Feeding Injury of the Azalea Lace Bug (Heteroptera: Tingidae)[1]

W. E. Klingeman, S. K. Braman and G. D. Buntin

Department of Entomology, University of Georgia, College of Agricultural and Environmental Sciences, Griffin, GA 30223 USA

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Abstract Azalea lace bug, *Stephanitis pyrioides* (Scott), feeding rates were investigated in controlled laboratory bioassays. Individual newly-eclosed nymphs were transferred to cut stems of 'Girard's Rose' azaleas and maintained at either 20°C for 26°C for the duration of their lifetimes. Feeding rates, determined using computer assisted image area analysis, were calculated for both nymphs and adults. In both trials, females caused significantly more feeding injury per day than males. However, the overall amount of injury inflicted during lace bug lifetimes was similar for males and females at both temperatures. During adulthood, feeding injury by individual lace bugs resulted in a mean (±SD) of 6.35 ± 4.61 cm^2 leaf area injury at 20°C and 3.93 ± 2.06 cm^2 leaf area injury at 26°C. Nymphal feeding was a small fraction of the injury inflicted by the adults and averaged 0.43 ± 0.15 cm^2 at 20°C and 0.30 ± 0.10 cm^2 at 26°C. The determination of azalea lace bug feeding-injury potential is critical to the development of decision-making guidelines.

Key Words Integrated pest management, *Rhododendron* spp., *Stephanitis pyrioides,* azalea lace bug, feeding injury

The azalea lace bug, *Stephanitis pyrioides* (Scott), is the most important pest of azaleas (*Rhododendron* spp.) in the eastern United States (Neal and Douglass 1988, Raupp et al. 1985). Both nymphal and adult azalea lace bugs feed by inserting their stylet mouthparts through stomata on the abaxial surface of azalea leaves and extracting cell contents from the palisade parenchymal layer. The resulting chlorotic stippling is evident on the adaxial surface of leaves (Buntin et al. 1996). Leaf undersides are characteristically spotted with brown or black, varnish-like excrement and cast skins of juvenile azalea lace bugs (Johnson and Lyon 1991). While damage to azalea leaves is aesthetically displeasing, azalea lace bug injury also reduces photosynthesis and respiration in injured leaf tissues. Photosynthetic rates in the remaining chlorophyll also are impaired as a result of stomatal closure (Buntin et al. 1996). Adult female azalea lace bugs cause more leaf injury than either males or nymphs (Buntin et al. 1996). However, the rate and amount of damage caused by nymphal and male or female azalea lace bugs has not been quantified. Knowledge of the rates of damage caused by nymphal and adult azalea lace bugs is critical to the development of accurate decision-making criteria. Data reported herein define azalea lace bug feeding rates under controlled laboratory conditions.

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Materials and Methods

Azalea lace bug colony. Azalea lace bugs collected in Spalding Co., GA, were maintained in a colony on mixed varieties of azaleas at the Georgia Experiment Station in Griffin. Colonies were housed in 1.0-m^3 screen-mesh cages and held at 27 ± 1°C under a 14-h photoperiod. Investigations of azalea lace bug feeding utilized newly-eclosed lace bug nymphs removed from the colony.

Preparation of experimental arenas. Experimental arenas were created by drilling a 3.2-cm diam hole into the base of an 11.0 × 5.0 cm plastic vial (Thornton Plastic Co., Salt Lake City, UT). A saran mesh screen (50.0-cm diam) (Chicopee Manufacturing Co., Cornelia, GA) was glued to the end of the arena. A 9.2-mm diam hole was drilled into the vial's plastic lid, a 2.0-cm section of 6.4-mm I.D. Nalgene Grade VI Premiuim Non-Toxic Tubing (Nalge Co., Rochester, NY) was inserted, and the assembled arena was placed into a 120.0-ml specimen jar containing 60.0 ml of tap water.

'Girard's Rose' azaleas, which are representative of many evergreen Girard hybrids common in the nursery trade (Galle 1987), possess dark green foliage upon which lace bug feeding injury is readily apparent. Terminals of Girard's Rose azalea were trimmed to fit the arenas by removing apical meristems and any injured or underdeveloped leaves. Ten fully-developed leaves were left on each cut terminal. The basal ends of cut stems were inserted into the nalgene tube. The interface of stem and tubing was wrapped with Parafilm "M" Laboratory Film (American Can Co., Greenwich, CT). This prevented nymphs from emigrating from the experimental arenas.

