Patterns of Initial Colonization of Cucurbitis, Reproductive Activity, and Dispersion of Striped Cucumber Beetle, *Acalymma vittata* (F.) (Coleoptera: Chrysomelidae)\(^1\)

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**ABSTRACT** Studies of the striped cucumber beetle (StCB), *Acalymma vittata* (F.), were conducted to: 1) develop predictive models for time of first colonization of cucurbit hosts in the spring, and for time of mating and oviposition activity; and 2) develop guidelines for sampling over a range of densities and precision levels. There was no apparent trend of thermal unit accumulation associated with time of first colonization, and so a degree-day model approach was abandoned. However, evidence suggests that time of first colonization is associated with daily mean temperatures greater than 12°C. A strong correlation was found between change in number of beetles per plant and the previous days' mean temperatures. Both mating and oviposition activity were positively influenced by temperature in the range of 18 to 26°C. Access to foliage influenced maturation rate but not mating. Thresholds of mating and oviposition activity were found to be 13°C and 10°C, respectively. A high degree of aggregation of StCB adults (\(b = 1.986\)) was described, and sample size estimates for three desired levels of precision under a random sampling design are presented.

**KEY WORDS** *Acalymma vittata*, striped cucumber beetle, cucumber, *Cucumis sativa*, degree-day model, colonization, mating, oviposition, sampling precision, index of aggregation, Chrysomelidae, Coleoptera.

The striped cucumber beetle (StCB), *Acalymma vittata* (F.), is a key pest of cultivated cucurbitis throughout North America east of the Rockies (Smith 1966). Much of the basic biology of this insect was described earlier in the twentieth century by Houser and Balduf (1925), Jewett (1927), and Gould (1944). These researchers noted that a significant characteristic is the sudden mass attack on newly-emerged cucurbit seedlings. Lewis et al. (1990) confirmed that such effective host finding involves olfactory cues received from seedlings. All of the early studies reported observations of adults feeding on pollen of early blooming spring trees and shrubs. Although researchers have identified several overwintering habitats, such as wooded borders of fields, wooded ravines, tall thatch, and hedgerows (Houser and Balduf 1925, Gould 1944), there is no

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known preferred habitat. This lack of knowledge regarding overwintering sites may contribute to the difficulty in predicting time of initial colonization.

Elsey (1988) observed mating StCBs on both cucumber and zucchini shortly after an early April planting in coastal South Carolina. The first peaks in population occurred on both cucurbit species at similar times, approximately 2-3 wks after initial appearance of adult beetles. Ovaries were reported to be undeveloped in the majority of adults checked during the winter months, and so it appears that there is a reproductive diapause regulated by photoperiod (Elsey 1988).

There is evidence for elevated activity on warm days during winter months. Several investigators (Houser and Balduf 1925, Elsey 1988) observed adults active in the field on warm days in December in Ohio and South Carolina, and the present investigators observed active StCBs on warm days in November and December of 1989, 1990, and 1991 (unpublished data). In the latter observations, no mating pairs were ever seen. This observation suggests that adult StCBs enter a hibernation period (Tauber et al. 1986) and supports the occurrence of a reproductive diapause.

Since StCBs do not colonize experimental plots in any clear pattern, such as along an edge, and they tend to occur in an aggregated distribution (Radin 1992), an adequate number of samples should be taken to make control decisions. Currently, no state provides economic threshold recommendations for growers. Rotenone is commonly used by small-scale farmers and gardeners.

For management of many pests, prediction of initial colonization and oviposition, and development of a sampling plan, are necessities. A series of studies were conducted to develop predictive models for time of initial colonization and oviposition by StCBs, based on physiological time measured in degree-days. Spatial distribution data were collected from experimental squash and cucumber plots as a basis for determining the minimum number of samples required for accurate population estimates of adults.

