Consumption of Eggplant Foliage by Colorado Potato Beetle (Coleoptera: Chrysomelidae)[1]

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ABSTRACT Feeding of second- to fourth-instar Colorado potato beetle, *Leptinotarsa decemlineata* Say, on eggplant was monitored at constant temperatures of 20, 26, 29, 32 and 35° C, and at 16, 20, 27, 29, and 33° C for adults to determine the effects of temperature on consumption. For comparison, consumption by each stage relative to fourth instars was standardized to feeding equivalants. A significant non-linear relationship was found between temperature and consumption for each life stage tested. Placement of each life stage on an equivalent feeding basis showed second instars consume on average 21.5% as much foliage as fourth instars, third instars 51.2% the amount of fourth instars, and adults 39.0% the level of fourth instars. These feeding equivalents can be used to develop field sampling plans and toxicant bioassays.

KEY WORDS Colorado potato beetle, foliage consumption, eggplant, *Leptinotarsa decemlineata*

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important insect pest of eggplant, *Solanum melongena* L., and potato, *Solanum tuberosum* L., in New Jersey. Fourth instar counts above eight larvae per plant depress flowering and reduce yield of eggplant (Cotty and Lashomb 1982). In commercial eggplant fields, however, Colorado potato beetle populations containing all life stages at the same point in time occur, making management decisions difficult. Equivalency, defined as the total injury equivalents for a population at a point in time (Pedigo et al. 1986), has been used to describe differential injury in cabbage (Harcourt 1954, Shelton et al. 1982). In potato, each feeding stage of Colorado potato beetle consumes different amounts of foliage and is dependent on temperature (Logan et al. 1985, Ferro et al. 1985, Lactin et al. 1993).

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This study was conducted to estimate equivalency based on foliage consumption by larval and adult stages of Colorado potato beetle relative to temperature because damaging populations in eggplant consist of all larval stages and adults. These equivalents can be used for future incorporation in a sequential sampling plan; feeding bioassays for toxicants from which accurate calculations of the amount of foliage and pesticide consumed can be determined.

Materials and Methods

All leaf material utilized in this study was collected by excising whole leaves of approximately the same age from greenhouse-grown 'Harris Special Highbush' eggplant. After excision, leaves were immediately inserted into floriculture vials containing 1/4 strength Hoaglands' solution (Hoagland and Arnon 1950) and rinsed with water to remove debris. "Leaf Discs" were then created by trimming leaves to 63.6 cm^2 by placing a bisected 9-cm plastic Petri® dish over the midrib of each leaf. To evaluate the acceptability of leaf discs in measuring consumption, the non midrib tissue from the left to the right side of 80 discs was removed, placed in individual aluminum weighing cups, and dried in a 50°C oven for 40 h. Dry weight was measured using a Mettler HK 160™ balance calibrated to the nearest 0.0001 g. Student *t* test was used to test for differences in average dry weight between sides (Sokal and Rohlf 1981).

All individuals used in this study were taken from a post-diapause laboratory colony that had been reared on eggplant for two generations. First instars were not utilized because individual first instars consume less foliage than can be accurately weighed. Following eclosion, first instars were maintained on untrimmed excised leaves and monitored until head capsule widths showed transition to the second instar. Seven- to eight-day post-emergence adult females, confined singly in plastic cups with males prior to the beginning of the experiment, were used in the study. All studies were conducted at an 18:6 LD cycle. Larval studies were conducted at 20, 26, 29, 32 and 35 ± 1°C; adults at 16, 20, 27, 29 and 33 ± 1°C. A wide range of temperatures was used for adults because they are more active at lower temperatures than larvae during spring emergence (Lashomb et al. 1984).

To estimate consumption, dry weight measurements were used because eggplant leaves of the same area were observed to vary in thickness. Additionally, leaf-chewing insects consume a volume of plant tissue rather than an area.