Infestation, maintenance, and mortality assessment. A fine camelhair brush was used to transfer a single newly-eclosed first-instar azalea lace bug nymph to the abaxial surface of one randomly chosen leaf within each arena. Each nymph was inspected 24 h after infestation to ensure that no mortality had occurred due to handling.

Temperature and photoperiod for treatments in two trials were selected to approximate early-May (20°C) and late-July (26°C) mean conditions typical of central Georgia. Sixty prepared stems were infested for each treatment. These were maintained in Model I-35VL growth chambers (Percival, Boone, IA) set at either 20 ± 1°C or 26 ± 1°C. In the growth chambers, 15 arenas were held in each of 4 opaque 13.2-L Keepers™ unit trays (Rubbermaid, Inc., Wooster, OH). Terminals used in the 26°C trial were infested on 28 July 1997 and were maintained at high (<90%) RH under a 14-h photoperiod. Terminals in the 20°C trial were infested on 9 August 1997 and were maintained at high (<90%) RH under a 13-h photoperiod. A pan of water in the growth chamber provided high humidity levels, evident in the formation of water droplets within the arenas. RH was monitored using an Indoor/Outdoor Thermometer/ Hygrometer (Tandy Corp., Forth Worth, TX).

Nymphs were inspected daily throughout juvenile development. Once the final juvenile molt to adulthood occurred, lace bugs were removed from the terminal and the gender of each adult was recorded. Lace bugs were transferred to a freshly prepared terminal, where they were permitted to feed for the duration of their adult lives. Arenas were observed daily to ascertain the date of adult mortality and to assess the condition of the terminal. As needed, a small section at the base of the stem was trimmed to clear blocked vascular tissues. Terminals showing signs of desiccation, wilt, or disease were replaced with freshly prepared stems. Regardless

Table 1. Development and damage characteristics of male and female azalea lace bugs (mean ± SD) on 'Girard's Rose' cuttings held at 20 ± 1°C

Variable	Female ± (SD) (n = 46)	Male ± (SD) (n = 10)	$P > \|t\|$*
Longevity (days)			
Nymphal development	21.7 ± 1.7	23.5 ± 2.4	†
Adults	91.2 ± 27.4	118.5 ± 39.1	**
Nymphs + Adults	112.9 ± 27.4	142.0 ± 37.9	†
Injured leaves (no.)			
Nymphs	1.0 ± 0.2	1.1 ± 0.3	NS
Adult	20.2 ± 8.6	24.9 ± 9.4	NS
Daily injury (cm^2)			
Nymphs	0.02 ± 0.01	0.02 ± 0.01	NS
Adults	0.07 ± 0.04	0.04 ± 0.02	**
Lifetime injury (cm^2)			
Nymphs	0.41 ± 0.14	0.53 ± 0.17	**
Adults	6.50 ± 4.31	4.64 ± 2.80	NS

* df = 54, ** = $P < 0.05$, † = $P < 0.0001$, NS = not significant.

of appearance, all terminals in the 26°C trial were replaced on 11 September, 9 October, and 2 November. Terminals in the 20°C trial were replaced on 1 October, 2 November, 1 December, and 5 January. Upon the death of the adult, the remaining terminal was removed and held for evaluation.

Injury assessment. In each trial, all 10 leaves were stripped from the injured terminals and sorted into groups of injured and uninjured leaves. Individual leaf areas were taken from both groups of leaves using a Li-Cor 3100 Leaf Area Meter (Li-Cor, Lincoln, NE). Mocha imaging software (Jandel Laboratories, San Rafael, CA) was used to quantify damage on 24 images of azalea leaf injury ranging from 0.5% to 82%. Leaves from both temperature regimes were compared to these sample images and provided an estimate of leaf-area injury due to azalea lace bug feeding. Percentages of injured leaf area were divided by both the durations of nymphal and adult stadia. This provided an average daily rate of injury inflicted by nymphs and adults at each temperature.

Statistical analysis. The availability of only two growth chambers resulted in experimental design limitations. As a result, statistical analyses and direct comparisons between temperatures were not possible. Student's *t*-tests were conducted by gender within each temperature to reveal significant differences among the development time of nymphs, adult longevity, rate of nymphal and adult injury and the number of leaves injured by both nymphs and adults (SAS Institute 1985). The *t*-test procedure in SAS also included a test of the equality of variances. The relationship of lace bug feeding injury to lace bug longevity was determined using PROC REG in SAS (SAS Institute 1985).