Materials and Methods

Time of initial colonization. It was hypothesized that adult beetles could be intercepted at the time of their first exodus from suspected overwintering habitats by placing flats of host plants in the vicinities of these habitats. Monitoring of initial beetle emergence took place in the spring of 1990 at four agricultural locations in southern Penobscot County, Maine, where there were known to be StCB populations. Four to six flats (27 by 54 cm) of highly attractive squash seedlings, *Cucurbita maxima* cv. 'Sweet Mama' (Radin 1992), were placed along wooded borders of each cucumber or squash field and checked every other day starting on 10 May, with total numbers of beetles recorded for each date. Voucher specimens of the beetles in this experiment are housed in the Department of Entomology, University of Maine Insect Collection, Orono, Maine. Air temperatures were monitored at three locations using recording hygrothermographs. Because of the close proximity of two sites in East Corinth, Maine (approximately 6 km apart), temperature data from one station was used for both locations.
A base temperature for a degree-day (DD) model was estimated by finding the mean number of accumulated DD's at emergence over a range of arbitrarily selected base temperatures. A base was selected where the ratio of the standard error to the mean (se/\bar{x}) was at a minimum (Groden 1982). This base was then used for calculation of thermal unit accumulation required for initial colonization.

Since data from two of the three sites (East Corinth and Costigan) at which air temperatures were monitored were not collected until 10 May 1990, mean daily temperatures (MDTs) at these sites were estimated from 1 April until 10 May using MDTs from the Stillwater site. This early season Stillwater data was substituted for the independent variables in the linear regression models of MDTs at each of these two locations from 10 May until 4 June. The linear relationships between Stillwater MDTs and the other two locations are described, respectively, by:

East Corinth MDT = -1.098 + 0.811 (Stillwater MDT); \( r^2 = 0.87 \) \hfill (1)

Costigan MDT = 1.223 + 0.924 (Stillwater MDT); \( r^2 = 0.74 \) \hfill (2)

Mating and oviposition study. One hundred seventy diapausing StCBs were overwintered (November 1990 to March 1991) in 0.25 liter plastic containers with tight-fitting clear plastic lids in a dark cool (ca. 10°C) basement. On 15 March 1991, these adults were divided into three groups and placed in growth chambers maintained at either 18°C, 22°C, or 26°C and a 16:8 (light:dark) photoperiod, while still being held in the containers. Half of the adults in each chamber were supplied with cucumber foliage and half were given no foliage. Adults were observed once daily, and females were removed and placed in individual petri dishes at the first observance of mating. Those beetles which had been given no foliage at the start continued in this way, and beetles originally given foliage were provided with foliage in petri dishes. Individual dishes were observed once daily, and the day of first oviposition was recorded for each. Since beetles deprived of foliage did not lay eggs, foliage was provided after 13 d.

Data were analyzed using one-way analyses of covariance (foliage as a factor), with temperature as a covariate, and days until first observed mating and days until first oviposition as dependent variables (Wilkinson 1989).

Sampling program determination. Plants were grown from seed in Jiffy Strips™ peat pots in the greenhouse and transplanted into plots at the University of Maine's Rogers Farm, Stillwater, Maine on 28 May 1991. Cultivars planted were 'Score', a hybrid pickling cucumber and 'NK 530', a squash hybrid variety of Cucurbita maxima. Six 225 m² plots (at a minimum distance of 100 m from each other) each contained 400 plants in a 20 row by 20 column array. Plants were spaced at 0.75 m in both directions. Plots consisted of equal numbers of squash and cucumber plants in four alternating groups of five rows (each considered a subplot) running north to south. The eastern-most group was cucumber, followed by squash, cucumber, and squash. The four subplots of each plot were divided into four sub-subplots: these consisted of 25 plants arranged in a five row by five column array. This resulted in a total of 16 sub-subplots per plot. Samples were taken during the cool, early morning
hours just after sunrise to avoid disturbing the adult beetles. Plots were sampled on ten dates through a period of 23 d starting on 2 June 1991. On each sampling date, five plants were selected at random from each sub-subplot, and the number of beetles per plant were recorded. The plot variances were transformed by $\log(s^2 + 1)$ and regressed on $\log(x + 1)$ transformed means for each plant type. Points for each plant type were pooled because 95% confidence intervals around slopes for each plant type were found to overlap. The resulting coefficients of the pooled regression were used to calculate expected variances over a range of 0.1 - 5 beetles per plant, which is a typical range of densities in plots of this size (Radin 1992), although more than 40 beetles have been observed on a single plant. These variances were used to calculate the number of samples required to estimate a population mean to within standard errors equal to 10%, 20%, and 40% of the mean adult beetle density using the following equation (Elliott 1977):

$$n = \frac{s^2}{D^2\bar{x}^2}$$

where D equals the desired level of precision (as a proportion of the mean) and n equals the number of samples.

