The Effect of Temperature on Survival and Development of First Instar *Monellia caryella, Monelliopsis pecanis,* and *Melanocallis caryaefoliae* (Homoptera: Aphididae)[1]

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ABSTRACT First instar nymphs of *Monellia caryella* (Fitch), *Monelliopsis pecanis* Bissell, and *Melanocallis caryaefoliae* (Davis), were exposed to temperatures of 25, 30, 35, and 40°C for up to 9 days. Test aphids were observed for growth, maturity, natality and mortality at each temperature. For three species mortality was low at 25°C but development was slowed; at 30°C mortality increased slightly but development and natality was optimum; at 35°C mortality was greatly increased and maturity was not attained; at 40°C first instar aphids did not survive beyond one day. In further testing with hourly observations at 40°C, *M. caryella* had 100% mortality after 6 h-exposure, *M. pecanis* had 100% mortality after 9 h, and *M. caryaefoliae* survived for 11 h and was the most tolerant of 40°C.

KEY WORDS *Monellia caryella, Monelliopsis pecanis, Melanocallis caryaefoliae,* temperature effect, pecan aphids.

Aphid population growth is influenced by air temperature (Hille Ris Lambers 1966) but it is the microclimate in the aphid habitat that is the major regulator of aphid abundance (Hodek et al. 1972). Another complicating factor may be the indirect effect on aphids resulting from plant response to soil and moisture temperatures. Field observations lead us to suspect that temperature likely influences both the natality and mortality of aphids, both directly and indirectly. There have been three laboratory studies of the effect of temperature on the aphids of pecan. Leser (1981) studied the effects of 10-35°C on *Monellia caryella* (Fitch); Flores (1981) studied the effects of 20-30°C on *M. caryella* and *Melanocallis caryaefoliae* (Davis) and Edelson (1982) studied the effects of 10-35°C on *M. caryella* and *Monelliopsis pecanis* Bissell. In all three studies, regardless of the temperature or species greatest mortality occurred in the first instar. Optimum temperature for three each species was about 25°C ± 5°C and temperatures of 35°C were very damaging to aphid survival.

Air temperatures during July and August in middle and south Georgia often ranges between 35 and 40°C for several successive hours daily and sometimes on several successive days. Numerous observations of field populations of these three species inhabiting commercial pecan orchards in the southeastern U.S. lead us to suspect that even short periods of high air temperature may be involved in the decline of populations of aphids on pecan trees in mid-summer

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(Tedders 1978). This study reports the effects of short and long periods of high temperature on first instar cohorts of *M. caryella, M. pecanis* and *M. caryaefoliae* and provides a comparison of seasonal aphid fluctuations relative to the variation in seasonal temperatures as affected by changing photoperiod.

Materials and Methods

At the beginning of each test aphids were first instar nymphs less than 24 h old. First instars were used because aphid outbreaks only occur after successful maturation of numerous newly born aphids during periods of low mortality and because first instars were shown to be the stadium most sensitive to high temperatures. Also the uniformity of age of first instar aphids was easily controlled at the start of tests.

Colonies of adult aphids maintained on 'Curtis' pecan seedlings (Tedders et al. 1970) held at ambient room temperature in laboratory cages and provided with 15 h photophase and 9 h scotophase (Tedders 1977) were the source of first instar nymphs for all experiments. Cages for testing the effects of temperature on first instar aphids were 63 X 16 mm disposable petri dishes each containing 15 cc of 1% water agar as a substrate for one 4 X 4 cm square of surface sterilized 'Curtis' seedling leaf tissue (Reilly and Tedders 1990). Leaf sections were taken from fully expanded, mature leaves of 60 day old, greenhouse-grown seedlings. The leaf section allowed for normal growth and development of aphids to maturity. All three aphid species were evaluated simultaneously during each test.

On the day preceding a test, 2 or 3 adult aphids were placed in each petri dish cage and held in a bioclimatic cabinet operating at 27°C, and 15 h photophase and 9 h scotophase. The adults were removed after 20 h and the remaining first instar progeny (F-1) were adjusted to consistent numbers in each cage by removal or transfer. Uneven numbers of aphids (between the species) were sometimes used because large numbers of aphids were not always available. Dishes with aphids were then immediately subjected to test temperatures within continuously lighted incubators until the required temperature-time treatment was received. When temperature treatments were 25, 30, 35 or 40°C, relative humidities in petri dish cages averaged 84.7, 95.8, 98.0 and 100% respectively. All tests were conducted as completely randomized designs.

