EFFECTS OF FOOD QUALITY AND AGE ON THE LARVAL ACTIVITIES OF ANATIS MALI AUCT. (COLEOPTERA: COCCINELLIDAE)

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Abstract

A method is described for measuring and comparing locomotion and other activities in predatory insects. The effects of food and age on the duration and relative time of occurrence of various activities are described for larvae of *Anatis mali*. Although the kind of food previously eaten affected the preference of *A. mali* for aphids, it did not affect developmental time or the duration of any activity. Food intake was greatest about the middle of the instars. Larvae of all ages spent more than twice as much time resting as in all other activities combined and changed activity about six times per hour. The product of the duration of a predator's activity and its relative time of occurrence provides an index that may be used to compare activities within and between species. In *A. mali*, the indices of feeding and resting decreased near the end of development, whereas the index of walking increased.

Introduction

Generalized locomotion with no apparent specific goal occurs in most species of predatory coccinellids. The probability of a contact between a predator and its prey increases as locomotion increases and this is important for the predator's survival when prey are scarce. Phipps (1963) described the locomotory activities of grasshoppers and showed that movement increased to a maximum near the middle of an instar and that more time is spent in movement in later than in earlier instars. This paper describes the effects of food quality, that is, species of dry, powdered aphid, and age on the duration and occurrence of drinking, ecdysis, feeding, resting, and walking in third- and fourth-instar larvae of *Anatis mali* Auctorum. Attempts were made to develop a method that could be used to compare activities in a number of predatory species.

Materials and Methods

The adult coccinellids that were used to provide larvae for the experiments were fed dried pea aphid, *Acyrthosiphon pisum* (Harris). Larvae were also reared from the first instar to the second ecdysis on this aphid or they were reared on dried corn aphid, *Rhopalosiphum maidis* (Fitch). The methods of preparing the food and of rearing the predators individually in cells or petri dishes were described elsewhere (Smith 1960; Smith 1965). The work was done at about 22 °C and 65% R.H. A constant artificial light was used, though natural light was admitted through the windows.

Sixteen larvae of *A. mali* were reared in cells from the first instar to the second ecdysis on an excess of food; eight were reared on *A. pisum* and eight on *R. maidis*. They were then transferred to petri dishes and reared to the adult stage. Of the larvae reared on *A. pisum*, four were given this aphid and four were given the choice of eating *A. pisum* or *R. maidis*. Similarly, of the

larvae reared on *R. maidis*, four were fed on this aphid and four were given the choice of foods. Each larva was given 10.0 mg of food, 5 mg of each kind in dishes with a choice. Drinking water was supplied in separate containers. Food was added daily as eaten and the food intake was calculated daily.

The third- and fourth-instar larvae were observed closely for about 3 hours each day during development. Each larva was inspected at intervals of 1 minute, when its activity was classified and recorded as drinking, feeding, molting, resting, or walking. These categories included all observable activities except movements not accompanied by walking. Observations were made in both a.m. and p.m., but usually from 9:00 a.m. to 12 noon. The mean duration of the various activities and the relative proportion of time occupied by each were calculated and recorded for each food class, instar, and day. Rate of change of activity was calculated and expressed as number of changes per hour. Means, standard errors, and coefficients of variation are given herein. Results were analyzed by means of the F test and differences were considered significant at the 1% level.

Results and Discussion

The quality of the food previously eaten affected the food preference of *A. mali* larvae. Individuals that were reared on *R. maidis* and then given the choice of eating this food or *A. pisum* ate significantly less *R. maidis* as third instars and significantly more as fourth instars than did individuals that were reared on *A. pisum* and then given the choice of foods. Individuals that were reared on *R. maidis* ate 5.9 mg of *A. pisum* and 2.8 mg of *R. maidis* as third instars and 22.8 mg and 25.1 mg of these foods respectively as fourth instars. Individuals that were reared on *A. pisum* ate 5.3 mg of *A. pisum* and 5.4 mg of *R. maidis* as third instars and 23.2 mg and 19.3 mg of these foods respectively as fourth instars.

No significant differences in the developmental time (third instar 2.8 ± 0.1 days; fourth instar 4.4 ± 0.1 days) were attributable to food quality and the combined 7.2 days included eight periods of observation in the a.m., three of the third-instar larva and five of the fourth-instar. Of the 10 mg of food eaten by the third-instar larva, 15% was eaten on the first day, 49% on the second day, and 36% on the third day. Of the 45 mg eaten by the fourth-instar larva, 20% was eaten on the first day, 30% on the second day, 30% on the third day, 10% on the fourth day, and 10% on the fifth day.

