MANAGEMENT CONSIDERATIONS FOR THE AZALEA LACE BUG IN LANDSCAPE HABITATS

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Abstract. The azalea lace bug is a severe pest of ornamental azaleas throughout much of eastern North America. Reports in the literature suggest that lace bugs occur more abundantly and damage azaleas more frequently in sunny, exposed landscapes compared to more shaded plantings. By measuring the light intensity over azalea plants in four damage categories (high, moderate, low and no damage), we were able to rigorously confirm this reported pattern. The highest light intensities were recorded over azaleas incurring the most lace bug damage and the lowest light intensities were registered over plants in the low damage categories. A survey of the literature showed that although caged lace bugs perform and reproduce best on shade-grown azalea plants, uncaged lace bugs do not survive well at all in shaded habitats where they apparently suffer higher mortality from natural enemies. Invertebrate predators such as spiders are implicated in relegating lace bugs to azaleas in sunny habitats where although lace bug performance is reduced on light- and water-stressed plants, overall survival is greatest. Infestations of lace bugs may be minimized by planting azaleas in shaded landscapes with mixed vegetation that provide refuge for invertebrate predators.

Management of the azalea lace bug (ALB), *Stephanitis pyrioides*, has proven challenging since its introduction into eastern North America in the late nineteenth century (1,34,35). Several factors contribute to its status as a primary pest of azaleas. First, ALB was introduced from Japan without its entourage of specialized natural enemies. Consequently, ALB spread unchecked following its introduction (1,21). Second, certain life history characteristics of ALB make control measures difficult. For example, eggs are inserted into the lower leaf surface along the midrib and nymphs and adults are secretive and feed from the underside of leaves (1,21,36) which affords them protection from most contact insecticides. Furthermore, ALB is multigenerational (1,21,23,37,38) and as the season progresses generational overlap promotes escape from chemical control measures to any individuals in the egg stage. Thus, in all but the first generation, several life stages may be present on infested azalea plants at any given time (23). With the advent of systemic insecticides such as acephate, chemical control can be more effective, but outbreaks of ALB still occur frequently (26).

Features of the azalea host plant or the habitat in which it grows can also promote lace bug attack and outbreak (26,33). For instance, evergreen azaleas are more heavily attacked than are deciduous species, in part for reasons concerning reduced plant resistance (3), but also because leaves carrying overwintering eggs persist, which promotes the spring colonization of new growth by hatching nymphs (1). Furthermore, among evergreen cultivars there is considerable variation in susceptibility to ALB attack (30).

In particular, ALB is thought to damage azaleas more frequently in exposed, dry landscapes than in shady more wooded habitats (2,14,26,37,38). However, the association between the light intensity in the habitat and the lace bug damage has not been rigorously quantified. Other sap-feeding insects are known to grow faster and exhibit population outbreaks on plants growing under stressed conditions (18,40). Elevated concentrations of free amino acids and carbohydrates in the stressed plant are thought to contribute to increased insect performance and population growth (5,18,19,40). Because azaleas and other ericaceous plants are adapted to the low light conditions of the forest understory (2), these shade-adapted plants growing in exposed habitats may experience stress from intense solar radiation and insufficient water (2,17,19,25). Consequently, one might conjecture that infestations of ALB on azaleas growing in open habitats stem from plant stress.

Alternatively, natural enemies may occur more frequently in certain azalea habitats and thereby influence the spatial distribution of ALB. Because invertebrate predators and non-specialized parasitoids are the most important natural enemies of lace bugs (1,4,6,13,24,31, P. Leddy pers. comm.), invertebrate predators could also influence the distribution of ALB in the urban landscape.

This account has three objectives. First, we attempt to rigorously confirm reports that ALB infestations are more damaging in exposed landscape habitats (2,26,37,38). Second, we review the literature to assess how factors such as host plant stress and natural enemies may influence the distribution of ALB in its landscape habitats. Last, based on our review, we make several management recommendations that may deter ALB infestations in urban plantings.

The Study System - Azaleas, Lace Bugs and Natural Enemies

Dozens of azalea species and cultivars are planted as ornamentals around homes and parks. In the Washington D.C. area azaleas are among the most frequently planted shrubs comprising 20% of all ornamental plantings (12,14,27,28). In their natural habitats azaleas grow as shade-adapted understory shrubs (2). Nonetheless, azaleas will grow in sunny conditions, and if given sufficient water and care, they can flower profusely (2). However, full exposure to sun and dry soil conditions often adversely affects the growth and survival of neglected azaleas (2,37,38).