Larval consumption was measured by placing single leaf discs in 40 19.5 × 14.1 × 9.5 cm plastic boxes. A 0.85-cm wooden barrier was then placed over each midrib and petiole to limit feeding to one side of midrib. Individual, newly-molted second instars were introduced on the left side of each leaf disc and remained there for 24 h. Leaf discs were replaced daily, and the left and right sides of the midrib were excised and dried separately. Daily consumption was calculated by subtracting the weight of the left side from the right. When exuvia were found, daily consumption was accumulated for the completed stage. Late in the development of each fourth instar a small amount of vermiculite and peat moss mix (1:2) was placed in a corner of the box. When the larva pupated, the feeding study for that larva was terminated. This procedure was repeated 50 times for each temperature.

Adult consumption was determined identically to that of larvae, with the exception that each adult was individually confined in a 9-cm, plastic, top-vented Petri® dish containing a plastic barrier glued to the lid and a hole bored through the side to accommodate the leaf petiole. After each adult was placed in the dish, the top was positioned with the barrier directly over the midrib and held in place with a rubber band to prevent movement.

Non-linear regressions, using the model ($y = e^{nx}*(1-Ae^{mx})$), were used to describe the effect of temperature on consumption by individual instars and adult females (SAS Institute 1995). This model is a modification of the equations developed by O'Neal (1968, 1972) to describe the effect of temperature and different types of biological activity and is useful in characterizing responses when a temperature maximum is observed (Spain 1982).

Results and Discussion

No significant difference in average dry leaf weight between left and right sides was found (left side = 0.1261 g ± 0.0002 SE; right side = 0.1258 g ± 0.0002 SE; $P \leq 0.05$). Based on the lack of significant difference in mean dry weights it was concluded that the "leaf disc" technique was acceptable for measuring consumption.

Dry weight leaf consumption of eggplant by Colorado potato beetle larvae was influenced by temperature. Figure 1 shows average consumption for second through fourth instars for 20, 26, 29, 32 and 35°C. Consumption for second instars increased from 4.36 ug (±0.34) at 20°C to 7.25 ug (±0.60) at 32°C and then decreased to 3.69 ug (±0.80) at 35°C. Similar patterns of consumption were observed for third instars and fourth instars, with maximum consumption occurring at 32°C, followed by a decrease in consumption at 35°C. A significant relationship for consumption by each instar was found (2nd - $r^2 = 0.73$, $P \leq 0.01$; 3rd - $r^2 = 0.56$, $P \leq 0.01$; 4th - $r^2 = 0.75$, $P \leq 0.01$) confirming that consumption was highly dependent on temperature.

The amount of food consumed by adults depended significantly on temperature ($r^2 = 0.64$, $P \leq 0.01$) (Fig. 2). Consumption ranged between 6.31 ug (± 0.30) at 16°C and increased to 15.44 ug (± 0.48) at 27°C. Mean consumption at 29°C dropped slightly to 12.29 ug (± 0.53), but increased to 14.99 ug (± 0.63) at 33°C.

Table 1 shows the feeding equivalents for the larval stages and adult females. Feeding equivalents were standardized based on fourth instars as 100%, and the other instars were calculated as a percentage of fourth instar consumption. Fourth instars consume from 1.5 to 2.8 times more foliage than third instars; however, adults consumed from 38 to 80% of the amount consumed by fourth instars. This pattern is consistent with results published by Ferro et al. (1985) and Tamaki and Butt (1978) for Colorado potato beetle feeding on potato. Second-instar consumption ranged from 17.0 to 25.9% that of fourth instars, third-instar consumption from 36.0 to 66.3% that of fourth instars, and adult consumption ranged between 38.0 to 81.4% that of fourth instars.

Table 2 shows developmental times for second through fourth instars relative to rearing temperature. Compared with results published by Ferro et al. (1985), Colorado potato beetle larvae develop at different rates when fed eggplant than

