Evaluating Grower, Landscape Manager, and Consumer Perceptions of Azalea Lace Bug (Heteroptera: Tingidae) Feeding Injury

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ABSTRACT A survey using modified azalea stems was used to establish a "tally threshold value" for assessing azalea lace bug, *Stephanitis pyrioides* (Scott), feeding injury to azalea shrubs. Consumers and green-industry professionals, represented by ornamental growers, landscape architects, and landscape managers, recognized azalea lace bug injury when injured leaf area exceeded 2%. Purchase and treatment decisions of professionals and consumers were evaluated by surveying responses to *Rhododendron indica* variety *alba* 'Delaware Valley White' azaleas representing a range of damage. Survey participants also provided a brief biographical background and answers to questions regarding pesticide use, ability to identify diseases, pests, and beneficial organisms, and willingness to consider pesticide alternatives. Professionals and consumers expressed a strong interest in limiting urban pesticide use. The 2 groups indicated a hypothetically acceptable level of 6–10% plant damage by arthropod pests. A 2% injury threshold was used to determine the level of proportional damage (the percentage of leaves displaying 2% or more lace bug leaf feeding injury) resulting in either the rejection of plant purchase or initiation of treatment. A nonlinear curve was fit to treatment and no-purchase responses of professionals and consumers using a modified 3-parameter Mitscherlich nonlinear growth function. Half of the surveyed professionals and consumers indicated that damage proportions >10% (1.03% actual injury) were sufficient to reject an azalea for purchase. Proportional damage levels >43% (3.3% actual injury) would be necessary to prompt 50% of the respondents to initiate treatment of damaged azaleas to control lace bugs.

KEY WORDS *Rhododendron, Stephanitis pyrioides,* azalea lace bug, integrated pest management, aesthetic injury, survey

AMONG THE GOALS of landscape integrated pest management (IPM) is a reduced reliance on pesticides. This goal can be achieved by integrating chemical control with management tactics based on arthropod and plant biology. Acceptance and use of landscape IPM is impeded, however, by a lack of adaptable and affordable alternatives to traditional chemical control and limitations of the perceived reliability of IPM programs (Potter and Braman 1991; Latimer et al. 1996a, 1996a; Braman et al. 1998). Professionals in the green industry may often have an incomplete understanding of the biology of landscape pests and pest natural enemies and of pest sampling and monitoring needs. Too, they have an insufficient knowledge of management-action thresholds for landscape pests (Potter and Braman 1991, Raupp et al. 1992, Braman et al. 1998). Among consumers, a limited tolerance of aesthetic damage to plant materials has been demonstrated (Potter and Braman 1991; Raupp et al. 1992; Latimer et al. 1996a, 1996b; Braman et al. 1998). Finally, landscape IPM is challenged by incompatibilities between chemical and biological control options (Potter 1994). Despite these limitations, there are economic, political, and legal issues associated with urban pesticide use that provide motivation for the development of integrated management plans that rely on aesthetic thresholds for making treatment decisions. To develop an effective IPM program, landscape managers require experimentally tested techniques for diagnosing plant damage levels and initiating pest control. Few managers have the time or equipment to precisely quantify such damage.

"Tally threshold valuation" (Jones 1996) provides a presence or absence summation mechanism that can be used to readily quantify insect injury. A tally threshold, based on the ability of growers and consumers to recognize lace bug injury, has not been developed for azaleas. Landscape managers might incorporate such a threshold, using even low injury levels, into an azalea lace bug management program. Prior surveys of consumer attitudes for azaleas damaged by azalea lace bug feeding have suggested that consumer decisions to purchase plants are influenced by evidence of lace bug injury (Oliver and Alverson 1990). These surveys were unable to quantify this response adequately, however, and did not attempt to identify an appropriate threshold level upon which purchase or treatment decisions were based.

Azaleas, *Rhododendron* spp., are key plants that are well represented throughout landscapes in the eastern United States (Raupp et al. 1985, Braman et al. 1998).