The azalea lace bug is a primary pest of azaleas wherever they are grown (36), and ALB is by far the most damaging pest in the mid-Atlantic states of the United States (1,2,14,37,38). In Maryland, overwintering eggs generally hatch in late April to mid-May (22,33). Nymphs pass through five instars (8) each lasting from two to fifteen days depending on the ambient temperature (1,4,7,23). There are three to four generations per year in Maryland, with peaks of adult abundance in June, late July and late September (1,21,22,23,33,37, 38).

Both nymphs and adults of the ALB feed from the lower surface of azalea leaves by piercing the mesophyll cells with their stylets. Feeding destroys the cells and results in a blanched stippled appearance to the upper surface of the leaf (1,36). The lower leaf surface often becomes discolored by dark fecal material and cast nymphal skins (36). Injury can be unsightly, and aesthetic loss is a primary problem in ornamental landscapes (12). Furthermore, the visible damage caused by lace bug feeding may lower the sale value of infested azaleas (9). Plant vigor may be greatly reduced with the loss of photosynthetically active tissue, and heavy infestations can result in leaf desiccation, premature leaf-drop, and even plant death (37).

Invertebrate predators are the most important natural enemies of lace bugs including ALB (1,6,31, P. Leddy pers. comm.), although an egg parasitoid is known to occur (4,10). Spiders, coccinellid beetles, chrysopid lacewings, and hemipterans are the most often reported predators (1,31). In Maryland, the mirid bug, Stethoconus japonicus, is a ravenous, specialized predator of ALB (13,24).

Association between Light Intensity and ALB Damage

Methods. To test whether or not infestations of ALB were larger on azaleas growing in exposed locations, measurements of lace bug damage (an indirect assessment of population size) and illumination (footcandles) were taken from a variety of habitats ranging from full sun to full shade at the U.S. National Arboretum in Washington, D.C. We elected to use lace bug damage (measured at the end of the season) as an index of infestation size, because 1) the sampling effort to determine ALB damage is much less compared to that necessary to assess population density by the visual counting of lace bugs, 2) damage represents the accumulated feeding activities of ALB over an extended period of time and therefore may more accurately indicate infestation size than direct counts at a few times during the season, and 3) there is generally a positive association between lace bug density and lace bug damage (26).

All light measurements were made with a hand-held light meter (Sekonic Studio Deluxe, model L-398). Azaleas damaged by ALB were assigned to one of four categories: 1) no damage (no stippling/ fecal deposits on any leaves of the azalea plant), 2) low damage (up to 25% stippling of the total leaf surface area of the plant), 3) moderate damage (between 25% and 50% stippling of the leaf surface area), and 4) high damage (between 50% and 100% stippling of the leaf surface area).

Damage was assessed on azalea plants (chosen randomly throughout the National Arboretum) until 8 plants were measured in each of the four damage categories. Light intensity readings were taken 25 cm above each of the 32 plants at mid-day on August 28, 1985.

Light intensity data were analyzed using ANOVA, and means among the four plant damage categories were compared using Planned Contrast Bonferroni *t* tests (SAS Institute 1985).

Results. Natural patterns of infestation at the U.S. National Arboretum confirmed published reports that ALB occurs more abundantly and damages azaleas more frequently in exposed sunny habitats compared to shaded locations. In general, we found a positive association between ambient light intensity and the amount of ALB damage incurred by azalea plants (Fig. 1). The highest light intensities were recorded over plants that incurred the greatest amount of ALB damage, and low light conditions were associated with plants that were not damaged or maintained only low infestations. Mean light intensity differed significantly among plants in the high, moderate, and low or no damage categories ($F_{3,28} = 22.78$, $p<0.01$).

Factors Influencing the Distribution of ALB

Our finding that ALB is more abundant and damages azaleas more severely in sunny, exposed settings appears to be consistent with the plant stress hypothesis which suggests that light and water stresses predispose plants to attack by herbivorous insects and promote outbreaks (18,20,39,40). Others have previously suggested that full sun stresses azaleas and makes them prone to ALB attack (2,14). However, Trumbule (33) demonstrated experimentally that ALB showed decreased longevity, reduced fecundity, and diminished preference for feeding and ovipositing on azaleas grown in full sun. In contrast, ALB performed best on plants grown under 75% shade, plants that were growing more vigorously than those grown under full-sun conditions. Furthermore, the survival and fecundity of ALB did not differ between bugs raised on high and low water-stressed azalea plants (33). ALB damage, however, was slightly higher on azaleas subjected to the high water stress treatment suggesting that perhaps feeding rate was increased on stressed plants. Together, these experimental data provide little support for the notion that light or water stress in open habitats predisposes azaleas to attack by ALB. Moreover, a paradox emerges. How do we reconcile the occurrence of damaging ALB infestations in exposed habitats (Fig. 1) with the experimental data showing that ALB prefers not to feed and performs less well on sun-grown azaleas?

