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INFLUENCE OF PREDATOR AND PREY DENSITIES ON LARVAL CANNIBALISM IN LADYBEETLE, *Coccinella undecimpunctata* L. UNDER LABORATORY CONDITIONS

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ABSTRACT

Influence of predator and prey densities on larval cannibalism in aphidophagous, *Coccinella undecimpunctata* L. was studied under laboratory conditions.

Cannibalism increased with reduced food availability. In the absence of prey, there was a significant differences of larval cannibalism and recorded the highest rate of cannibalism. Cannibalism rate also increased with an increase in larval density of predator. The high rate of cannibalism was recorded at high larval density. Third and fourth levels of density of predator(9 and 12 larvae/ unit) had the highest cannibalism rate in the first instar at the first aphid density (25aphids/unit). There were significant differences between larval densities of the four larval instars of *C. undecimpunctata*.

Keywords: *Coccinella undecimpunctata*, cannibalism, larval density, prey levels.

INTRODUCTION

Cannibalism is a frequent behavior in animals and plays an important role in population dynamics (Fox, 1975; Polis, 1981). Several studies have recognized that the predatory species of ladybeetles show cannibalism of eggs and larvae (Banks, 1956; Dixon, 1959; Kaddou, 1960; Brown, 1972; Dimetry, 1974; Osawa, 1989). Larval cannibalism is a function of relative vulnerability and frequency of encounters (Agarwala and Dixon, 1993).

The coccinellid predators are candidates for the biological control of aphids and other soft-bodied insects on several economic crops and have been proven to consume these species commonly found as pests. However, their impact as biological control agents is sometimes variable and even if ladybirds are found together with aphids, they do not necessarily eat them if other food sources such as pollen are more easily available (Majerus, 1994). Predatory ladybeetles can mainly be categorized as either aphidophagous or coccidophagous depending on the nature of their prey. The developmental times of these groups of ladybeetles are related to their prey species (Agarwala and Dixon, 1993).

In the case of aphidophagous ladybeetles, larval performance is influenced by the quality of aphids (Blackman, 1967; Hukushima and Kamei, 1970; Hamalainen and Markkula, 1972; Pasteels, 1978; Hodek and Honek, 1996). Cannibalism a perfectly natural behavior for many species of insects and mites (Elgar and Crespi, 1992), is a common occurrence in predaceous ladybeetles (Coleoptera: Coccinellidae) and confers nutritional and competitive advantages to the cannibals (Gagne *et al*., 2002; Osawa, 2002; Snyder *et al*., 2000). Cannibalism and interspecific predation can be among the most important mortality factors for juvenile coccinellids (Wright and Laing, 1982; Schellhorn and Andow, 1999 a). Obrycki and Kring (1998) identified cannibalism as a major problem in the mass rearing of coccinellid species for augmentative biological control programs; however there appears to be considerable variation among coccinellid species in their propensity to cannibalize.

Little information is available on the effect of predator and prey densities on larval cannibalism in *C. undecimpunctata*. Therefore, the aim of this study is to determine whether larval density and prey levels could influence the cannibalism in *C. undecimpunctata* under laboratory conditions.

MATERIALS AND METHODS

The adults of *C. undecimpunctata* were collected from cowpea fields at the Experimental Research Station, Faculty of Agriculture, Mansoura University and reared on cowpea aphid, *Aphis craccivora* Koch. The egg clusters and single eggs laid by females of each species were removed daily, and monitored until hatching.

To test whether the rate of cannibalism increased as a function of larval density, newly molted larvae of *C. undecimpunctata* were taken from egg clusters and placed together in groups of three, six, nine, and 12 larvae per Petri dish (12 cm. in diameter). All Petri dishes were divided into two treatments. The first one was provided daily with 25, 50, 75 individuals of *A. craccivora* as preys. Meanwhile, the second treatment did not receive any preys. The treatments were run from newly first instar larvae till pupation. Fifteen replicates were examined for each one. The larvae were monitored daily and if mortality occurred, it was qualitively ascribed to either cannibalism (if feeding was observed or the remains were small or nonexistent) or starvation (if the remains were intact or no evidence of cannibalism).

All of the experiments were run in an air-conditioned insectary at 28.0 ±2.0 °C, 75.0 ± 5 % RH and the photoperiod of 14L: 10 D.

V. Data analysis

Effect of larval density or larval instars on cannibalized larvae and cannibalism percentages with or without feeding were subjected for one way analysis of variance (ANOVA), and the means were separated using Duncan's Multiple Range Test (CoStat Software, 2004).