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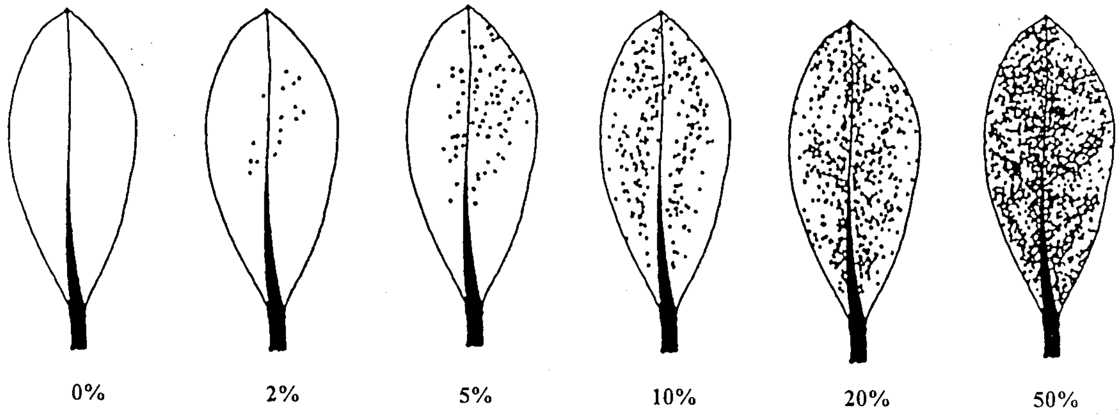

Fig. 1. Representative percentages of actual azalea lace bug feeding injury evidenced by infested azalea leaves. Images shown above are *negatives* and represent the images of leaf injury used in the photographic array for nondestructive comparison and assessments.

A survey in the metropolitan Atlanta area revealed that 87% of the landscape management firms surveyed maintain azaleas as a component of the landscapes they manage; further, 67% report that those azaleas occasionally or often require insecticide applications (Braman et al. 1998). Most deciduous and evergreen azaleas readily support populations of azalea lace bug, *Stephanitis pyrioides* (Scott) (Raupp et al. 1985, Smith and Raupp 1986, Braman and Pendley 1992, Wang et al. 1998). Azalea lace bugs cause aesthetic injury to azaleas by feeding on the palisade parenchymal cells of the spongy mesophyll (Buntin et al. 1996). Chlorotic stippling becomes apparent on the upper surfaces of azalea leaves after lace bug feeding (Johnson and Lyon 1991).

Our objective was to define purchase and treatment thresholds for incorporation into the development of decision-making criteria for azalea lace bug control. Additionally, we sought to better understand the green-industry professional and consumer perceptions of azalea lace bug feeding injury, pesticide use philosophies, and the willingness of respondents to implement alternative management strategies.

Materials and Methods

Azalea Lace Bug Colony. *S. pyrioides* colonies, housed in 1.0-m^3 screen cages in the entomology insect rearing facility at Griffin, GA, were used to create injury levels on azalea plants. These colonies were established and periodically replenished using adult azalea lace bugs collected from natural populations found near Griffin, GA. Colonies were reared on several cultivars of evergreen azaleas under conditions of 27 ± 1°C and a photoperiod of 14:10 (L:D) h.

Imposing Plant Damage Levels. In December 1996, 30 'Delaware Valley White' azaleas obtained from a commercial nursery were placed in 1.0-m^3 screen cages where nymphal and adult lace bugs fed freely. Plants exhibiting damage were chosen to represent a range of lace bug feeding injury. To quantify injury levels, all leaves with mechanical damage or necrotic spots not attributed to lace bug feeding were first removed. Damage for all leaves used in this study was measured using Mocha imaging software and a photographic array of 24 computer analyzed images of damaged azalea leaves (Jandel, San Rafael, CA). Images demonstrated a range of damage from 0.5 to 82% and were prepared using injured Delaware Valley White azalea leaves from shrubs that were not used for the live-plant inspections. Individual shrub injury levels were based on nondestructive estimates of the percentage of azalea leaves showing lace bug feeding injury. Leaves on 3 randomly selected terminals per half were compared with the array and assigned a corresponding level of injury (Fig. 1). These injury values, which are termed actual injury, were summed using percentage canopy leaf area injury estimates calculated from the total number of leaves on 6 terminal shoots per shrub.

Because winter dormant shrubs rapidly developed mature buds and flowers when introduced into the greenhouse after the surveys were concluded, plants were used once for each survey. Azaleas used in the Georgia Green Industry Association's Wintergreen Trade Show survey had an average (±SD) of 28.5 ± 7.5 terminal shoots per shrub. Plants used in the Southeastern Flower Show survey averaged 17 ± 2.5 terminal shoots per shrub.