In order to establish background data under our conditions and for these experiments, first instars of the three species were evaluated for survival, development, and reproduction at the four temperatures. Aphid mortality was determined after 1, 2, 5, 7, 9, and 12 days. Also, data were collected to determine the number of days required for the first aphid to mature, the number of aphids matured by 9 days, and the number of progeny (F-2) produced by cohort adults at 9 days. Treatments were replicated three times. Petri dishes each contained five first instar nymphs of *M. caryella* or *M. caryaefoliae* and seven nymphs of *M. pecanis.*

For the second experiment the survival of aphids was determined after exposure to temperatures of either 30, 35, and 40°C, each for periods of 2, 4, 6, 8, 10, and 12 h. Following exposure to a temperature-time period, the petri dishes with aphids were transferred to a continuously lighted incubator at 27°C until

the aphids either died or matured. Aphids in dishes held at 27°C served as the untreated controls. Dishes with aphids at each temperature were replicated five times at 30 and 35°C and three times at 40°C. The number of first instar F-1 nymphs per dish were: *M. caryella* five at 30°C, four at 35°C and three at 40°C; *M. pecanis* six at 30°C, five at 35°C and five at 40°C; *M. caryaefoliae* nine at 30°C, two at 35°C and eight at 40°C.

Experiment three was performed to obtain greater resolution of the effects of 40°C in a continuously lit incubator for hourly periods up to 12 h. Following exposure, dishes with aphids were transferred to the 27°C incubator where they were held until they matured or died. Untreated controls were held at 27°C for comparison. All dishes with aphids were examined after 1 and 4 days. Treatments to petri dishes with aphids were replicated three times at each temperature and the number of aphids contained in each dish was: six *M. caryella*; seven *M. pecanis*; and eleven *M. caryaefoliae.*

Results and Discussion

In experiment one, all three species exhibited the least mortality at 25°C at nine days but aphid maturity and reproduction were delayed, presumably the result of the cooler temperature. At 30°C all three species developed most rapidly and the adults produced the most progeny per adult but *M. caryella* showed signs of increased mortality at this higher temperature. At 35°C all three species displayed greatly increased mortality after nine days, aphid development was slowed and cohorts were noticeably smaller. Most cohorts developed only to third or fourth instar and these died before reaching adulthood. All cohorts of the three species were killed after 1 day exposure to 40°C (Table 1).

In experiment two, significant differences from the controls were not observed in the survival of nymphs of any species exposed for 2, 4, 6, 8, 10, or 12 h at 30°C or 35°C. However, the results of the effects of exposure times at 40°C for all three species verified our findings in experiment one and each species experienced increased mortality with exposure time, until 100% mortality was obtained. *Monellia caryella* was most sensitive to 40°C and 100% mortality occurred after 6 h. *Melanocallis caryaefoliae* was the most tolerant of 40°C but 100% mortality occurred by 10 h. *Monelliopsis pecanis* seemed intermediate between these two and 100% mortality occurred before 10 h.

Experiment three was more precise than experiment two since larger numbers of aphids were used and observations were made hourly. Results were similar to those of experiment two and these data clearly showed that *M. caryella* was the most sensitive to 40°C; withstanding the exposure for just over 4 h. *Monelliopsis pecanis* withstood 40°C for 2 h without mortality, but 100% mortality occurred at 6 h. *Melanocallis caryaefoliae* withstood 40°C for 8 h without 100% mortality.

Since the results of experiments two and three at 40°C were similar, the data were pooled for even greater resolution and are presented as Fig. 1. The responses of *M. caryella, M. pecanis* and *M. caryaefoliae* each were curvilinear and each was fitted to a different polynomial equation. Fits of data to the equations were: *M. caryella*, $r^2 = 0.93$, $P \leq .0001$; *M. pecanis,* $r^2 = 0.94$, $P \leq .0001$; *M. caryaefoliae,* $r^2 = 0.84$, $P \leq .0001$. Plotted curves of the pooled data indicate that

Table 1. Survival of three aphid species after 9 days exposure to either 25, 30, 35 or 40°C; number of days required for first adult to mature; number of aphids maturing by 9 and 12 days; number of progeny (F-2) produced by 9 days. Numbers are totals of 3 replicates.