Table 2. Development and damage characteristics of male and female azalea lace bugs (mean ± SD) on 'Girard's Rose' cuttings held at 26 ± 1°C

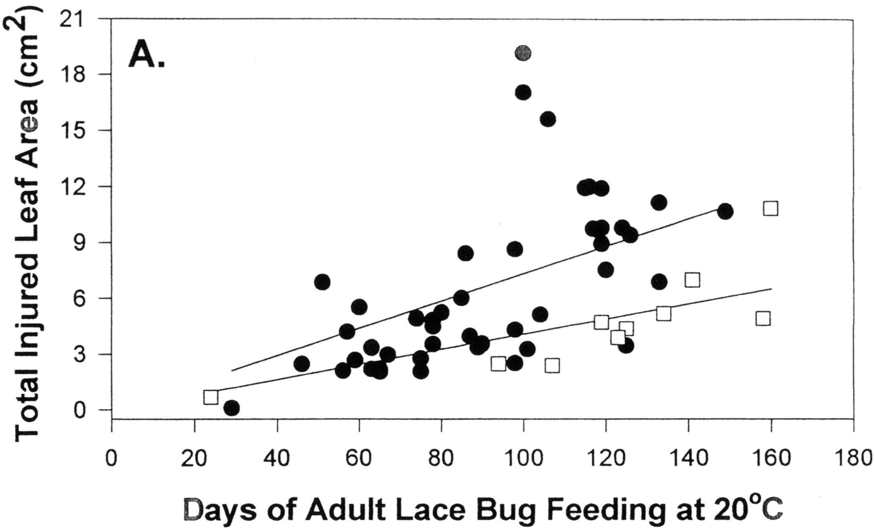
Variable	Female ± (SD) (n = 40)	Male ± (SD) (n = 14)	$P > \|t\|$*
Longevity (days)			
Nymphal development	10.4 ± 1.6	9.6 ± 0.8	NS
Adults	54.7 ± 24.6	85.8 ± 22.6	†
Nymphs + adults	65.0 ± 24.1	95.4 ± 22.7	†
Injured leaves (no.)			
Nymphs	1.0 ± 0.0	1.1 ± 0.3	NS
Adult	14.8 ± 7.6	22.7 ± 6.2	†
Daily injury (cm^2)			
Nymphs	0.03 ± 0.01	0.03 ± 0.01	NS
Adults	0.07 ± 0.04	0.05 ± 0.02	**
Lifetime injury (cm^2)			
Nymphs	0.30 ± 0.11	0.31 ± 0.08	NS
Adults	3.97 ± 2.28	3.82 ± 1.31	NS

* df = 52, ** = $P < 0.05$, † = $P < 0.0001$, NS = not significant.

Results and Discussion

Student's *t*-test results demonstrated that variances were equal among all investigated variables. In trial 1 at 20°C, temperature and photoperiod typical of spring and fall conditions in Georgia resulted in a significantly longer development time for male than female lace bug nymphs (Table 1). Nymphal development times were not significantly different in trial 2 at 26°C, where temperature and photoperiod were typical of Georgia summers (Table 2). Male *S. pyrioides* generally lived longer than their female counterparts (Tables 1, 2). Regardless of gender, development was delayed and longevity was greater, in our study, for lace bugs maintained at 20°C than 26°C. In an early report, Bailey (1951) suggested that male azalea lace bugs are short-lived as adults and die shortly after mating. Recent research efforts, including our own, refuted this early belief (Neal and Douglass 1988, Braman et al. 1992).

In the 20°C trial, mean leaf size (±SD) was 5.73 ± 0.46 cm^2, while in the 26°C trial leaves averaged 5.84 ± 0.75 cm^2. As developing juveniles, nymphs remained relatively immobile at each temperature and typically fed on just a single leaf (Tables 1, 2). By comparison, adults were more mobile. Males fed on significantly more leaves than females at 20°C and 26°C (Tables 1, 2). On a daily basis, nymphs inflicted less injury than adult lace bugs in both trials (Tables 1, 2). Differences in the injury rate of nymphs were significant only between males and females maintained at 20°C (Table 1). For adult females, daily feeding rates were significantly higher than males maintained at either 20°C or 26°C (Tables 1, 2). This finding is consistent with pre-



