship to be significantly lower in shaded woodlots than in open sunny areas (Trumbule et al., 1995) because they provide better habitats for arthropod predators (Leddy, 1996). The differences in lace bug populations between complex and simple landscapes in earlier studies by Leddy (1996) were attributed to higher lace bug mortality in complex landscapes and were due to predation and were not a direct result of light intensity or temperature.

In a nursery, azaleas are often placed in temporary lots with plants in kind, creating a low diversity environment. These plants may be exposed to full sun or grown under shaded areas. A better understanding of what conditions encourage lace bug populations could help nurserymen improve management of azalea lace bug populations. It is unknown whether previous differences observed between sun and shade are the direct result of light intensity or broader induced variables such as habitat diversity or duration of establishment. The objectives of these experiments were 1) to determine differences between azalea lace bugs densities and associated arthropods in containerized azaleas placed in sun and shade and 2) to determine if first-generation azalea lace bug populations differ between cohorts exposed to or isolated from natural enemies in the nursery environment.

Materials and methods

EXPERIMENT 1. Five 12 × 9 ft (6 × 3 m) areas in an open grassy field at the Cherry Farm Insectary, Clemson, S.C., were covered with 4-mil [0.004-inch (0.1-mm)] black plastic lining and 3 inches (7.5 cm) of bark mulch and

divided in half. One half of each area remained open and exposed to full sun, while the other half was covered with the shade of a 9 × 9 ft (3 m) 49% shade polypropylene black shade cloth (Park Seed, Greenwood, S.C.) placed on a 4.5 × 4.5 × 4.5 ft (1.5 m) metal frame. The sides of the shade frames were left open to a height of 28 inches (70 cm) to allow for free arthropod movement. Thus, two experimental treatments, sun and shade, were created in each plot.

Each 12 × 9 ft (6 × 3 m) area contained 12 'Coral Bell' azaleas in 1-gal (3.79-L) pots, six grouped for exposure to sun and six grouped under shade, creating five sun-shade treatment replicates. Drip irrigation was provided for 20 min daily between 1500 and 1800 HR. To establish lace bug populations for treatment, adults were collected from established azaleas in Clemson in May and June 1996 and placed the azaleas in plots. Eight male and 28 female *S. pyrioides* were added to each six-pot group of azaleas. Adults were placed on the top center foliage.

For each treatment, light intensity above and within foliage and temperature and relative humidity within foliage were measured within each plot using an Extech Instruments light meter (Forestry Suppliers, Jackson, Miss.) and an Oakton Thermohygrometer Kit (Forestry Suppliers, Jackson, Miss.). For 8 d (18 to 21 June and 25 to 28 June 1996), light intensity (above foliage), and temperature and percent relative humidity (RH) were measured at 1000, 1400, and 1600 HR. Light intensity (above and within foliage), temperature, and percent RH were measured weekly between 1400 and 1600 HR (2 July to 16 Oct. 1996).

Two lace bug-damaged stippled leaves were randomly collected weekly for 11 consecutive weeks (2 July to 21 Sept.) from one plant in each plot. Leaves were brought into the laboratory and examined under a dissecting microscope to observe and record egg parasitism and lace bug egg populations. The plant from which leaves were taken was tipped and beaten over a funnel to dislodge and collect insects in a jar of 70% alcohol weekly for 5 consecutive weeks (2 July to 2 Aug. 1996). Beat samples were grouped into four feeding guilds: 1) herbivores with piercing-sucking mouthparts, 2)

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Table 1. Means ($\pm$ SE) of environmental readings for light intensity above and within the foliage, percent relative humidity and temperature within azalea foliage between sun and shade treatments at 1000, 1400, and 1600 HR during presampling (18 to 21 July and 25 to 28 July) and for weekly afternoon sampling readings (2 July to 16 Oct. 1996).

Reading	Sun	Shade
Light above foliage (lx) ^z		
1000 HR	885.0 (27.342)	450.5 (12.231)
1400 HR	1108.9 (94.486)	567.8 (48.461)
1600 HR	952.6 (43.975)	486.1 (32.581)
Afternoon	864.2 (40.970)	408.1 (20.592)
Light within foliage (lx)		
Afternoon	26.9 (2.762)	
Temperature (°F) ^y		
1000 HR	83.8 (32.641)	83.7 (32.621)
1400 HR	95.2 (33.359)	94.1 (33.233)
1600 HR	94.3 (33.100)	93.2 (33.120)
Afternoon	90.1 (32.950)	89.4 (32.918)
Relative humidity (%)		
1000 HR	59.6 (0.988)	58.8 (1.066)
1400 HR	48.7 (2.315)	48.6 (2.098)
1600 HR	40.1 (1.476)	40.4 (1.366)
Afternoon	45.0 (0.819)	44.6 (0.825)

^z1.0 lx = 0.0929 fc.