Tally Threshold Evaluation. Survey responses to a preliminary questionnaire suggested a highly discriminatory recognition of azalea lace bug injury. To establish a tally threshold for azalea lace bug feeding injury recognition, we investigated the amount of injury necessary to elicit injury-recognition among 50% of survey participants familiar with horticultural or entomological science. To accomplish this, 12 terminal shoots of 'Girard's Rose' azaleas were trimmed into a simplified stem that had 2 stems of new growth tissues. Girard's Rose azaleas are similar to Delaware Valley White azaleas, which were unavailable at the time of our recognition-threshold survey, in that they possess like-sized, dark green leaves on which feeding injury is readily apparent. Apical meristems and all leaves that had insect or azalea lace bug feeding damage, disease, or malformation were removed. Cut stems were suspended by a 2.0-cm section of Nalgene Grade VI Premium NonToxic Tubing (6.4 mm i.d., Nalge, Rochester, NY) inserted through a hole cut into the lid of a 11.0 by 5.0-cm plastic vial (Thornton Plastic, Salt Lake City, UT). Under continuous observation, individual female adult azalea lace bugs were restricted to a single leaf per stem to induce feeding injury to 0.25, 0.35, 0.5, 0.75, 1.0, 2.0, 3.0, and 5.0% of the leaf area. To increase the accuracy of responses at low levels, we duplicated low levels of injury and used 2 uninjured control stems. Responses for duplicated levels were averaged to create a single value for each percentage level reported. Simplified stems were randomized and labeled for display. A sample stem, on which azalea lace bug feeding injury was readily apparent, was included to ensure that participants in the survey were rating the same feature. Damage on the sample averaged 5% injured leaf area on 25 leaves with damage to individual leaves ranging from 0 to 18%. A survey was designed which also asked survey participants to select stems having azalea lace bug feeding injury. To match the level of sophistication and training that is increasingly common among green industry professionals and landscape architects, surveys were presented to undergraduate students of horticulture at the University of Georgia in Athens, and faculty, staff, and graduate and undergraduate students at the Georgia Experiment Station in Griffin, GA. Four biographical questions were included in the survey to qualify respondent occupation, garden or landscape experience, and disease and insect identification ability. Damaged leaves were removed from the terminal stems at the conclusion of the survey, and leaf area measurements were made using a LI-3100 Leaf Area Meter (Li-Cor, Lincoln, NE). Leaves were videographed and analyzed using Mocha software to confirm the percentage of leaf tissue exhibiting azalea lace bug feeding injury.

Assessment of Azalea Lace Bug Aesthetic Damage. A comprehensive survey instrument incorporating tally threshold estimates was designed to investigate the purchase and treatment decisions of both professionals and consumers of azaleas with lace bug damage. A preliminary survey was conducted at the Ornamental Open House held in September 1996, in Griffin, GA. Respondents completed a 2-page survey while examining the live plant specimens. Damaged azaleas used for each survey were randomly arranged on a table that allowed easy access for respondent viewing. Respondents were not discouraged from any method of inspecting plants. Survey participants answered 9 questions that asked them to assess their knowledge of plant diseases, beneficial and pest organisms, manner and frequency of pesticide use, and plant scouting practices. Respondents concluded the survey by contributing answers to 11 biographical questions. Survey responses gave insight into the respondent's income level, education, age and gender, years of gardening experience, and profession. Thirty-eight participants returned usable surveys. An analysis of responses to the 1st survey helped to identify vague or misleading questions. Questions were altered to include useful information not previously requested. After the survey was refined, a separate group of azaleas was infested for each subsequent survey to obtain a range of damage as previously described.

A sampling of wholesale and retail nursery grower, landscape manager, and landscape architect members of the Georgia Green Industry Association was used to study trends among green industry professionals. The 1st group of 12 azaleas was presented at the Wintergreen Trade Show, in January 1997, in Atlanta, GA, where respondents returned 122 useable surveys. Azaleas in this group included 0.0, 1.4, 1.9, 2.0, 2.1, 2.3, 2.7, 3.1, 4.4, 6.2, 8.6, and 13.5% actual injury. The 2nd group of 12 azaleas was presented at the Southeastern Flower Show held in Atlanta, in February 1997. Consumers returned 249 useable surveys over a 5-d period. This group of azaleas displayed 0.0, 0.2, 0.6, 1.1, 1.2, 1.4, 2.1, 2.6, 3.2, 6.1, 15.6, and 36.0% actual injury. In addition to actual damage levels, the proportional levels of plant damage were estimated for shrubs using a 2% tally threshold generated from the simplified stem survey (see *Results* section). Leaves with <2% injury to the leaf area were not counted as injured for the assessment of proportional injury. Proportional injury was calculated as the percentage of the total number of leaves on 6 terminals that had >2% lace bug feeding injury. Actual injury on plants used in the Wintergreen Tradeshow corresponded to 0, 17, 39, 44, 45, 46, 51, 54, 69, 81, 87, and 88% proportional injury. Consumers at the Southeastern Flower Show inspected plants having 0, 1, 16, 34, 38, 39, 51, 54, 66, 79, 95, and 97% proportional injury. Results reported below are based on the proportional injury values. Purchase and treatment responses were compared for both surveys using reported income values pooled among low and moderate incomes into 4 tested ranges.

