N O T E

Influence of Temperature, CO_2 Concentration, and Species on Survival and Development of Lace Bugs (Hemiptera: Tingidae)[1]

S. Kristine Braman[2], Shakunthala Nair and Evelyn Carr

Department of Entomology, 1109 Experiment Street, University of Georgia, Griffin, Georgia 30223 USA

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The trend of increasing temperature and CO_2 concentration, commonly referred to as global climate change, could potentially alter the relationship between plants and insects as well as pest management strategies and global green industry economics. Previous studies have shown that herbivore performance in elevated CO_2 concentrations depends largely on their method of feeding (Bezemer and Jones 1998, Oikos 82: 212 - 222). Additionally, response to CO_2 and temperature increases are often insect species specific (Johns and Hughes 2002, Global Change Biol. 8:142 - 152). An increase in temperature and CO_2 concentration can affect insects directly by altering their feeding habits, growth, development, reproduction, and range of habitat; and indirectly by changing the chemical and physical compositions of plant tissues (Flynn et al. 2006, Environ. Exp. Bot. 56:10 - 18). Studies that focus on the interactive effects of temperature and CO_2 simultaneously are particularly needed.

Lace bug responses to CO_2 concentration and temperature were studied because lace bugs are key ornamental pests. Understanding how these pests respond to increasing temperatures and CO_2 concentrations will aid in refining decision-making criteria for pest management. Azaleas, rosaceous plants, and chrysanthemums are all major landscape ornamentals that play a large role in the greenhouse and nursery industry. The lace bugs being studied affect the aforementioned plants. Damage occurs to plants when lace bug adults and nymphs feed from the underside of the leaves, extracting cell contents from the upper palisade parenchyma layer, producing chlorosis and stippling. In severe infestations foliage becomes bronzed or bleached, and early leaf abscission can occur (Braman and Pendley 1993, J. Entomol. Sci. 28:417 - 426). The average temperatures for successful development of the azalea lace bug, *Stephanitis pyrioides* (Scott), and hawthorn lace bug, *Corythucha cydoniae,* (Fitch), are between 22°C and 33°C (Braman et al. 1992, J. Econ. Entomol. 85:870 - 877; Braman and Pendley 1993, J. Entomol. Sci. 28:417 - 426). All previous experiments

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[2]Address inquiries (email: kbraman@uga.edu).

involving lace bugs were performed at ambient CO_2 concentrations. The objective of this experiment was to determine how higher temperatures and CO_2 concentration levels affect the development and survival of 3 lace bug species on their respective host plants.

The experiment was conducted at the University of Georgia Envirotron located on the Griffin Campus. The Envirotron is a research facility consisting of multiple walk-in chambers where the relative humidity, air temperature, photoperiod and CO_2 concentration levels can be controlled (Chong et al. 2004, J. Entomol. Sci. 39:387 - 397). A total of 6 chambers in this study was maintained under alternating temperature regimes on 12h schedules of 25/15°C or 35/25°C and CO_2 concentration levels of either 400 or 800 µmol mol^{-1}. The photoperiod within the chambers was maintained at 16h daylight, and the relative humidity was maintained at 75%.

Adults of 3 lace bug species, chrysanthemum lace bug (*Corythucha marmorata* [Uhler], azalea lace bug (*S. pyrioides*) and hawthorn lace bug (*C. cydoniae*) were field collected. Suitable host plants were provided by the nursery industry. *Cotoneaster* spp. and *Rhododendron* spp. for hawthorn and azalea lace bug, respectively, were provided in one -gallon (3.75 L) nursery trade containers. Chrysanthemums were grown in 15cm diam plastic pots in Metro Mix 300 potting soil and allowed to establish for about 6 months before being transferred to the Envirotron along with the other provided plants. All plants were allowed to acclimate to the Envirotron chambers for 2 wks prior to being infested. Each plant was initially infested with 6 female/male pairs of the appropriate host-specific lace bug species. The plants were placed in wooden frame cages covered with nylon screen inside the walk-in environmental chambers.

Table 1. Effect of varying temperature and carbon dioxide levels on growth of lace bug species: Summary of analysis of variance table, with respective F-value.

Source	df	Egg	Nymph	Adult	Total
Rep	2	(NS)	(NS)	(NS)	(NS)
		2.61	0.74	1.25	2.5
Temp	1	***	(NS)	(NS)	**
		21.16	0.25	1.99	14.08
CO_2	1	(NS)	(NS)	(NS)	(NS)
		0.76	0.49	0.78	0.10
Species	2	**	(NS)	(NS)	*
		6.75	1.35	1.38	3.97
Temp* CO_2	1	(NS)	(NS)	(NS)	(NS)
		1.48	1.82	0.38	0.23
CO_2* Species	2	*	(NS)	(NS)	*
		5.06	1.69	0.88	3.98
Temp* Species	2	**	(NS)	(NS)	**
		7.17	1.47	2.47	5.85

NS = not significant ($P > 0.05$), * = significant ($0.05 > P > 0.01$), ** = highly significant ($0.01 > P > 0.001$), *** = very highly significant ($P < 0.001$); Values in parentheses represent the statistical F-value.