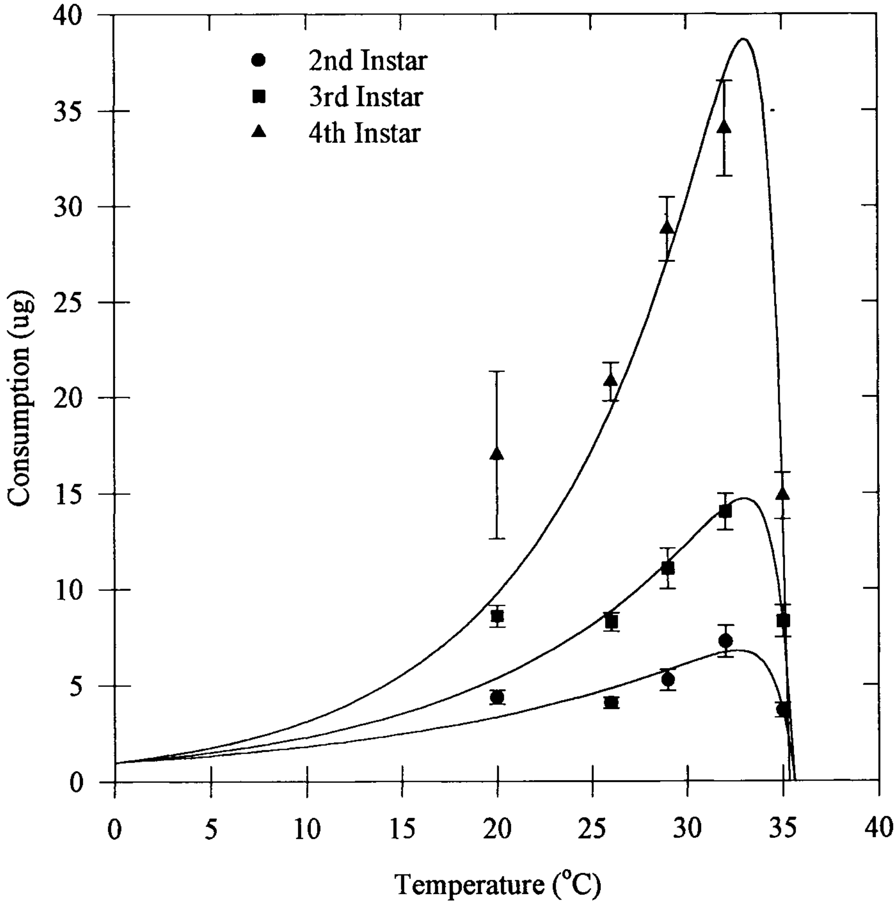

Fig. 1. Average consumption (ug) of eggplant by dry weight for Colorado potato beetle larvae relative to temperature (2nd instar - $y = e^{0.061x}$ (1-(1.8 5 $10^{-15} * e^{0.953x}$)), $r^2 = 0.73$, $P \leq 0.01$; 3rd instar - $y = e^{0.084x} * (1-(4.697 \times 10^{-16} * e^{0.992x}))$, $r^2 = 0.56$, $P \leq 0.01$; 4th instar - $y = e^{0.114x} * (1-(3.712 \times 10^{-16} * e^{1.006x}))$, $r^2 = 0.75$, $P \leq 0.01$).