Statistical Analyses. Data from each of the surveys and from the tally thresholding trial were analyzed using PROC REG and PROC GLM programs in SAS (SAS Institute 1985). Treatment and no-purchase responses were regressed using proportional lace bug injury. The least squares procedure for linear models (PROC REG) and maximum likelihood estimates of parametric nonlinear models (PROC NLIN and Marquart Method) were used to obtain the best fit model describing the purchase and treatment trends (SAS Institute 1985). A modified 3-parameter Mitscherlich nonlinear growth function was used to generate predicted treatment and no-purchase values (Ware et al. 1982). The response level for 50% of the participants was calculated using the Mitscherlich curve equation.

Results

Tally Threshold Determination. Respondents participating in the simplified stem survey in Griffin and Athens returned 54 completed surveys. Mean responses for the Griffin and Athens groups were not

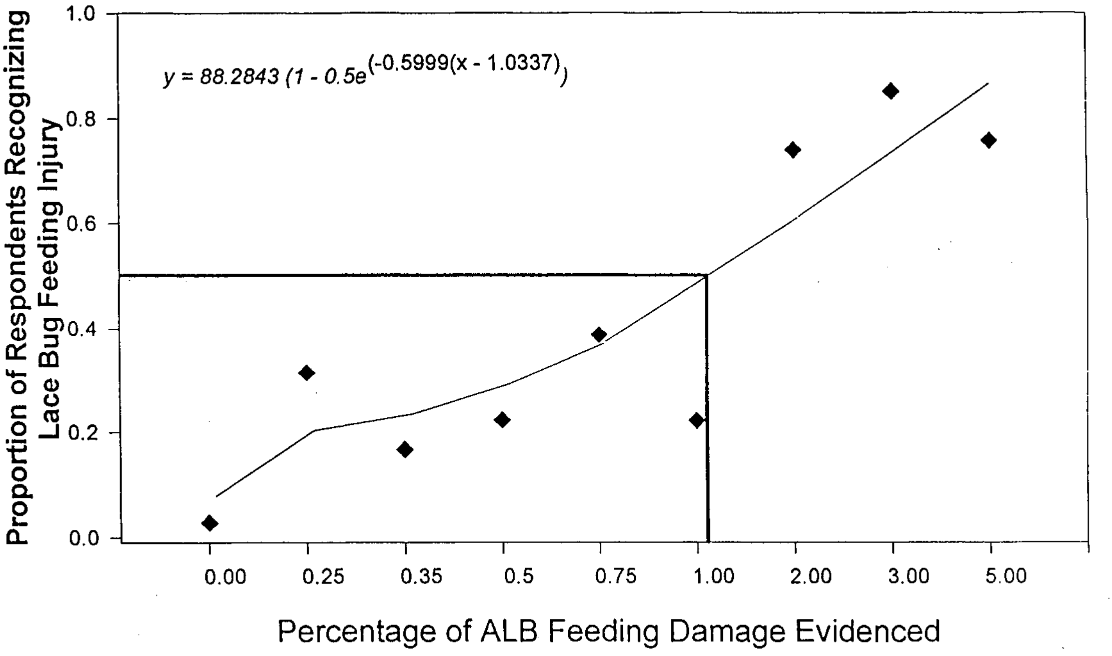

Fig. 2. Mitscherlich curve of simplified stem results for survey respondents recognizing azalea leaves with azalea lace bug (ALB) feeding injury. Using the curve equation, 50% of the survey participants successfully diagnosed injury at 1.03%.

statistically different ($F = 0.01$; df = 1, 468; $P = 0.91$). Survey responses to the tally thresholding exercise were pooled to determine a single value for the percentage of injury recognizable to 50% of the participants. Survey analysis using the Mitscherlich curve of pooled responses indicated that 50% of the respondents were unable to discriminate leaf injury below a predicted value of 1.03% (Fig. 2). This predicted value occurred along a gradient of injury-recognition ability, which increased sharply between 1% and 2% injury (Fig. 2). Identification of limited injury on simplified stems indicated that a tally threshold based upon a 2% level of azalea lace bug feeding damage was an appropriate level for injury assessment. The mean leaf area of Girard's Rose azalea leaves used in this study was 4.14 ± 1.27 cm^2. Thus, the 2% injury level corresponded to 0.083-cm^2 leaf area injury on an average leaf.