The resolution of this apparent dilemma resides in the differential survival of ALB in open and shaded habitats. When cohorts of ALB nymphs were established on azaleas growing on azalea plants placed in a shaded woodlot, ALB survival was significantly less than companion cohorts of ALB established on azaleas arranged on an open lawn (33). For this experiment, ALB cohorts were not caged and they were continuously exposed to natural enemies. While other factors may be involved, the partial remains of ALB nymphs in this experiment implicated invertebrate predators, such as spiders, as the causal agents of mortality. The high diversity of non-host vegetation in woodlot settings and the well-developed litter and understory strata, may encourage natural enemies by providing shelter and alternate prey (see 15,16,32,

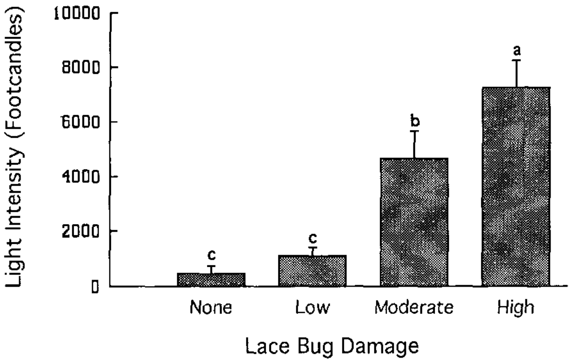

Figure 1. Light intensity (foot candles) over azalea plants assigned to four azalea lace bug (*Stephanitis pyrioides*) damage categories (no, low, moderate, high). All plants were growing across a spectrum of habitats ranging from full sun to full shade at the U.S. National Arboretum, Washington, D.C. Means ±1 SE with different letters are significantly different (P< 0.01, Bonferroni t test).

P. Leddy, pers. comm.). Thus, it appears that predators contribute to the exclusion of ALB from the shaded azaleas on which ALB inherently performs best and relegate it to plants growing in more exposed habitats where its overall survival is reduced. A similar scenario exists for the white peach scale insect, *Pseudalacaspis pentagona*, which flourishes in cages on woodlot mulberry trees protected from enemies, but is normally restricted to trees growing in open landscape habitats where invertebrate predators are less abundant (11).

Recommendations for Management

When considering pest management options for ALB in the urban landscape, choice of site and planting design remain the most effective means of minimizing damaging infestations. Landscape settings that provide shade, water and enhanced habitat diversity are most important. Shade-adapted azaleas are less stressed when they are planted in shaded, moist sites (2,26). In contrast, azaleas growing in poorly-irrigated locations in the open sun are more subject to light and water stress. Even though ALB occurs more abundantly on azaleas growing in the open sun (2,14,26,37,38), our research shows that ALB does not inherently prefer to feed or perform as well on light-stressed azaleas compared to shade-grown plants (33). ALB is apparently relegated to azaleas growing in exposed locations by natural enemies which are more abundant and effective at suppressing ALB in shaded habitats with diverse vegetation (33). Thus, providing 1) partial shade, 2) a diverse landscape planting consisting of other shade-adapted species of plants, and 3) mulched beds should minimize ALB infestations by providing refuge for the natural enemies of ALB, namely invertebrate predators such as spiders, true bugs, tree crickets and lacewings.

If azaleas already occur or must be planted in hot, exposed habitats, several management activities must be implemented to minimize ALB infestations. First, exposed plants must be monitored more frequently and thoroughly to detect incipient lace bug populations. Second, exposed plants will likely require more frequent insecticide treatments to reduce lace bug populations and injury. ALB damages water-stressed azaleas more severely than well-irrigated plants, and increased damage in this case apparently results from the elevated feeding rate of ALB under water-stressed conditions (33). Thus, providing azaleas with ample water and mulch should reduce the excess damage associated with increased feeding rate. Furthermore, selecting certain azalea cultivars for exposed plantings may further diminish ALB problems. For instance, deciduous azaleas are generally less susceptible to ALB attack than are evergreen azaleas (3), but there is also considerable variation among evergreen cultivars in resistance to ALB (30). Of twenty evergreen cultivars tested, "Purple Splendor" and "Macrantha" were least susceptible to ALB injury. Planting such "resistant" cultivars in exposed settings and keeping them mulched and well-watered may lessen unsightly ALB damage.