RESULTS

In the presence of prey, there was a statistical variation between larval densities of the first larval instar of *C. undecimpunctata* in the cannibalism percentage (Table 1). At 25 aphids/unit, the cannibalism percentage was ranged from 0 to 45.8%. Meanwhile, At 50 aphids/unit, the cannibalism percentage was ranged from 0 to 18.75%. The cannibalism percentage was zero at 75 aphids/unit. The third and fourth larval densities (9 and 12 larvae/unit) had the highest cannibalism percentage in the first instar (33.3 and 45.8%) at the 1st aphid density (25 aphids/unit).

At 3 larvae/unit, there was no statistical variation in the cannibalism percentage in the first larval instar (Table 1). Meanwhile, at 6 larvae/unit, the cannibalism percentage was 16.6 and 12.5% at 25 and 50 aphids/unit. Meanwhile, At 9 larvae/unit, the cannibalism percentage was 45.8, 18.75, and 0% at 25, 50, and 75 aphids/unit. The fourth larval density (12 larvae/unit) had the highest cannibalism percentage in the first instar (45.8%) at the 1st aphid density (25 aphids/unit).

In the absence of prey, there was a statistical variation in the cannibalism percentage in the first larval instar (Table 1). The percentage of cannibalism was 41.6, 50.0, and 50.0% at the 1st, 2nd, and 3rd larval densities (Table 1). The highest rate of cannibalism was achieved at the 4th larval density (12 larvae/unit). This mean the highest rate of cannibalism was achieved in absence of prey and overcrowding of first larval instar of predator.

Table 1. Average number of cannibalized larvae and larval cannibalism percentage[a] in *C. undecimpunctata* in the first instar larvae which confined together at different larval and aphid densities under laboratory conditions.

Predator density	Aphid densities			Without aphids
	25	50	75	
3	0.0±0.0c^{B} (0%)	0.0±0.0b^{B} (0%)	0.0±0.0a^{B} (0%)	1.25±0.48c^{A} (41.6%)
6	1.0±0.71bc^{AB} (16.6 %)	0.75±0.48ab^{B} (12.5 %)	0.0±0.0a^{B} (0%)	3.00±0.41bc^{A} (50.0%)
9	3.0±0.58b^{B} (33.3%)	0.0±0.0b^{C} (0%)	0.0±0.0a^{C} (0%)	4.50±0.29b^{A} (50.0%)
12	5.5±0.65a^{A} (45.8%)	2.25±0.63a^{B} (18.75%)	0.0±0.0a^{C} (0%)	7.25±0.48a^{A} (60.4%)

[a]Means followed by the same small letter in a column at different larval density or capital letter in a row at the same density at different densities of aphids are not significantly different at the 1% level of probability (Duncan's Multiple Range Test).

In the presence of prey, there was a statistical variation between larval densities of the second larval instar of *C. undecimpunctata* in the cannibalism percentage (Table 2). At 25 aphids/unit, the cannibalism percentage was ranged from 8.30 to 20.8%. Meanwhile, At 50 aphids/unit, the cannibalism percentage was ranged from 0 to 18.75%. The cannibalism percentage was ranged from 0 to 6.25% at 75 aphids/unit. The fourth larval density (12 larvae/unit) had the highest cannibalism percentage in the second instar (20.8%) at the 1st aphid density (25 aphids/unit).

At 3 larvae/unit, there was a statistical variation in the cannibalism percentage in the first larval instar (Table 2). At 6 larvae/unit, the cannibalism percentage was 12.5, 4.1, and 0% at 25, 50, and 75 aphids/unit. Meanwhile, At 9 larvae/unit, the cannibalism percentage was 19.4, 11.1, and 2.7% at 25, 50, and 75 aphids/unit. The fourth larval density (12 larvae/unit) had the highest cannibalism percentage in the second instar (20.8%) at the 1st aphid density (25 aphids/unit).

In the absence of prey, there was a statistical variation in the cannibalism percentage in the second larval instar (Table 2). The percentage of cannibalism was 50.0, 54.1, 61.1 and 58.3% at the 1st, 2nd, 3rd, and 4th larval densities (Table 2). The highest rate of cannibalism was achieved at the 4th larval density (9 larvae/unit).

Table 2.Numbers of cannibalized larvae and larval cannibalism percentage[a] in *C. undecimpunctata* in the second instar larvae which confined together at different larval and aphid densities under laboratory conditions.

Predator density	Aphid densities			Without aphids
	25	50	75	
3	0.25±0.25b^{B} (8.3%)	0.00±0.0b^{B} (0%)	0.00±0.00a^{B} (0%)	1.50±0.29b^{A} (50 %)
6	0.57±0.25ab^{B} (12.5 %)	0.25±0.25b^{B} (4.1 %)	0.00±0.00a^{B} (0%)	3.25±0.48ab^{A} (54.1%)
9	1.75±0.48ab^{B} (19.4%)	1.0±0.41ab^{AB} (11.1%)	0.25±0.25a^{AB} (2.7%)	5.50±0.65ab^{A} (61.1%)
12	2.50±0.65a^{B} (20.8%)	2.25±0.63a^{B} (18.75%)	0.75±0.48a^{B} (6.25%)	7.00±0.41a^{A} (58.3%)

[a]Means followed by the same small letter in a column at different larval density or capital letter in a row at the same density at different densities of aphids are not significantly different at the 1% level of probability (Duncan's Multiple Range Test).