Temperature (°C)	Beginning First Instar Aphids (No.)	Aphid Survival Days 1 (%)	2 (%)	5 (%)	7 (%)	9 (%)	Days Required For First Aphid To Mature (No.)	Aphids Maturing Days 9 (No.)	12 (No.)	F_2 Progeny Produced at 9 days (No.)
					Monellia caryella					
25	15	100	100	100	100	80	6	11	11*	6
30	15	100	100	100	53	13	5	2	2	10
35	15	93	87	73	20	0	-	-	-	-
40	15	0	-	-	-	-	-	-	-	-
					Monelliopsis pecanis					
25	21	100	100	100	100	100	9	2	21	3
30	21	100	100	100	100	100	6	21	21	142
35	21	95	90	67	48	33	-	-	-	-
40	21	0	-	-	-	-	-	-	-	-
					Melanocallis caryaefoliae					
25	15	100	100	100	100	100	9	1	15	2
30	15	100	93	93	93	93	7	14	14	244
35	15	80	80	73	73	67	-	-	-	-
40	15	0	-	-	-	-	-	-	-	-

* Four adult aphids died by day 12.

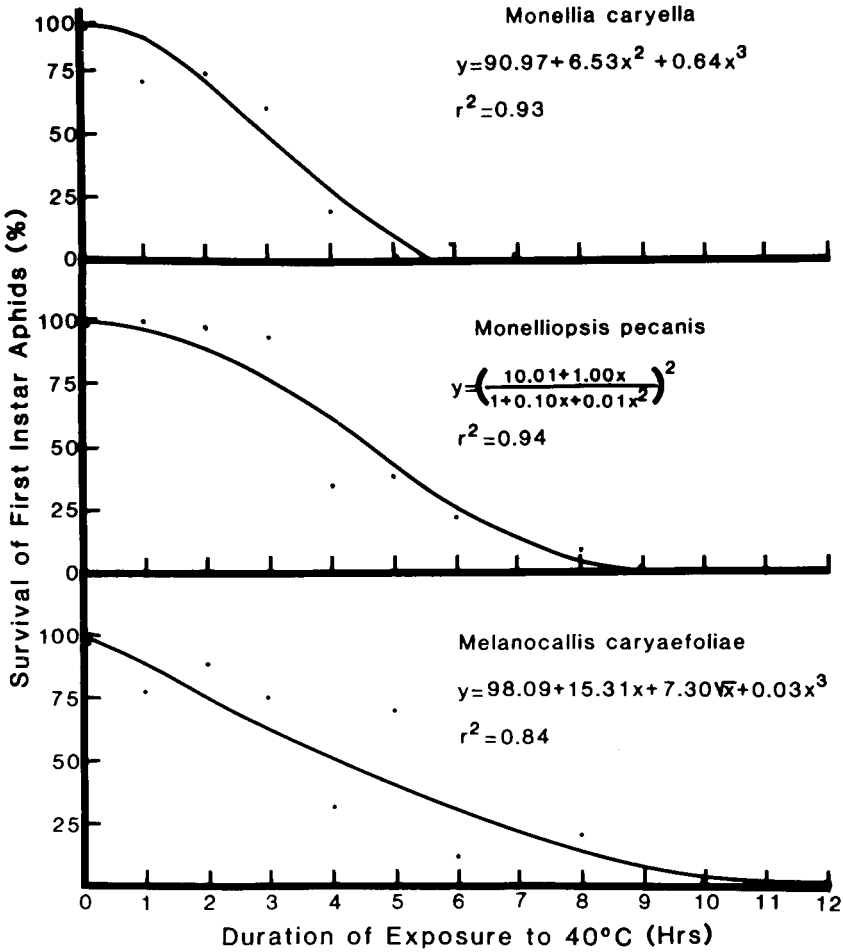

Fig. 1. Percentage survival of first instar *M. pecanis*, *M. caryaefoliae*, and *M. caryella* after exposure to 40°C. Mortality determined at 2 h and 1 h intervals from pooled data of experiments two and three.

at 40°C few *M. caryella* would survive beyond 5.5 h, no *M. pecanis* would survive beyond 9 h and no *M. caryaefoliae* would survive beyond 11 h.

