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HONEYDEW : A FOOD RESOURCE OR ARRESTANT FOR THE MEALYBUG PREDATOR *CRYPTOLAEMUS MONTROUZIERI ?*

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The study investigated whether honeydew is a source of food or is an arrestant stimulus for adults and 4th instar larvae of *Cryptolaemus montrouzieri*. Adult predators fed on honeydew but produced few viable eggs. In the presence of honeydew the adult and larvae spent a significantly longer time searching and made more intensive searches on leaf surfaces than on clean parts of the leaf. We concluded that the honeydew was both a food resource and an arrestant.

KEY-WORDS : mealybug, honeydew, arrestment stimulus, searching.

Homopteran host insects such as aphids, mealybug and scale insects excrete copious amounts of honeydew which is rich in sugar, some amino acids and waxes. Honeydew comprises substances directly derived from the host plant and some produced by the insect itself (Gray, 1954 ; Gray & Frankel, 1954). Frequently chemicals associated with this material have been termed 'kairomones'.

Kairomones attract beneficial insects from a distance (high volatile component) or can elicit intensive searches in the vicinity of the contaminated substrate (searching stimulants, low volatile component) (Vinson, 1968 ; Waage, 1978 ; Nordlund, 1981). Most work with honeydew has been done on searching behaviour of parasitic Hymenoptera (Vinson, 1976) and very little is known for predators. The coccinellids have been reported feeding on the honeydew of their aphid prey (Hagen, 1962). This study examined the mealybug predator *Cryptolaemus montrouzieri* (Mulsant) and its prey the mealybug *Pseudococcus affinis* (Mask.). The experiment investigated whether honeydew acts as an arrestment stimulus which intensifies the search for prey or is simply a nutritive material on which they stop to feed.

MATERIALS AND METHODS

HONEYDEW AS A FOOD RESOURCE

Virgin females of the predator were taken from a culture reared on potato sprouts heavily infested with *P. affinis* and maintained at 26 °C. Each predator was placed singly in a ventilated plastic box (78 × 47 × 22 mm) with a piece of damp cotton wool. The following regimes were used with 16 individuals for each treatment.

(1) All stages of mealybugs with honeydew.
(2) All stages of mealybugs with commercial honey.
(3) Adult mealybug before producing the cottony ovisacs.
(4) *Saissetia oleae* (Olivier) as an alternative prey.
(5) Mealybug honeydew on wet filter paper and as droplets.
(6) Commercial honey on wet filter paper and as droplets.
(7) 50 % sucrose on wet filter paper and as droplets.
(8) Distilled water on wet filter paper and as droplets.

Each female was kept with a surplus of food in each regime, and females were confined with mature males in separate boxes for three hours every day in order to ensure mating. The pre-ovipositional period, rate of fecundity and egg viability were measured for a period of 3 weeks. The experiment was conducted in a Gallenkamp Compenstat cooled incubator at 28 ± 1 °C, 50 % r.h. under continuous illumination (20-25 W/m^2). Means were compared using analysis of variance.

HONEYDEW AS AN ARRESTMENT STIMULUS

Sexually mature, uniform size and aged adult females were collected from a culture reared at room temperature and fed with streaks of 50 % honey for 24 hours, in a well ventilated plastic box with a piece of wet cotton wool in the corner. The adults were removed to a similar box without food or water for one more day. Fourth instar beetle larvae, just after moulting, were selected from a culture reared at 26 °C and kept 24 hours without food or water. Predator searching behaviour was observed on clean and honeydew infested parts of specially prepared leaves. Large and pest free leaves of *Bergenia cordifolia* (Saxifragaceae) were soaked and rinsed several times with distilled water. Surplus water on the leaf surface was then evaporated in an incubator at 12 °C. The leaves were half covered with aluminum foil and placed for 12 hours under potted coffee bushes *Coffea arabica* heavily infested with *P. affinis* so that they became uniformly coated with honeydew. Before use, dead bodies of insects and other unwanted subjects were removed from the leaf surface using a fine paint brush. The arena for this study was a polyvinyl cylinder (15 cm in diameter × 5 cm deep) with a transparent lid of acetate sheeting. The inside wall of the cylinder was coated with fluon (PTFE, CL3800, ICI). The arena was illuminated at 65 W/m^2 using the two flexible arms of a cold laboratory light (Schott, KL1500) from 5 cm above the arena. Each predator was also exposed to this lighting for a period of 30-45 minutes prior to placing in the arena. A JVC video camera fitted with a 70-130 mm lens was used to record the searching behaviour to avoid any possible disturbance while allowing the analysis of different behavioural responses from the recordings. Observations were started two minutes after the releases of each predator into the arena, and made for a period of 300 seconds and repeated 12 times with different individuals.