Food quality had no significant effect on the duration of a period of feeding or on the duration of the other activities. The mean durations of a period of feeding with the coefficient of variation in parenthesis for larvae reared on *R. maidis* and given a choice of eating this aphid or *A. pisum*, for larvae reared on *A. pisum* and given a choice, for larvae reared and fed on *R. maidis*, and for larvae reared and fed on *A. pisum* were 11.8 ± 2.5 minutes (89%), 10.9 ± 1.9 minutes (97%), 9.8 ± 1.5 minutes (94%), and 7.8 ± 1.5 minutes (152%) respectively. Data for the various food classes were combined.

Few changes in activity occurred within the 1-minute interval of inspection and no differences in the sequence of activities were attributable to time of day. Each 3-hour daily study period afforded at least 50 periods of observation on resting and walking and 10 on feeding.

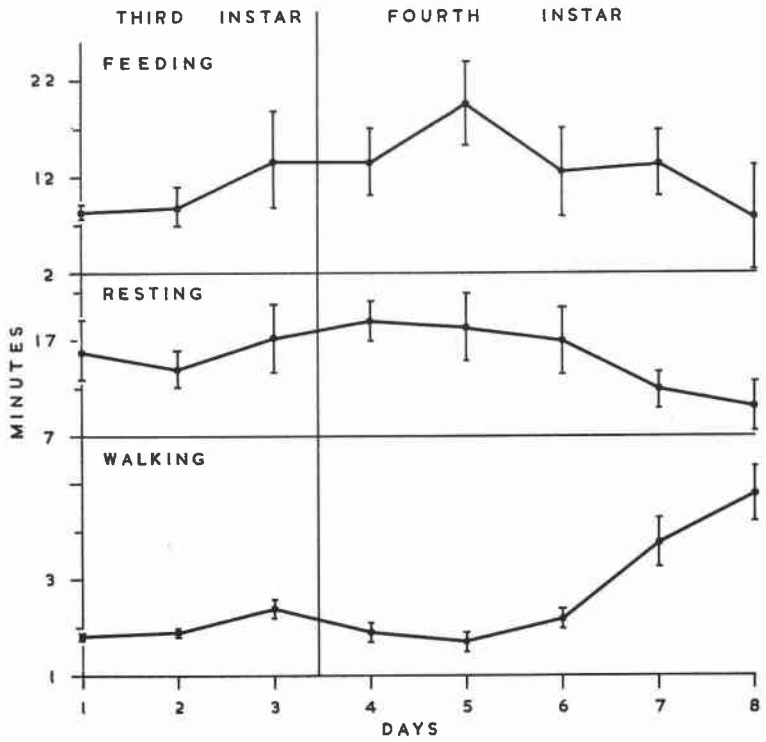

FIG. 1. Variation with age in the duration of a period of feeding, resting, and walking for *A. mali* larvae fed on dry *A. pisum* and *R. maidis*.

The 3-hour period of observation was about 14% of the combined longevities of the third- and fourth-instar larvae of *A. mali*. Although it was long enough to make an adequate study of feeding, resting, and walking, it did not include enough replicates of drinking. It remains to be shown that it is long enough for a study of larvae under variable conditions that presumably would elicit a greater rate of change of activity than was found in this study. A more active species than *A. mali* would also probably require a longer period of daily observation.

The daily variation in the duration of a period of feeding or resting was notably greater than the variation between stages or between days, but variation was much less in the duration of a period of walking (Fig. 1).

Ecdysis and drinking were observed less frequently than the other activities. Both the second and third ecdyses were preceded and followed by periods of rest. When it had completed its feeding, the fourth-instar larva attached itself by the posterior end to the surface of the dish, where it remained as a prepupa and pupa. The third ecdysis lasted about 19 minutes and was preceded by a period of rest lasting from 30 to 50 minutes. After this ecdysis the larva rested for 8–28 minutes. A period of drinking lasted about 2 minutes in both third- and fourth-instar larvae.

TABLE I

Mean and coefficient of variation (% in parenthesis) of various activities of third- and fourth-instar larvae of *A. mali*

Stage	Changes in activity in 1 hour	% time spent			
		Feeding	Resting	Walking	Drinking
Third instar	6.4 (70)	7.7 (70)	81.3 (10)	10.6 (40)	0.4 (70)
Fourth instar	6.1 (101)	12.9 (50)	68.7 (10)	18.1 (60)	0.3 (90)

A. mali larvae spent more than twice as much time resting as for all other activities combined, and changed activity about six times per hour or engaged in three activities per hour (Table I). The fourth-instar larva spent significantly less time resting and more time feeding and moving than did the third-instar larva. Feeding reached maxima on the second and sixth days, that is, about midway through the third and fourth instars (Fig. 2). At its peak, walking comprised less than 40% of larval activities.