Monellia caryella, M. pecanis and *M. caryaefoliae* occur in mixed populations within the canopy of pecan trees with major outbreaks usually occurring in mid-May and during September. Normally, pecan trees are nearly devoid of aphids during mid-July. Figure 2 was partially derived from the collections of aphids from the field for 5 years (pooled data and visually smoothed curves, 1982-1986) and illustrates the time periods when these three aphids may reach outbreak

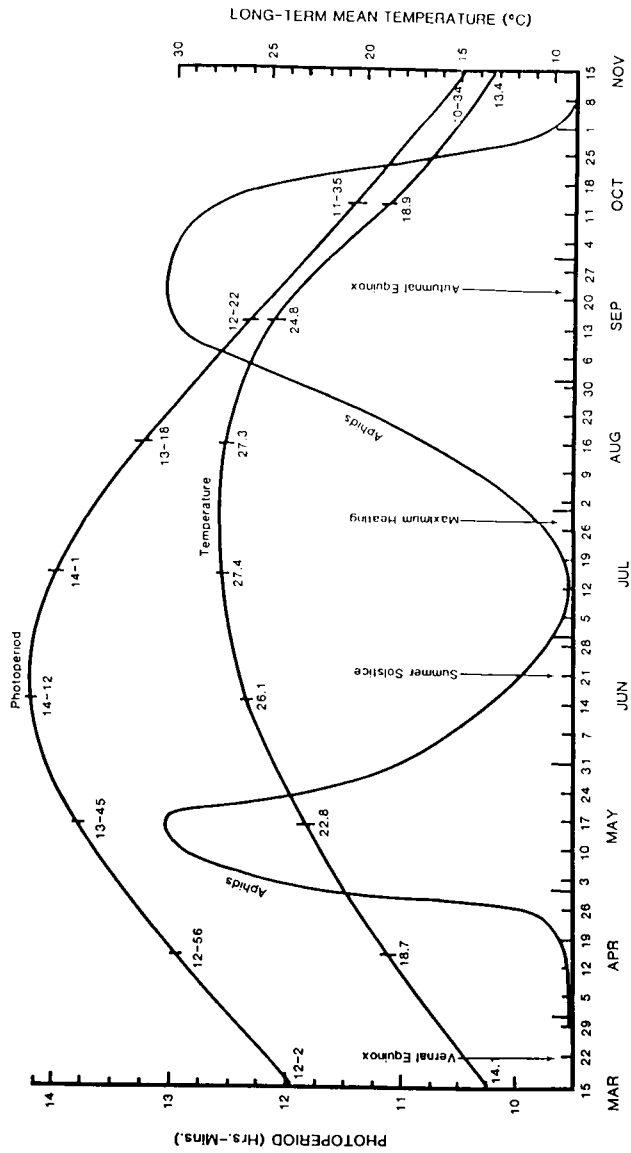

Fig. 2. The hypothetical occurrence of *M. pecanis*, *M. caryaefoliae*, and *M. caryella* (pooled data, 1982-1986) during the pecan growing season versus the seasonal photoperiod and ensuant long term mean temperature (average of means of Albany and Macon, GA Climatological Data, National Oceanic and Atmospheric Administration).

levels during the growing season. The figure also illustrates the changing photo-period, the vernal equinox, the summer solstice, the autumnal equinox, and the changing ambient air temperature for south Georgia. The temperature curve is an average of weekly, long-term means for Albany and Macon, Georgia. Photoperiod varies only a few seconds between these two cities. The figure provides a good representation of the mean temperatures for most of the pecan growing industry in Georgia. Air temperature is a function of length of photoperiod, but maximum air heating occurs nearly 5 weeks after summer solstice; the result of cumulative soil, water and air heating. Maximum air temperatures during late July and early August often reach 37.7°C or higher for several hours during the day on several successive days. Figure 2 suggests that high temperatures, may in part, be responsible for the absence of aphids during that period since lowest aphid numbers and maximum air temperatures occur almost simultaneously.

Laboratory temperatures between 25 and 30°C seem to favor the development of all three species and these findings are in reasonable agreement with those by previous authors. Temperatures near 35°C were noticeably detrimental to the development and natality of all three species since none reached adulthood at 9 days. This study indicates that temperatures of 40°C are likely to have a profound effect on aphid survival in the orchard environment and provides additional circumstantial evidence that air temperature is functioning to suppress aphid population growth in mid-summer. Also, this information helps to explain the outbreak of *M. caryaefoliae* during hot, dry periods near mid-summer because first instars of this species are considerably more tolerant to very high temperatures. Conversely, outbreaks of *M. caryella* often occur during cooler, damp periods in the spring and late-summer and are rarely observed at mid-summer. Such was the case in middle Georgia during 1991. *Monelliopsis pecanis* appears to occupy a temperature regulated niche between that of *M. caryella* and *M. caryaefoliae*.

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