^y°C = 5/9(°F - 32).

herbivores with chewing mouthparts, 3) spiders, and 4) other generalist predators and parasitoids. Arthropod specimens were separated into individual vials and identified to family. For 13 consecutive weeks (24 July to 9 Oct.) each plot was rated on a scale of 1 to 5 for intensity of stippling, with 1 = 0% stippling and 5 = 100% stippling damage on all six plants in the plot.

A two-way analysis of variance (ANOVA) was used to determine if significant differences ($P \leq 0.05$) existed between sun and shade for each feeding guild. Leaf samples, beat samples and environmental readings were analyzed by a two-way ANOVA to determine if significant differences ($P \leq 0.05$) existed between sun and shade over time.

EXPERIMENT 2. One hundred-twenty 'Fashion' 12 cm azalea cuttings were rooted in 7 inches (17.5 cm) of PVC pipe containing peatmoss. Cuttings were maintained in a wooden frame covered in 2-mil [0.002-inch (0.05-mm)] clear plastic to maintain humidity until well rooted. About 2500 adult azalea lace bugs were collected from Valdosta, Ga., on 3 Mar. 1997, $\approx$ 2 weeks before the anticipated occurrence of azalea lace bug adults in Clemson. To infest cuttings with eggs, adult lace bugs were placed on cuttings for 1 week, then removed. Sixty of the cuttings were covered with a

wire mesh cage wrapped in white organandy to prevent invasion of predators and other arthropods into the cages.

Two weeks after adults were removed, cuttings were paired (caged and uncaged) in 2-gal plastic pots and placed randomly in an azalea area at Gro-Mor Nurseries, Easley, S.C. Ten pairs were randomly removed and permanently returned to the laboratory in each of 6 sequential sampling periods during 15 and 22 Apr. and 16, 13, 20, and 27 May 1997. Cuttings were examined for egg, nymphal and adult populations, and parasitism. All data were analyzed using a t test to determine if significant differences ($P \leq 0.05$) existed between caged (predator excluded) and uncaged (predator accessible) first generation cohorts.

Results and discussion

EXPERIMENT 1. There were no significant differences for percent RH or light intensity within the foliage, but there were significant differences in light intensity above the foliage and temperature for sun and shade treatments (Table 1). Significant differences for temperature existed between treatments and for interaction between date and treatment at 1000 HR but not later in the day ($P \leq 0.001$ and 0.001, respectively). This was due to the faster rate of warming of ambient air in the sun treatment than the shade treat-

ment. Light intensity above the foliage did differ significantly between sun and shade treatments at 1000 ($P \leq 0.001$), 1400 ($P \leq 0.001$), and 1600 HR ($P \leq 0.001$) and during afternoon sampling ($P \leq 0.001$). This was expected because of the 47% shade cloth used. Light intensity above the foliage also differed significantly between the date $\times$ treatment interaction at 1400 ($P \leq 0.001$), 1600 HR ($P \leq 0.001$), and during afternoon sampling ($P \leq 0.001$), indicating light intensity changed over time. Although the sun-shade treatments created significant differences for light intensity above the canopy, there was a lack of significant differences for percent RH or light intensity within the foliage between treatments or interaction. Therefore, these treatments would not account for differences observed, if any, in arthropod populations or azalea lace bug feeding damage.

A comparison of treatments for the total number of azalea lace bug eggs and eclosed eggs showed no significant differences at $P \leq 0.05$. Means ($\pm$ SE) for eclosed eggs in sun and shade were 0.382 (± 0.15) and 0.436 (± 0.20), respectively (Fig. 1). Therefore, lace bug oviposition or eclosion was not affected by treatment.

In this study, stippling damage ratings did not differ significantly between sun and shade treatments or in date $\times$ treatment interactions. Therefore, there was no significant change in stippling damage over time. Means ($\pm$ SE) for stippling damage by week are shown in Fig. 2. The lack of significant differences suggests that in small monocultures of containerized azaleas,

Fig. 1. Mean number of total azalea lace bug eggs and eclosed eggs per two azalea leaves collected weekly from sun and 49% shade-exposed containerized azaleas over 11 consecutive weeks from 2 July to 21 Sept. 1996. Bars represent standard error of the mean.