There was a statistical variation between larval densities of the third larval instar of *C. undecimpunctata* in the cannibalism percentage (Table 3). At 25 aphids/unit, the cannibalism percentage was ranged from 33.3 to 50.0% (Table 3). Meanwhile, At 50 aphids/unit, the cannibalism percentage was ranged from 0 to 37.5%. The cannibalism percentage was ranged from 0 to 25.0 at 75 aphids/unit. The fourth larval density (12 larvae/unit) had the highest cannibalism percentage in the third instar (50.0%) at the 1st aphid density (25 aphids/unit).

At 3 larvae/unit, there was a statistical variation in the cannibalism percentage in the third larval instar (Table 3). Meanwhile, at 6 larvae/unit, the cannibalism percentage was 50.0, 33.3, and 20.8% at 25, 50, and 75 aphids/unit. Meanwhile, At 9 larvae/unit, the cannibalism percentage was 36.1, 22.2, and 25.0% at 25, 50, and 75 aphids/unit. The fourth larval density (12 larvae/unit) had the highest cannibalism percentage in the third instar (50.0%) at the 1st aphid density (25 aphids/unit).

In the absence of prey, there was a statistical variation in the cannibalism percentage in the third larval instar (Table 3). The percentage of cannibalism was 41.6, 75.0, 77.7, and 70.8% at the 1st, 2nd, 3rd, and 4th larval densities (Table 3). The highest rate of cannibalism was achieved at the 3rd larval density (9 larvae/unit).

Table 3.Numbers of cannibalized larvae and larval cannibalism percentage[a] in *C. undecimpunctata* in the third instar larvae which confined together at different larval and aphid densities under laboratory conditions.

Predator density	Aphid densities			Without aphids
	25	50	75	
3	1.00±0.00b[B] (33.3%)	0.00±0.00b[C] (0.0%)	0.00±0.0b[C] (0.0%)	1.25±0.25d[A] (41.6 %)
6	3.00±0.71ab[AB] (50.0 %)	2.00±0.00ab[B] (33.3 %)	1.25±0.63ab[B] (20.8%)	4.50±0.29c[A] (75.0%)
9	3.25±0.63ab[B] (36.1%)	2.00±1.00ab[B] (22.2%)	2.25±0.95ab[B] (25.0%)	7.00±0.41b[A] (77.7%)
12	6.00±1.08a[AB] (50.0%)	4.50±0.87a[B] (37.5%)	3.00±1.08a[B] (25.0%)	8.50±0.65a[A] (70.8%)

[a]Means followed by the same small letter in a column at different larval density or capital letter in a row at the same density at different densities of aphids are not significantly different at the 1% level of probability (Duncan's Multiple Range Test).

In the presence of prey, there was a statistical variation between larval densities of the fourth larval instar of *C. undecimpunctata* in the cannibalism percentage (Table 4). At 25 aphids/unit, the cannibalism percentage was 50.0, 66.6, 47.2, and 45.8% at different larval densities. Meanwhile, At 50 aphids/unit, the cannibalism percentage was 16.6, 62.5, 25.0, and 43.7%. The cannibalism percentage was 0, 50.0, 25.0, and 39.5% at 75 aphids/unit.

Table 4.Numbers of cannibalized larvae and larval cannibalism percentage[a] in *C. undecimpunctata* in the fourth instar larvae which confined together at different larval and aphid densities under laboratory conditions.

Predator density	Aphid densities			Without aphids
	25	50	75	
3	1.50±0.29b[AB] (50%)	0.50±0.50d[BC] (16.6%)	0.00±0.00c[C] (0%)	2.00±0.00d[A] (66.6 %)
6	4.00±1.00ab[A] (66.6 %)	3.75±0.48b[A] (62.5 %)	3.00±0.58ab[A] (50%)	4.50±0.29c[A] (75%)
9	4.25±0.75ab[B] (47.2%)	2.25±0.48c[BC] (25%)	1.00±0.41bc[C] (25%)	7.25±0.48b[A] (80.5%)
12	5.50±1.04a[B] (45.8%)	5.25±0.25a[B] (43.7%)	4.75±1.05a[B] (39.5%)	9.50±0.29a[A] (79.8%)

[a]Means followed by the same small letter in a column at different larval density or capital letter in a row at the same density at different densities of aphids are not significantly different at the 1% level of probability (Duncan's Multiple Range Test).