Demographics and Landscape Management Practices of Survey Participants. In the whole-plant selection surveys, 62% of professionals and 89% of consumers were homeowners. Males comprised 59.2% of professionals, whereas 60.9% of the surveyed consumers were female. A high percentage of the professionals and consumers, 65.1 and 49.6% respectively, were graduates of college or technical school. At 39.2%, consumers were more likely to have graduate degrees than professionals, represented by 27.3% of the respondents. Among surveyed consumers, 54.3% reported annual household incomes from $51,000 to $100,000. Only 38.5% of the professionals reported incomes approximating these levels. Too, only 33.1% of consumers and 44.2% of professionals reported garden club or professional memberships.

Mean rankings of survey responses revealed that both groups strongly valued the appearance of their garden and landscape plantings, at 4.2 and 4.4 on a 5-point scale for professionals and consumers, respectively. With a mean rank of 3.4 for both beneficial insect and ornamental pest and disease recognition, professionals had a higher degree of confidence in their abilities than consumers, who scored 2.9 for pest and disease recognition and 3.1 for beneficial insect recognition. At 3.8 among professionals and 3.7 among consumers, readership of grower publications was relatively high. When asked of their interest in hiring an ornamental pest scout, however, interest was moderate to neutral with mean rankings averaging 2.7 for professionals and 3.0 for consumers. In contrast, both professionals and consumers were interested in reducing pesticide use through management alternatives, at mean rankings of 4.0 and 4.1, respectively.

Scouting practices were similar for industry professionals (6.5%) and consumers (5.2%) with few in either group scouting more frequently than once a week. Weekly scouting was reported for 28.6% of professionals and 25.8% of consumers. Only 18.1% of professionals and 18.6% of consumers reported scouting on a 2-wk cycle. While 25.2% of consumers reported an infrequent scouting schedule, too, 19.5% of industry professionals reported scouting activity conducted every few months.

Finally, when pests were present, 37.1% of professionals and 37.6% of consumers used pesticides. When

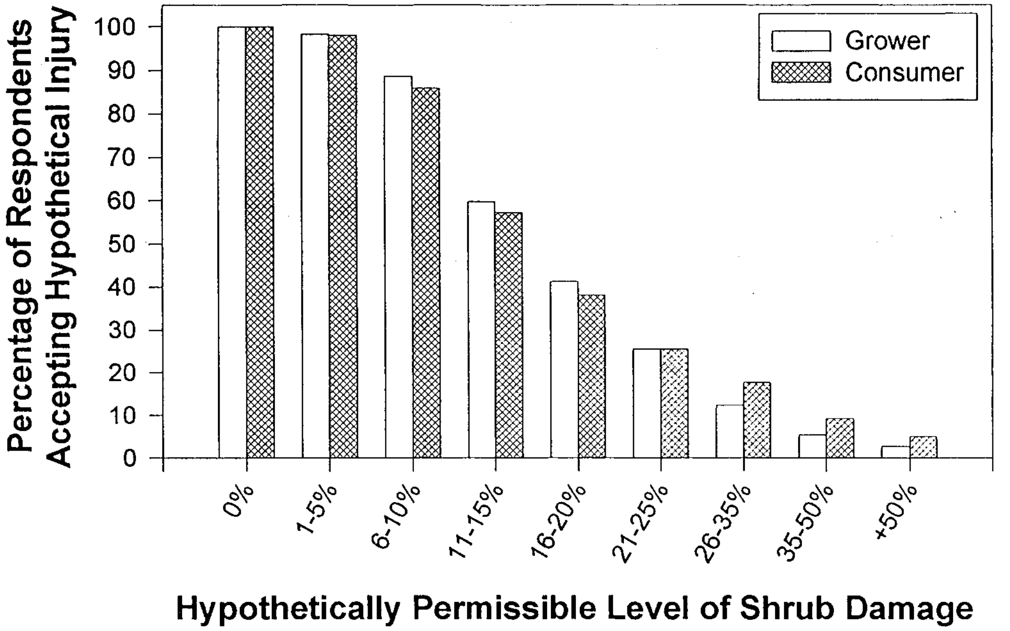

Fig. 3. Responses of survey participants to the hypothetical acceptance of injury. Half of the grower/managers and consumers surveyed reported that they were willing to accept a 6–10% hypothetical level of azalea lace bug feeding injury to reduce pesticide use in their landscapes.

damage was visible, 34.5% of professionals and 29.5% of consumers applied pesticides. Respondents who either totally avoided pesticide use or who used pesticides as a preventive measure were represented by 12.1% of the industry professionals and 16.9% of the consumers surveyed.