Fig. 2. Mean stippling damage on a scale of 1 (0% stippling damage) to 5 (100% stippling damage) for sun and shade treatments collected from 13 consecutive weekly samples (24 July to 9 Oct. 1997). Bars represent standard error of the mean.

Fig. 3. Mean number of individuals grouped by feeding guild, spiders, piercing-sucking herbivores (p/s), chewing herbivores, and predators-parasitoids (p/p) on sun- and shade-exposed containerized azaleas collected from five consecutive weekly beat samples from 2 July to 2 Aug. 1996. Bars represent standard error of the mean (SE).

sun and shade are not factors in determining feeding preference.

The arthropods collected fell into four guilds according to their feeding habits or taxonomic classification: predator-parasitoid (eight families), spiders (six families), chewing herbivores (two families), and piercing-sucking herbivores (nine families). Guild means ($\pm$ SE) were calculated from 5 weeks of beat samples (Fig. 3). There were no significant differences between sun and shade treatments for any guild in beat samples at values of $P \leq 0.05$. A lack of date $\times$ treatment interactions indicates no change in guild populations over time. This study indicates that sun-exposed or shaded plants may not make a difference in azalea lace bug egg populations, stippling damage, or feeding guilds in a nursery setting.

EXPERIMENT 2. Azalea cuttings had a mean ($\pm$ SE) of 75.09 ($\pm$ 6.00) total lace bug eggs each before placement in the nursery on 8 Apr. 1997. No eclosion occurred in the samples taken at 1 and 2 weeks following placement in the nursery, so the third sample was taken 4 weeks after initial placement. Mean maximums, the highest number observed from samples collected, ($\pm$ SE) of 31.00 ($\pm$ 8.57) and 50.9 ($\pm$ 17.23) eclosed eggs were found on caged and uncaged cuttings, respectively (Fig. 4). Mean maximum observed densities per cutting for second, third, fourth and fifth instars were 7.50 ($\pm$ 6.75), 4.10 ($\pm$ 2.28), 3.50 ($\pm$ 1.95) and 1.20 ($\pm$ 0.59) for caged cuttings and 1.10 ($\pm$ 0.99), 1.20 ($\pm$ 0.99), 1.40 ($\pm$ 1.29) and 1.5 ($\pm$ 1.10) for uncaged cuttings, respectively.

Adults were found in both caged and uncaged treatments. Based on population densities of fourth and fifth stadia in the sixth sample of this experiment, additional fifth instars and adults may have been observed in a seventh or eighth sample if collected, but could not have exceeded the number of fourth instars present. Changes in population density in both treatments

over time may be due to death during, before and after eclosion and ecdysis.

Although low numbers of potential natural enemies, mostly spiders, were observed visually throughout this experiment, no significant differences were observed between caged and uncaged azalea lace bug populations for any particular stadia within any of the six samples. Population densities were not significantly different within treatments of second, third or fourth stadia. This suggests that predation did not significantly affect densities of the first generation azalea lace bug population in a low diversity nursery setting.

Sun and shade do not affect oviposition or feeding preference by azalea lace bugs in a monocultural setting when light intensity within the foliage, temperature, and relative humidity are not significantly different. The four

Fig. 4. Mean population density of azalea lace bug emerged eggs, second, third, fourth and fifth instar nymphs and adults collected from azalea cuttings in six sequential samples collected on 15 and 22 Apr., 6, 13, 20, and 27 May 1997. Bars represent standard error of the mean (SE).

designated feeding guilds of this study—piercing-sucking herbivores, chewing herbivores, predators—parasitoids, and spiders also show no preference to sun or shade. A lack of significant differences between caged and uncaged cuttings indicates there were no consequential effects of predation or parasitism upon egg eclosion or subsequent instars of the first generation of azalea lace bug populations. Therefore, growing azaleas in sun or shade has no effect on lace bug populations when the plants are in a monocultural environment. Under these conditions, the azalea lace bug can thrive relatively free of predation pressure. An intentional change in community structure may impact azalea lace bugs on azaleas. A more diverse environment allows predators to establish, thereby reducing azalea lace bug populations and their feeding damage. This suggests nurseries would benefit from growing azaleas with other plants to enhance the plant community structure and provide habitats for azalea lace bug predators.

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