Results and Discussion

Time of initial colonization. Accumulated DDs, counted from 1 April 1990 (Julian day 91) until dates of first emergence at four locations (Costigan: day 136; East Corinth: days 147 and 149; Stillwater: day 149), were averaged over a range of base temperatures from zero to 15°C. Through this range, variability (se/\bar{x}) decreased with decreasing DD base, but never reached a minimum, continuing to decrease down to -10°C. Thus, these data do not meet the assumptions of a DD model (Groden 1982).

Figure 1 shows MDTs over time, with arrows indicating the times at which beetles were initially observed. Lower MDTs occurred during the period between days 137 and 145, while there were peaks right around the times of initial colonizations, which suggests that adults first became active on days when the mean temperature reached at least 12°C. Since no flats of seedlings had yet been placed at monitoring sites on days 117 and 121, it is unknown whether beetles were active on these unusually warm days. Lewis et al. (1990) reported the attraction of hundreds of beetles to flats of squash seedlings placed on the edge of wooded windbreak areas between commercial cucurbit fields, and noted that fluctuation of numbers of beetles on seedlings appeared to be related to ambient temperatures, with greater activity on days when the high temperature surpassed 18°C. If habitats such as leaf litter, thatch along fence rows, or wooded ravines are used for overwintering, as reported by Gould (1944), it follows that the time of emergence could be highly variable due to microclimate differences in these habitats. Thermal unit accumulation may not be a useful tool to predict colonization, but occurrence of the first few warm days (>12°C) usually in May may be a better predictor in Maine. Other insects which overwinter in litter are predicted to become active according to similar guidelines, such as the plum curculio, Conotrachelus nenuphar (Herbst), which should be monitored when spring temperatures reach 15°C (Los 1992).
Mating and oviposition study. Results for this experiment are listed in Table 1. The mean number of days until first observed mating was not affected by access to foliage ($F = 0.81; \text{df} = 1,43; p > 0.05$) but was affected by temperature ($F = 78.1; \text{df} = 1, 43; p < 0.05$). Oviposition was affected by both access to foliage ($F = 24.1; \text{df} = 1,43; p < 0.05$) and by temperature ($F = 90.0; \text{df} = 1,43; p < 0.05$).

To determine temperature thresholds of activity for mating and oviposition, the means of the reciprocals of days to mating and oviposition (= rate) were regressed over the three temperatures, resulting in the following relationships, respectively:

\begin{align*}
\text{rate of mating} &= -0.23 + 0.018 \text{ (average air temp.)}, r^2 = 0.99 \\
\text{rate of preoviposition development} &= -0.0575 + 0.0057 \text{ (average air temp.)}, r^2 = 0.978
\end{align*}

These equations were solved for $y = 0$, resulting in thresholds for mating and oviposition activity of $13{\degree}C$ and $10{\degree}C$, respectively. Since StCBs will seek cucurbit hosts at temperatures above $12{\degree}C$, it is likely that this threshold for
Table 1. Mean number of days to initial StCB mating and oviposition at 18, 22, and 26°C.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Mating</th>
<th>Mean Number of Days (S.E., n)</th>
<th>Oviposition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Foliage</td>
<td>Without Foliage</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>10.7 (0.5, 8)</td>
<td>11.2 (1.1, 12)</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>7.7 (0.8, 11)</td>
<td>7.9 (1.8, 7)</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>4.5 (0.5, 9)</td>
<td>5.0 (0.9, 10)</td>
<td></td>
</tr>
</tbody>
</table>

Mating activity in an environmental chamber is a good approximation to mating activity in the field. These temperature relationships suggest that while beetles will be mating shortly (1-2 wk) after spring emergence in Maine, oviposition is not likely to take place until 1 mon or more after emergence and colonization of the crop. This could have significant implications in a trap cropping strategy, since a lag-time exists between beetle presence in the field on a trap crop and potential for reproduction on that trap crop.