The following activities were recorded for adults and larvae : Times spent feeding on honeydew, walking on the leaf surface, resting, dispersing (off the leaf, either flying or climbing the arena walls) and the number of flight attempts and turns (more than 90° angle). The distance and speed of walking was measured with a map measurer after tracing the walking path on a transparent acetate sheet fixed to the video monitor. Observation periods were carried out at 0900, 1300 and 1700 hours in order to include any diurnal patterns of activity. Data obtained in this experiment for adults and fourth instar larvae were compared using a 't' test. (Cochran & Cox, 1957).

RESULTS

HONEYDEW AS A FOOD RESOURCE

The effect of honeydew and other diets on the fecundity of *C. montrouzieri* is summarised in table 1. The highest fecundity was observed when the predator was given mealybugs with honey as food. Honeydew alone enabled the predator to produce a few viable eggs indicating there is some source of protein in honeydew. But the pre-ovipositional period was longer and the egg's viability was lower than any other feeding regime with the exception of treatment honey and sucrose diets ($P < 0.05$). Adult mealybugs alone as food resulted in significantly fewer eggs.

TABLE 1

Mean fecundity rate, pre-oviposition period and egg viability of C. montrouzieri *under various feeding regimes*

Diet	Mean number eggs/ female/per day l.s.d. 5 % = 1.56 $\bar{x}$	s.d.	Pre-oviposition (days) l.s.d. 5 % = 0.9 $\bar{x}$	s.d.	% eggs viability l.s.d. 5 % = 15 $\bar{x}$	s.d.
Mealybugs + honeydew	9.2	1.0 B	4.1	0.3 M	93.6	5.2 Z
Mealybugs + honey	13.3	2.4 A	4.4	0.5 M	98.4	1.8 Z
Mealybugs only	7.0	1.2 C	5.5	0.5 L	55.5	17.8 Y
S. oleae	3.5	1.1 D	6.8	1.0 K	50.1	7.7 Y
Honeydew	1.3	0.1 E	11.0	0.5 J	47.3	4.2 Y

Means within columns with the same letter are not significantly different.

Predators fed with honey, sucrose and water produced no offspring and were omitted from the statistical analysis.

HONEYDEW AS AN ARRESTMENT STIMULUS

Table 2 shows the mean time spent in various activities by twelve predators during a 300 s observation on clean and honeydew coated parts of a leaf. There was a highly significant and abrupt change in behaviour as the insects crossed from clean to honeydew coated parts. Fig. 1 shows the searching pattern of both adult and larvae of *C. montrouzieri* on clean and honeydew coated parts of leaves.

DISCUSSION AND CONCLUSION

When the mealybugs are scare, alternative host resources such as the soft scales and honeydew may play a vital role to sustain the predator. According to Hodek (1957) such alternative foods may not provide optimal food but they kept the predator *Coccinella septempunctata* L. alive until another food source was found. The reduction of egg viability when fed on honeydew or *S. oleae* alone could be attributed to nutrient deficiencies for the developing embryo, because in most cases a dead larva was seen inside the chorion. This