Assessment of Aesthetic Damage by Azalea Lace Bugs. A hypothetical question was posed to survey participants before viewing actual plants, which asked how much visible arthropod damage would be acceptable on their landscape plants to avoid using a pesticide. Trends of consumers and professionals were similar (Fig. 3). More than 50% of the respondents in each of the 2 groups indicated a hypothetical tolerance to 11–15% lace bug injury levels on azaleas, but >80% of participants would hypothetically accept ≤10% damage. Neither education (green industry professionals, $F = 1.54$; df = 5, 103; $P = 0.32$; consumers, $F = 1.38$; df = 5, 220; $P = 0.38$) nor income level (green industry professionals, $F = 1.48$; df = 3, 103; $P = 0.38$; consumers, $F = 1.05$; df = 3, 222; $P = 0.48$) significantly affected responses.

Hypothetical responses were comparable to the responses given by survey participants for live plant inspections. Proportional feeding injury levels on live plants encompassed a wide range of values when actual injury was estimated using the 2% injury recognition threshold. A comparison of proportional injury to actual injury among all the live azaleas revealed that the majority of the azaleas used for the surveys had <5% actual injury throughout the canopy (Fig. 4). Variability between actual and proportional lace bug feeding injury was limited in the range of <5% actual injury, or 80% proportional injury. With >5% actual injury to the azalea canopy, predictions of corresponding proportional levels of injury could not be reliably made. Student *t*-test comparisons revealed no significant differences among professional or consumer survey responses regarding unwillingness to purchase azaleas ($t = 0.11$, df = 10, $P = 0.09$) or treatment preferences for injured azaleas ($t = 0.83$, df = 10, $P = 0.44$). Neither the education level of industry professionals ($F = 1.91$; df = 5, 90; $P = 0.10$) or consumers ($F = 0.76$; df = 5, 233; $P = 0.58$) nor income level among professionals ($F = 0.94$; df = 3, 88; $P = 0.48$) or consumers ($F = 0.86$; df = 3, 235; $P = 0.46$) significantly influenced responses. Additionally, recommendations of azaleas needing treatment were not significantly influenced by the education level of professionals ($F = 0.89$; df = 5, 102; $P = 0.49$) or consumers ($F = 1.56$; df = 5, 233; $P = 0.16$), or by the income level of professionals ($F = 0.10$; df = 3, 104; $P = 0.96$) or consumers ($F = 2.44$; df = 3, 233; $P = 0.07$).

The Mitscherlich curve equation was used to investigate pooled responses to live plant inspections. One half of the participants indicated that ≈11% of a shrub's leaves having >2% injury was sufficient to elicit a refusal-to-purchase response (Fig. 5). No-purchase decision curves were not significantly ($t = 0.11$, df = 10, $P = 0.09$) different among consumer and professional responses. When survey responses were pooled, selection of live plants for purchase was not significantly influenced by education level ($F = 1.19$; df = 5, 304; $P = 0.61$) or income level ($F = 1.54$; df = 3, 279; $P = 0.20$). In comparison to no-purchase trends, 50% of those surveyed indicated that an injured shrub

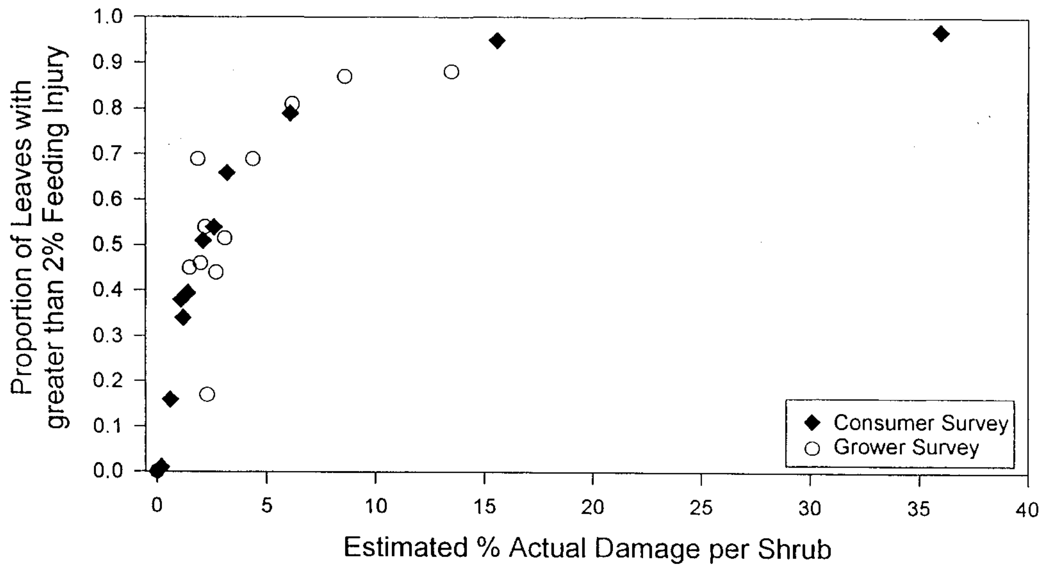

Fig. 4. A comparison of actual and proportional damage levels of azalea shrubs among plants used to survey growers and landscape managers at the Wintergreen Tradeshow and consumers at the Southeastern Flower Show.