Sampling program determination. The linear regression of the pooled (plant types) transformed data \( r^2 = 0.862, 119 \text{ df}, p < 0.05; \text{ Fig. 2} \) resulted in the equation:

\[
\log(s^2 + 1) = -0.02 + 1.986 \log(\bar{x} + 1)
\]  

(6)

This was rearranged as:

\[
s^2 = 0.955 (\bar{x} + 1)^{1.986 - 1}
\]  

(7)

and solved over a range of expected means from 0.1 - 5 beetles per plant. Expected variances derived from equation (7) were used in equation (3) at three levels of precision (0.1, 0.2, 0.4), to generate the three sample size curves in Figure 3. Due to the high degree of aggregation of this insect \( b = 1.986 \), large numbers of samples are required to estimate low density populations to within a 10% standard error of the mean. Since it was shown that beetles do not colonize along edges of fields (Radin 1992), a random sampling plan can be used.

Prediction of the time of initial colonization of cucurbits by StCBs is useful for anticipating the buildup of economically significant populations and for initiation of population sampling. We have shown that a simple DD model for initial colonization may not be applicable to StCB. In Maine, however, cucumber wilt disease is of infrequent occurrence. Therefore, it might be
Fig. 2. Regression of $\log (s^2 + 1)$ on $\log (\bar{x} + 1)$ for StCB per plant.

$$\log (s^2 + 1) = -0.02 + 1.986\log (\bar{x} + 1)$$

$$r^2 = 0.862$$

Fig. 3. Required sample sizes at three levels of precision (percentage confidence limits of the mean) as a function of beetle density.
possible to develop an economic threshold for StCB in Maine based upon adult densities and the associated crop loss. The occurrence of peak population densities from the time of initial colonization in conjunction with the absolute densities will determine the frequency of insecticide applications for control. Studies conducted in mixed squash/cucumber plots in Maine in 1991 (Radin 1992) resulted in adult beetle density peaks at 10 or 11 d after initial colonization. In these mixed squash/cucumber plots, changes in population were found to be correlated with mean temperatures of the previous day \( r = +0.89 \), Fig. 4). Peaks did not occur in a South Carolina study (Elsey 1988) until 3 wk after initial colonization. The difference between these two studies in "time until peak density" might be due to differences in temperature, with greater searching and colonization activity associated with higher temperatures. It was also reported by Elsey (1988) in South Carolina that during one of the 1986 season beetles assumed to be overwintered arrived in two waves, one in early April and another in early May. It is possible that this later wave might have occurred during a period of unusually warm weather. Indeed, 1986 NOAA weather data from the airport in Charleston, SC, shows higher daily mean temperatures during the first and last weeks of April and at the beginning of May (1 - 8 April: \( \bar{x} = 21.5 \pm 1.4^\circ C \), C.V. = 6.6%, 25 April - 6 May: \( \bar{x} = 22.5 \pm 2.6^\circ C \), C.V. = 11.7%) than the middle two weeks of April (9 - 24 April: \( \bar{x} = 16.5 \pm 2.5^\circ C \), C.V. = 15.1%). Thus, our data and the data from South Carolina suggest that once a cucurbit crop has been colonized, particular attention should be paid to population levels on unusually warm days. Sampling and application of an insecticide, if necessary, should occur during the earliest hours of the morning, since StCBs are particularly active and prone to disperse by flight when the temperature is high.

![Figure 4](image_url)  
Fig. 4. Relationship between change in StCBs per squash plant and the previous day's mean air temperature in 1991 \( r = +0.89 \).
In conclusion, this study has shown that the behavior of StCB is highly aggregative and that this beetle’s colonization and activity in the field is associated with warm temperatures above 12°C. These relationships determine in part the dynamics of colonization and interplant movement and have implications for sampling of adult populations. Strong temperature dependent relationships between mating activity and sexual maturation have also been demonstrated. The latter may have significant implications in management of this pest.

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