In certain circumstances, especially where azalea production facilities are concerned, conventional control of ALB using pesticides may be the only management alternative available. In those situations where chemical pesticides are likely to be used, two factors must be considered. First, the choice of pesticide is very important. Systemic insecticides such as acephate are much more likely to provide control of ALB since both nymphs and adults feed on leaf undersurfaces and are therefore more difficult to reach with contact insecticides. Second, the earlier the ALB infestation is detected and treated, the more likely control can be achieved with one insecticide application. A single spray of systemic insecticide after overwintering eggs have hatched, but prior to adult oviposition, is generally effective since generational overlap and the presence of an invulnerable egg stage are avoided. Close monitoring of azaleas in late April to mid-May (Mid-Atlantic States) is critical to the success of a single treatment spray program. Inspection of the underside of leaves, especially those in the interior of the azalea canopy, for the overwintering eggs and newly emerged nymphs should be performed on a weekly basis in spring. If it is necessary to control actively feeding stages (nymphs and adults), then thoroughly apply insecticidal soap or horticultural spray oil. These contact insecticides will help conserve natural enemies, however, thorough coverage to the undersurface of leaves is critical for maximum efficacy.

Finally, ongoing research will continue to provide advances in knowledge regarding natural enemies of ALB and may lead to the development of more specific biocontrol and cultural control options. Nevertheless, research to date indicates that proper siting of azaleas in the shaded landscape, followed by sound irrigation practices, will go far to conserve natural enemies and reduce the status of ALB as a primary pest in the urban landscape.

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Résumé. Les rapports retrouvés dans la littérature suggèrent que la punaise de l'azalée est retrouvée plus abondamment et endommage les azalées plus fréquemment lorsque celles-ci se retrouvent dans des aménagements paysagers en milieu ensoleillé et ouvert comparativement à celles en milieux plus ombragés. En mesurant l'intensité de lumière au-dessus des plants d'azalée classées en quatre catégories de dommages subis (élevé, moyen, faible ou aucun dommage), il a alors été possible de confirmer de façon rigoureuse la véracité de cette situation. Même si les punaises de l'azalée " font une vie meilleure " en milieu artificiel et se reproduisent mieux sur des plants d'azalées en milieu ombragé, les punaises en milieu naturel ne survivent pas aussi bien dans des habitats aux conditions plus ombragées car les populations d'insectes souffrent alors apparemment d'un haut degré de mortalité par leurs ennemis naturels. Les prédateurs invertébrés, tel que les araignées, sont impliquées dans un processus qui tend à reléguer les punaises vers les milieux plus ensoleillés, car même si les " performances " de cet insecte sont alors réduites avec des plants plus ensoleillés et en situation de stress hydrique, le taux de survie des punaises devient alors plus élevé. Les infestations de punaises peuvent être diminuées en plantant les azalées dans des aménagements en milieux ombragées en compagnie d'autres espèces de plantes afin de procurer aux invertébrés une niche pour leur maintien et leur survie.

Zusammenfassung. Die Beiträge in der Fachliteratur berichten häufig, daß Azaleenglanzkäfer in sonnigen und offenen Landschaften weitaus häufiger vorkommen und auch größeren Schaden anrichten als in schattigen Lagen. Durch Messungen der Lichtintensität oberhalb von Azaleenpfanzen aus vier Schadenskatergorien (hoch, mittel, niedrig und kein Schaden) konnten wir diese Behauptungen untermauern. Obwohl sich gefangene Glanzkäfer am besten auf Schattenazaleen entwickeln und reproduzieren, haben freie Glanzkäfer eine geringere Lebensrate an schattigen Stanorten, wo sie ihren natürlichen Feinden ausgesetzt sind. Wirbellose Feinde, wie die Spinne sind an der Begrenzung von Glanzkäfern auf Azaleen an sonnigen Standorten beteiligt; obwohl die Lebenskraft der Glanzkäfer auf licht- und wassergestressten Pfanzen reduziert ist, so ist doch die Überlebensrate am höchsten. Der Befall durch Glanzkäfer kann durch eine Pflanzung in einer schattigen Landschaft mit gemischter Vegetation, welche für wirbellose Feinde mehr Unterschlupf bietet, minimiert werden.