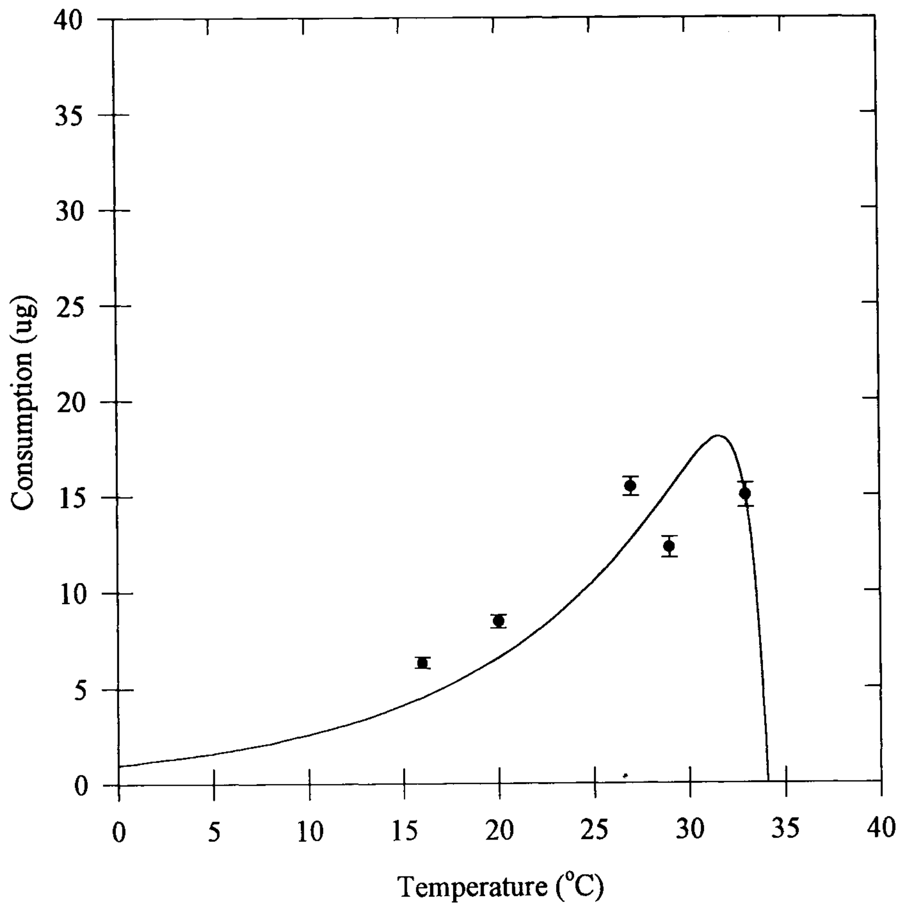

Fig. 2. Average consumption (ug) of eggplant by dry weight for adult Colorado potato beetle females relative to temperature ($y = e^{0.094x} * (1\text{-}(1.249 \times 10^{-15} * e^{1.006x}))$, $r^2 = 0.64$, $P \leq 0.01$).

Table 1. Feeding equivalents of Colorado potato beetle relative to fourth instars and temperature.

Life Stage	Temperature (°C) 20	26	27	29	32	33	35
2nd	17.0	14.8	–	12.9	15.7	–	25.9
3rd	36.0	38.2	–	38.9	38.4	–	66.3
4th	100.0	100.0	–	100.0	100.0	–	100.0
Adult*	40.0	–	81.4	38.0	–	39.2	–

*Mated females.

Table 2. Developmental times in days for Colorado potato beetle larvae at different constant temperatures (x ± SE).

Life Stage	Temperature (°C) 20	26	29	32	35
2nd	2.12 ± 0.06 (40)*	2.21 ± 0.07 (39)	2.11 ± 0.06 (47)	2.08 ± 0.05 (36)	1.29 ± 0.09 (37)
3rd	5.12 ± 0.09 (39)	5.05 ± 0.09 (37)	4.51 ± 0.12 (45)	4.11 ± 0.07 (34)	4.36 ± 0.35 (25)
4th	9.28 ± 0.14 (38)	9.28 ± 0.13 (36)	8.00 ± 0.19 (45)	7.29 ± 0.17 (27)	11.38 ± 0.57 (21)

*Number in parentheses is the number of observations.

when fed potato. Second instars fed eggplant took 2.12 d ± 0.060 to develop, while those fed potato took 3.80 d. Fourth instars fed eggplant developed slower than those fed potato. Developmental times ranged from 7.29 to 11.38 d, both of which are longer than beetles fed potato at the same general range of temperatures. The slower development may reflect that eggplant is not as suitable as potato for development. Oviposition by Colorado potato beetle on eggplant is substantially lower than on potato (Jansson et al. 1989).

Placement of different life stages on an equivalent basis in terms of feeding has implications on any sampling program that may be developed. In eggplant, economic injury levels are based on feeding damage caused by fourth instars (Cotty and Lashomb 1982). By utilizing the equivalences determined, a more accurate assessment of damage can be made by incorporating feeding by all life stages into one threshold. This factor can be used in the development of a single sequential sampling scheme, as opposed to one for each life stage.

These results, likewise, serve to make a convenient, economical, and easily standardized larval bioassay conducted within this range of temperatures. Economy may be achieved because slowed development at lower temperatures allows the investigator to spread the bioassay through time. Because we have shown that dry weight of both sides of the leaf disc are equal, known amounts of a toxicant such as *Bacillus thuringiensis* Berner can be applied to one side, and the amount consumed can be accurately calculated.

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