must have >43% of its leaves injured with >2% injury to prompt treatment (Fig. 6). Consumer and professional treatment preferences were not significantly different ($t = 0.83$, df = 10, $P = 0.44$).

Discussion

The dark green leaf color of Girard's Rose azaleas, which were used for the azalea lace bug injury-rec-

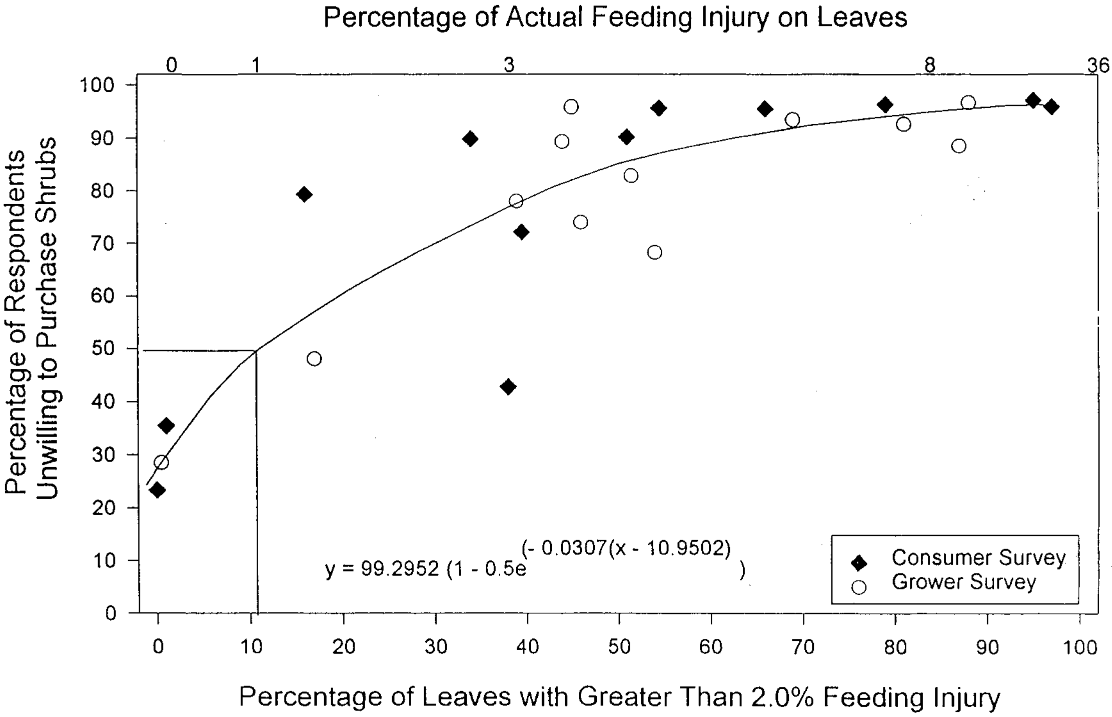

Fig. 5. Mitscherlich curve responses of purchase decisions by survey participants. Proportional injury ≥11% was sufficient to cause rejection for the purchase of damaged azaleas by 50% of the survey participants.