There were 3 replications of each lace bug, temperature, CO_2 concentration combination. All plants were watered but not fertilized for 3 months. Plants were then destructively sampled, all foliage was examined using a stereomicroscope, and all lace bug stages (eggs, nymphs, and adults) were counted.

A three-way factorial analysis of variance (PROC GLM) (SAS Institute 2003) was used to analyze data for survival of eggs, nymphs, and adults at each temperature, CO_2 concentration, and species, as well as the interactions between temperature and CO_2 concentration, temperature and species, and CO_2 concentration and species. The data were transformed prior to the analysis to conform to a normal distribution by taking the square root of the egg, nymph and adult counts. Means were separated using Tukey's Test.

Temperature had the greatest effect on survival and reproduction. The interaction between species and temperature was highly significant for eggs, adults and total counts (Table 1). The mean survival count for azalea lace bug was significant for temperature for eggs (F = 20.72, df = 1, P = 0.0039) and totals (F = 10.03, df = 1, P = 0.0194). However, the azalea lace bugs were not significantly affected by the tested CO_2 concentrations at any stage. The mean survival of hawthorn lace bug was significant for temperature, for eggs (F = 10.84, df = 1, P = 0.0166), and totals (F = 7.94, df = 1, P = 0.0304), and CO_2 concentrations had significant effects on the number of eggs (F = 7.22, df = 1, P = 0.0362), adults (F = 8.07, df = 1, P = 0.0295), and totals (F = 7.41, df = 1, P = 0.0345). The mean survival of chrysanthemum lace bug was not affected by temperature at any stage, but CO_2 concentrations affected the number of adults (F = 11.86, df = 1, P = 0.0183). None of the treatment factors had significant effects on nymphal numbers of any lace bug species. Figure 1 summarizes the

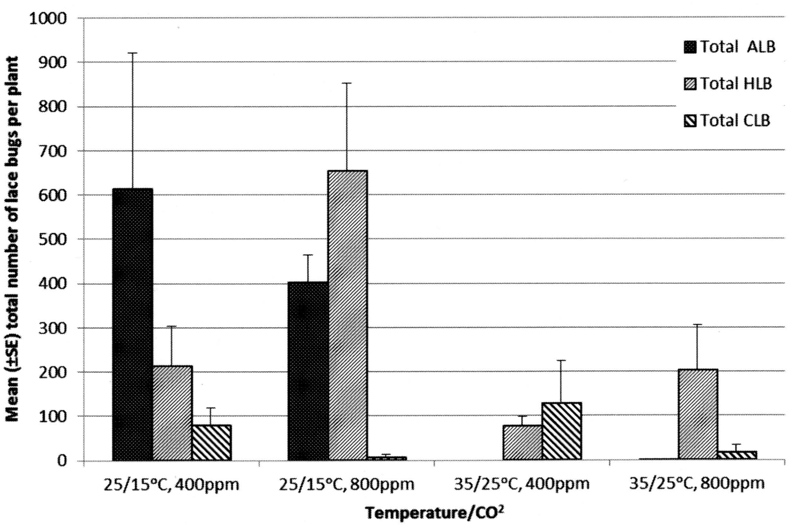

Fig. 1. Mean total number of lace bugs (eggs, nymphs and adults) per plant, in response to two temperature (25/15°C and 35/25°C) and two CO_2 (400 and 800 ppm) levels. ALB= azalea lace bug; HLB= hawthorn lace bug; CLB= chrysanthemum lace bug.

performance of the three lace bug species at different combinations of temperature and CO_2 concentrations.

The results of this study suggest that growth, survival, and reproduction of all lace bug species studied are more influenced by temperature than CO_2 concentration. Effects of both variables studied varied significantly with lace bug species. Among the 3 lace bug species, chrysanthemum lace bug was most tolerant to the higher temperature level, and it had moderate tolerance to the lower temperature level. Hawthorn lace bug had moderate tolerance, and azalea lace bug had no tolerance for higher temperatures, but both these species thrived at the lower temperature level.

Our research is consistent with previous studies that have been performed on other insect species at similar temperature levels and CO_2 concentrations and illustrate the fact that not all lace bug species will respond identically to changing climate. Tingidae contains approx. 250 genera and 2000 described species. The majority of species are highly specialized in their food habits. They are obligate plant feeders and, as such, have the potential to achieve economic status. On ornamentals, Johnson and Lyon (1988; Cornell Univ. Press. Insects that Feed on Trees and Shrubs) regarded Tingidae as the most important family in Hemiptera. Twenty- seven species were mentioned in the genus *Corythucha* alone, although few of those currently ever reach pest status. Similarly Beshear (1976, Georgia Agri. Exp. Station Research Bull. 188, 29 pp) found 29 species of lace bugs in Georgia and regarded only 8 of those as economically important at that time. Those species positively affected by increasing temperature and CO_2 concentration, like hawthorn lace bug in the present study, may pose increasing pest management challenges.