No notable change occurred in the duration of a period of feeding during the 8 days of observation, though the proportion of time spent in this activity

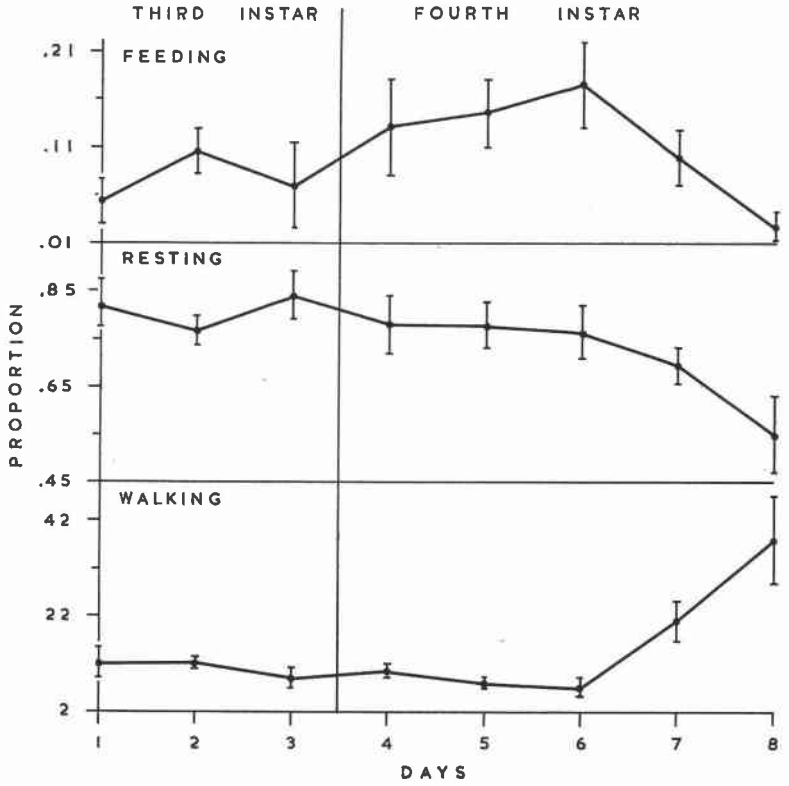

FIG. 2. Variation with age in the proportion of time spent feeding, resting, and walking for *A. mali* larvae fed on dry *A. pisum* and *R. maidis*.

decreased near the end of larval development. The duration of a period of resting and the proportion of time spent in this activity also decreased near the end of development. The mean duration of a period of feeding was 12.4 minutes and the mean proportion of time spent feeding for the first 6 and the last 2 days was 11.3% and 6.4% respectively. The mean durations of periods of resting for the first 6 and the last 2 days were 16.6 and 9.0 minutes, and the mean proportions of time spent in these activities were 79.2% and 62.6% respectively. The duration of a period of walking and the proportion of time spent in this activity varied less than for the other activities and both increased notably near the end of development. The mean durations of a period of walking for the first 6 days and the last 2 days were 2.0 minutes and 4.3 minutes and the mean proportion of time spent in this activity during the first 6 and the last 2 days was 8.7% and 29.3% respectively.

The product of the mean duration of an activity and its proportionate time of occurrence provides an index that may be used to compare various activities within species and between species. The index of feeding for *A. mali* larvae during the first 6 days after the second ecdysis is about 140 (12.4 × 11.3). Similarly the indices of resting and walking are 1315 and 17. The indices of feeding, resting, and walking for the last 2 days are 79, 563, and 126 respectively. Evidently resting was the dominant activity of both age classes of larvae. Feeding, which was next in importance during the first 6 days, was replaced by walking during the last 2 days. Walking or searching increased when feeding was about completed. Increases in walking activities commonly occur in all species of coccinellids shortly before the formation of the prepupa and probably mainly concern the location of a suitable site for the pupa.

Locomotory activities in the third- and fourth-instar larvae of *A. mali* did not increase up to the middle of an instar and then decrease, as reported for the grasshopper (Phipps 1963). More food was ingested about the middle of the third and fourth instars. This was reflected in a greater proportion of time spent in feeding at these times but not in a longer period of feeding.

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