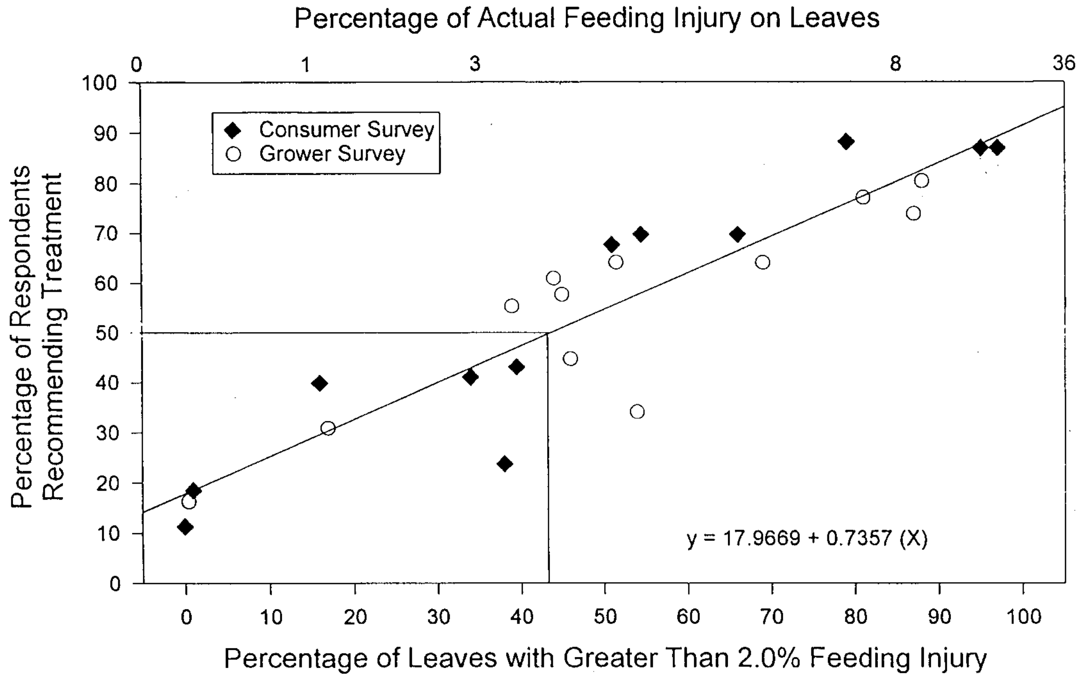

Fig. 6. Mitscherlich curve of treatment needs indicated by survey participants. Proportional injury ≥44% was sufficient to initiate treatment of injured azaleas by 50% of the survey participants.

ognition survey, provided a high contrast to the chlorosis imposed by *S. pyrioides* feeding. Despite this contrast, 50% of the respondents were unable to reliably distinguish injury of <2% of the azalea leaf surface. This may be partially explained by the presence of leaf hairs on the upper surface of azalea leaves, which are highly reflective and might mask low levels of azalea lace bug feeding injury. Use of the 2% injury threshold may report high proportional levels of shrub injury, which corresponds to low levels of actual azalea lace bug feeding injury within the canopy. This was demonstrated in our study with azaleas that had proportional injury levels of ≈40%, while actual overall injury to the shrub canopy was ≈3%. The plants exhibited good association between proportional and actual injury levels at levels below 80% proportional and 5% actual injury.

The 2% injury threshold allows a rapid quantification of the relative presence or absence of feeding injury on azalea leaves. Based upon this value, a presence/absence rating system can be developed allowing landscape managers to quickly assess aesthetic damage to azaleas in urban settings. Azaleas with readily apparent injury levels and the presence of azalea lace bugs can be treated with insecticides. Azaleas with levels of injury below the injury threshold require monitoring but may have lace bug populations that are naturally maintained by disease or predatory arthropods. Similarly, injury thresholds can be established for a number of ornamental plants that frequently have associated pest populations, thus providing the basis for developing aesthetic injury levels within a comprehensive landscape IPM program.

The highly discriminatory capacity shown by our survey participants for azalea lace bug injury is consistent with other research results. A study that investigated the effect of bagworm, *Thyriodopteryx ephemaraeformis* (Haworth), injury on the American arborvitae *Thuja occidentalis* L. found that one-half of individuals considered 5% missing or discolored leaf tissue damaging to a 1.2-m tree (Raupp et al. 1988). Other studies have also determined that <10% injury to plants is sufficient to label a plant unacceptable (Coffelt and Schultz 1993, Sadof and Alexander 1993).

In our study, there was a distinct contrast between the threshold for willingness-to-purchase predicted at 1.03% actual canopy injury (11% proportional injury) and the threshold to induce treatment predicted at 3.3% actual canopy injury (43% proportional injury) by survey participants. This suggests that both professionals and consumers have a greater tolerance to azalea lace bug feeding injury once azaleas are established in the landscape. Azaleas may tolerate lace bug feeding-injury at injury levels >13% of the available canopy area, without experiencing significant reductions in photosynthesis, respiration, or growth (Klingeman 1998). As a result, treatment at low injury levels is based primarily on aesthetics rather than on the potential for plant physiological injury. Educational and outreach efforts can be designed to possibly reduce pesticide use by providing homeowners and industry professionals with an understanding that azaleas in their landscape can tolerate significantly more lace bug feeding injury than our research demonstrated was necessary to initiate a treatment or unwillingness-to-purchase decision.

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