Whole Plant CO_2 Exchange Measurements on Azaleas Injured by Azalea Lace Bug Feeding

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Nature of Work: The azalea lace bug, *Stephanitis pyrioides* (Scott) is the most significant pest of cultivated azaleas in the southeastern landscape (2,11). Azalea lace bugs feed on cell contents within the palisade parenchyma and cause a readily apparent chlorotic stippling on leaves (7). Measurements made on single lace bug-injured azalea leaves demonstrate reduced photosynthetic rates. These reductions were correlated to the removal of leaf chlorophylls and other cellular contents (4). Additionally, analysis of single azalea leaf CO_2 exchange indicated that azalea lace bugs impair chlorophyll functioning in the remaining chloroplasts. This effect was attributed to corresponding stomatal closure in injured leaves (4).

Welter (13) reviewed the effects of arthropod and insect feeding on plant gas exchange within insect feeding-guilds. The majority of these studies also relied primarily on measurements of leaf gas exchange taken from individual leaves. Evans (6) cited several factors that may result in a poor correlation between single leaf photosynthesis measurements and both dry matter production and yield. Leaves selected for measurement are known to vary with age or condition. Analysis of a particular stage of leaf maturity is not necessarily representative of the overall photosynthetic rate of a plant canopy. Variability may also exist within a single leaf. The section of leaf chosen for measurement may not be typical of the whole. Collection of the many samples needed for statistical accuracy virtually ensures that leaf samples will be conducted over a lengthy time period. Variation, due to diurnal changes in photosynthetic rate, is likely to confound the data. Most importantly, root and shoot respirations are not measured. Growth and carbon use efficiency variables are not adequately quantified and cannot be reliably interpreted.

The shortcomings of individual-leaf gas-exchange analysis may be avoided by using whole-crop CO_2 exchange systems usin a growth chamber (3,5,12). Environmental conditions, including CO_2, temperature, light, and relative humidity variables are effectively maintained facilitating data interpretation (12). We undertook a whole-crop analysis of gas exchange in Girard's 'Pleasant White' azalea hybrids. Rooted azalea cuttings were maintained at 20°C for a 10:14 (L:D) photoperiod. A single acephate application (ml/l) was made on 42 undamaged control cuttings to maintain them in a lace bug-free condition during the study. Using 1.0m3 screen cages, cuttings were artificially infested to obtain low (6%), medium (13%), and high (31%) leaf area injury treatments.

Injury was quantified by comparing 1/2 of the leaves on each cutting to an array of 24 leaf images ranging from 0.5% to 82% injured leaf area. Leaf images were analyzed using Mocha software: a computer-assisted measurement program which utilized contrasting color overlays to quantify both total leaf area and injured leaf area (Jandel Laboratories, San Rafael, CA). Percent injury on each leaf was estimated for the 7 cuttings in each treatment group. Previous work on azaleas has indicated that leaf damage may be recognized when 2% or more of the leaf area is injured by feeding azalea lace bugs (W.E.K. unpublished data). We used this 2% threshold to calculate a mean proportional injury level for the 7 azalea cuttings included within each treatment group. Leaves with less than 2% injury among the leaf area were not counted as injured for this proportional level.

Treatment groups, each consisting of 7 azalea cuttings, were randomly selected from the 42 plants in each treatment level. Treatment groups were arranged into 6 replicates and together formed a randomized complete block design. Plants were watered before being placed in the chambers to alleviate potential water stress. In the chambers, treatment groups received a 14L:10D photoperiod. Photosynthetically active radiation (PAR) levels at canopy height averaged 600 (µol m^{-2} s^{-1}. Relative humidity within the chambers was held at 50% during the day and increased to 70% during the night. Diurnal temperatures in the growth chambers were maintained at 23 ± 1°C while nighttime temperatures dropped to 19 ± 1°C.

A multi-chamber whole plant CO_2-exchange system (12) measured net photosynthesis (P_{net}) and dark respiration (R_{dark}) for treatment groups during a 24-hour period. Gas exchange measurements, lasting 5 minutes per chamber, were taken sequentially for each treatment. Treatment groups, replicated 6 times, were analyzed in 3 trials lasting 24 hours each. Each trial consisted of 2 complete replicates as well as measurements taken within 2 empty acrylic chambers, which provided a baseline for comparison. Carbon use efficiency (CUE) is the ratio between carbon incorporated in plant dry mass and the total amount of carbon fixed in photosynthesis. Daily carbon gain (DCG) is the amount of CO_2 fixed by the canopy less the amount of CO_2 lost by respiration and is similar to crop growth rate. Long-term experiments using summed DCGs to provide a cumulative carbon gain (CCG) have found a close correlation

($r^2 = 0.998$) between cumulative carbon gain and plant dry mass (12). Carbon use efficiency, daily carbon gain, and gross photosynthesis were calculated from P_{net} and R_{dark} data. Once gas exchange measurements were concluded, leaves were removed from each plant and 25 leaves were randomly selected. Leaf area of the 25 leaves was determined using a LI-COR 3200 leaf area meter. Dry mass of the 25 leaves was taken, as well as dry masses of the leaves, stems and roots of each treatment group.

Results and Discussion: Injury levels imposed by artificial infestation was 6% actual leaf area injury for the low level treatment, or 42% proportional injury based on the 2% threshold. The medium treatment had 13% actual leaf area injury and 61% proportional injury, and the high treatment had 31% actual leaf area injury and 76% proportional injury.

Measurements of gas exchange taken from whole plants revealed differences among treatments of azalea lace bug-injured leaf area. Net photosynthesis in the high treatment, with 31% of the canopy leaf area showing azalea lace bug injury, had lower net photosynthesis than undamaged, low, or medium injury treatments. Dark respiration results revealed that both the medium (13% actual leaf area injury) and high (31% leaf area injury) levels were lower than respiratory rates demonstrated by undamaged and low (6% leaf area injury) treatments.

All injury levels presented different efficiencies of carbon use. The treatment having the highest level of injury demonstrated the least efficiency in carbon use: only 63.1% of the total carbon fixed by photosynthesis was attributed to dry mass production. Efficiency levels for undamaged, low and medium injury treatments exhibited a trend suggesting that carbon use efficiency increased with ALB feeding injury. Instead, the interaction of net photosynthesis and dark respiration were illustrated by these results. The trend described by daily carbon gain values closely paralleled that of net photosynthetic rate. Only plants averaging 31% actual leaf area injury had notable reductions in growth.

Significance to Industry: Azalea lace bug management practices have historically focused on chemical controls (1,10). In 1995, landscape managers, nurserymen, and homeowners spent in excess of $1.1 million to control lace bugs, including *Stephanitis pyrioides*, in Georgia alone (9). Heavy reliance on chemical controls has prompted investigations into integrated management programs for azalea lace bug. The results of this study suggest that azaleas are resilient under azalea lace bug feeding pressure. The proportional values of azalea lace bug injury demonstrate that plants in all selected treatment levels would be readily recognized as damaged in the landscape. Urban pest management programs in the southeast should work to increase consumer tolerance of lace bug injury. Additionally, the importance of plant placement and landscape structure should be emphasized as effective tools in mitigating population outbreaks of azalea lace bugs (8).

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