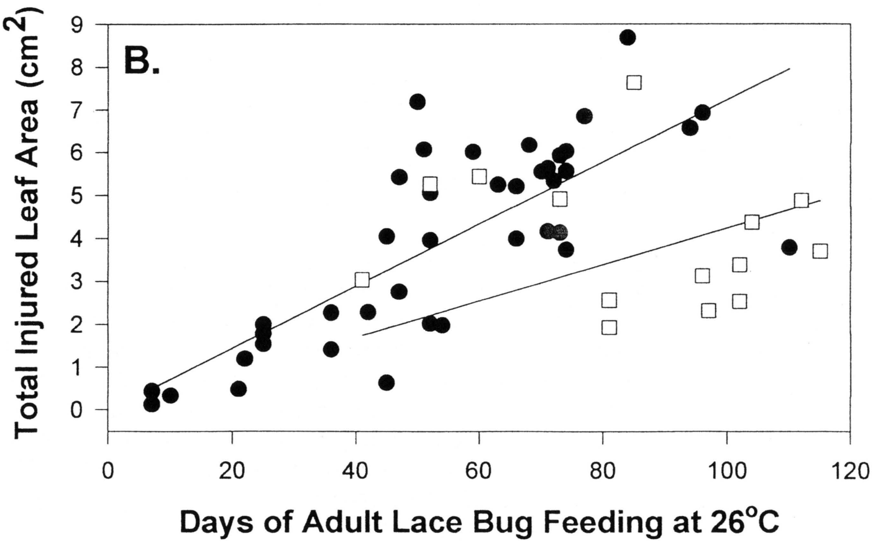


Fig. 1. A. Relationship of lace bug longevity to total injured leaf area for adult males ($y = -2.13 + 0.05$ (x), $r^2 = 0.66$, $P < 0.01$) and adult females ($y = -5.05 + 0.10$ (x), $r^2 = 0.46$, $P < 0.0001$) in the 20°C trial. B. Relationship of lace bug longevity to total injured leaf area for adult females ($y = -0.65 + 0.07$ (x), $r^2 = 0.63$, $P < 0.0001$) and adult males ($y = 2.05 + 0.02$ (x), $r^2 = 0.13$, $P > 0.05$) in the 26°C trial. In both trials, open squares signify male observations and closed circles identify observations on females.

vious azalea lace bug feeding studies (Buntin et al. 1996). Higher feeding rates by adult females may be explained by the demand throughout oviposition for nutrients needed for egg maturation. Mean lifetime injury levels were not significantly different among lace bug gender for either temperature because of the extended longevity of males (Tables 1, 2). The differences in lace bug longevity for each temperature had a considerable effect on the total amount of injury that may be inflicted by feeding *S. pyrioides.* Throughout the life span of individual azalea lace bugs, the mean total amount of feeding among males and females averaged (±SD) 6.78 ± 4.62 cm^2 at 20°C and 4.23 ± 2.07 cm^2 at 26°C.

Lace bug feeding during adulthood produced the majority of the injury inflicted on the 'Girard's Rose' cuttings. The relationship of feeding injury to lace bug longevity in the 20°C trial was significant for both adult males ($y = -2.13 + 0.05(x)$, $r^2 = 0.66$, $P < 0.01$) and for adult females ($y = -5.05 + 0.10(x)$, $r^2 = 0.46$, $P < 0.0001$) (Fig. 1A). In the 26°C trial, the relationship of adult female longevity to female injury was significant ($y = -0.65 + 0.07(x)$, $r^2 = 0.63$, $P < 0.0001$), while the adult male feeding injury rate was not significantly correlated to longevity ($y = 2.05 + 0.02(x)$, $r^2 = 0.13$, $P > 0.05$) (Fig. 1B).

The leaf area feeding-injury values expressed in these trials were calculated as injury within a contiguous area. Lace bugs, however, do not present tightly appressed injury patterns when feeding. The contiguous injury-area values presented herein are likely to cover a larger leaf area if distributed unevenly over the leaf surface in the chlorotic stippling patterns typically presented by lace bug feeding. Furthermore, our estimated injury levels are based on lace bug longevity and are likely exaggerated in comparison to a natural system. Our study, conducted under controlled environmental conditions, does not consider disease, predation, parasitism, and emigration or immigration. Natural enemies, including spiders, mirid plant bugs, lace wings, ants, and the mymarid parasitoid, *Anagrus takeyanus* Gordh, may reduce azalea lace bug populations and influence the potential for population growth (Balsdon et al. 1993, Leddy 1996, Trumbule et al. 1995, Wang et al. 1998). However, our determination of the rates of lace bug injury-infliction provides a useful baseline estimate for estimating injury levels of given population densities and thereby increases our understanding of azalea lace bug feeding. These findings may be incorporated into a decision-making plan for determining when azalea lace bug populations reach a level that warrants intervention.

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