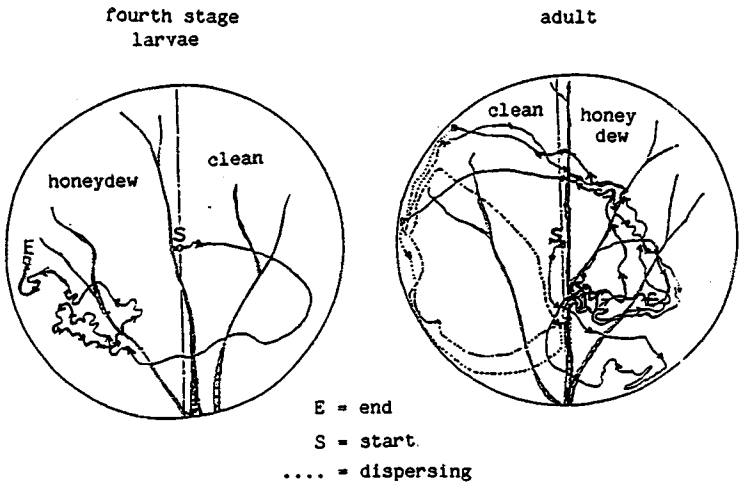

Fig. 1. An example of searching pattern of adult and fourth stage larvae of *C. montrouzieri* on clean and honeydew infested parts of leaves.

TABLE 2

Mean time(s) spent in different behavioural activities on honeydew coated and clean parts of a single leaf of Bergenia cordifolia *by* Cryptolaemus montrouzieri *during a period of 300 seconds.*

Behaviour	Adults					Larvae				
	honeydew		clean		t test	honeydew		clean		t test
	$\bar{x}$	s.e.	$\bar{x}$	s.e.		$\bar{x}$	s.e.	$\bar{x}$	s.e.	
Feeding	147.1	24.4	0.0	0.0		52.4	10.5	0.0	0.0	
Walking	61.6	11.6	26.3	6.8	**	120.5	11.3	49.9	7.3	***
Resting	2.9	1.0	3.5	1.4	ns	0.02	0.09	7.3	2.3	***
Dispersing	0.0	0.0	58.7	21.7		15.8	10.5	54.1	7.0	***
No of turns	14.1	2.8	1.5	0.4	***	4.9	0.6	0.8	0.2	***
No of flights	0.0	0.0	0.0	0.0	no jumps	0.0	0.0	0.0	0.0	
Speed cm/min	24.5	2.5	56.9	4.6	***	28.9	1.9	59.7	1.6	***
Total time	211.6	26.9	88.5	26.9	***	188.7	7.1	111.3	8.7	***

Note : Each figure represents the mean behavioural activities of 12 individuals.

confirms the report of Johansson (1964) that poor diet may cause reduced fecundity, egg size, egg viability and cause a longer pre-oviposition period. Further investigations are needed to study the longevity of adults when feeding on alternative foods.

Adult *C. montrouzieri* spent 98 % of their time (300 s) on leaves infested with honeydew in walking and feeding, whilst on clean leaves nearly 45 % of this time was spent in attempts to disperse from the leaf surface. Hence, the presence of honeydew is clearly responsible for longer periods of searching. An increase in the number of turns and lower

walking speed reduced the area covered by both adults and larvae indicating more intensive searching. This behaviour exhibited by larvae of coccinellids is very important because the only means of finding the host location is by physical contact (Kehat, 1968 ; Murakami & Tsubaki, 1984 ; Nakamuta, 1982 ; Heidari & Copland, 1992). The time spent feeding on honeydew by adults and larvae confirms that this is a source of food, although the larvae found it difficult to feed on ; this area requires further work.

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RÉSUMÉ

Le miellat est-il une source de nourriture ou un stimulus d'arrêt pour le prédateur de cochenilles, *Cryptolaemus montrouzieri ?*

Ce travail a pour but de déterminer si le miellat est une source de nourriture ou un stimulus d'arrêt pour les adultes et les larves de 4^{e} stade de *Cryptolaemus montrouzieri*. Les prédateurs adultes nourris de miellat produisent peu d'œufs viables. L'adulte et la larve de coccinelle font des recherches significativement plus longues et plus intensives sur les surfaces foliaires couvertes de miellat que sur les parties indemnes de miellat. L'étude conclut que le miellat constitue à la fois une source de nourriture et un stimulus d'arrêt.

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