At 3 larvae/unit, there was a statistical variation in the cannibalism percentage in the fourth larval instar (Table 4). Meanwhile, at 6 larvae/unit, the cannibalism percentage was 66.6, 62.5, and 50.0% at 25, 50, and 75 aphids/unit. Meanwhile, At 9 larvae/unit, the cannibalism percentage was 47.2, 25.0 and 25.0% at 25, 50, and 75 aphids/unit. The fourth larval density

(12 larvae/unit) had the highest cannibalism percentage in the fourth instar at 25, 50, and 75 aphids/unit.

In the absence of prey, there was a statistical variation in the cannibalism percentage in the first larval instar (Table 4). The percentage of cannibalism was 66.6, 75.0, 80.5, and 79.8% at the 1st, 2nd, 3rd, 4th larval densities (Table 4).

In general, there was a statistical variation between larval density of the four larval instars of *C. undecimpunctata* in the cannibalism percentage and also affected significantly by prey density.

DISSCUSION

The results of this study proved that there were significant differences between larval densities of the four larval instars of *C. undecimpunctata* and the cannibalism rate in the presence of aphids. The fourth level of density and the fourth and third instar larvae had the highest cannibalism rate. In the present study, the incidence of cannibalism increased with the increase in larval density, which reveals a density-dependent effect. This might be due to the increased rate of encounter between cannibals and victims. The present study conforms the finding of Dimetry (1976) who concluded that larval overcrowding increased the rate of cannibalism among all instars of *Adalia bipunctata* (L.). The incidence of larval cannibalism in *Harmonia axyridis* (Pallas) at higher larval density was 50% more than at lower density (McClure, 1987). Our results support the inferences of Kindlmann and Dixon (1993), who suggested that incidence of cannibalism increases in declining aphid colonies because of increase in predator density. These results are in agreement with those of Takahashi (1987) who reported that in the absence of aphids, larval cannibalism was frequent in the second and fourth instar larvae of *Coccinella septempunctata brucki* Mulsant, but most first instar larvae starved or were attacked by older larvae. Agarwala and Dixon (1992) observed that eggs and young larvae of *A. bipunctata* were more vulnerable to cannibalism than older larvae. Both egg and larval cannibalism were inversely related to the abundance of the aphids. The presence of aphids as extraguild prey significantly reduced the frequency of cannibalism. Nutritional benefits gained by cannibalism may increase population stability resilience, and decrease the probability of extinction (Schausberger and Croft, 2000). The performance of the larvae of predatory ladybird beetles is often affected by the species of aphid they eat (Blackman, 1967; Hukushima and Kamei, 1970; Hamalainen and Markkula, 1972; Pasteels, 1978). This finding is similar to that of Michaud (2003), where the rate of cannibalism in *H. axyridis*, *Olla v-nigrum* (Mulsant) and *Cycloneda sanguinea* L. significantly increased with reduction in the quantity of food supplied. Schellhorn and Andow (1999 b) observed high rates of cannibalism in three co-occurring ladybirds when aphid populations crashed.

Generally, the results here demonstrated that cannibalism was strongly density dependent and may contribute to population regulation of coccinellids. In aphidophagous communities, coccinellid predators are important because of their voracity and diversity. Cannibalism in the field is associated with a decrease in aphid populations and an asymmetry in the vulnerability of the coccinellids (Rosenheim *et al*., 1995; Sato *et al*. 2003).

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تأثير كثافات كل من المفترس والفريسة للمفترس أبوالعيد ذو الاحدى عشرة نقطة على الإفتراس الذاتى لليرقات تحت الظروف المعملية

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تم دراسة تأثير كثافة كل من يرقات المفترس وفريسة من البقوليات بمستويات مختلفة على الإفتراس الذاتى(النوعى) لنوع من أهم مفترسات فصيلة أبوالعيد وهو أبوالعيد ذو الأحدى عشرة نقطة تحت الظروف المعملية.
بيّنت النتائج أن هناك فرقًا معنوياً بين كثافة الفريسة وبين معدل الافتراس الذاتى فقد سجلت النتائج أعلى معدل للافتراس الذاتى فى عدم وجود المنّ كما سجلت النتائج فروقا معنوية بين كثافة الأعمار اليرقية الأربعة لمفترس أبوالعيد ذى الأحدى عشرة نقطة وبين نسبة إفتراس اليرقات Larval cannibalism وذلك فى وجود المنّ .فقد سجل المستوى الثالث والرابع لكثافة الاعمار اليرقية أعلى معدل للإفتراس الذاتى وبالتالى كلما زادت كثافة المفترس كلما زاد معدل الإفتراس الذاتى لمفترس أبو العيد ذو الإحدى عشرة نقطة .

قام بتحكيم البحث

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