Der Parasit wurde im Labor in den Eiern von *Spodoptera littoralis, Cacoecimorpha pronubana* und *Palpita unionalis* sowie als Kontrollart *Anagasta kühniella* gezogen.

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The role of predator and prey density as factors affecting behavioural and biological aspects of Adalia bipunctata (L.) larvae

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Abstract

Crowding of *A. bipunctata* larvae in the laboratory induced behavioural and biological differences when these larvae were reared with definite numbers of aphids in glass jars or under inverted plastic Petri-dishes. With increasing number of larvae, the percentage of

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survival decreased mainly due to increasing cannibalism. Cannibalism and death from other causes were reduced by increasing daily supply of aphids. Larval duration, number of consumed aphids per larva and pupal weight were also affected by prey density.

1 Introduction

The appearance of high percentage of cannibalism among predaceous larvae has been thought to be associated with crowding as well as with scarcity of food. One of the most interesting consequences of crowding is cannibalism. It occurs often in predaceous species but is reported also from phytophagous insects as *Agrotis ipsilon* (MANSOUR and DIMETRY 1972) and *Porthetria dispar* (LEONARD 1968) and even from aphids (BANKS et al. 1968). Among aphid predators, cannibalism is a common phenomenon as can be seen from the work of ARZET (1973) on *Chrysopa carnea,* RUSSELS (1970) on Anthocoridae, BANKS (1956), HODEK (1967), KEHAT (1968) and BROWN (1972) on Coccinellidae.

The present study was conducted to determine the effect of predator and prey density on survival, food consumption and on the percentage of cannibalism in *A. bipunctata* larvae. An estimate is made also on the effect of scarcity of food on the percentage of survival and percentage of cannibalism.

2 Material and methods

Egg batches of *A. bipunctata* were taken from a colony which was reared in the laboratory on *Myzus persicae* (Sulz.) at 25–26° C and 16 hr daily illumination. The eggs were incubated at 25–26° C and 75 % relative humidity till larval hatching. Different numbers of larvae were confined together in glass jars and were daily supplied with definite quantities of aphids *(Myzus persicae)* on brussel sprouts leaves. In each experiment ten replicates were conducted at a constant temperature of 25–26° C.

3 Results

3.1 Effect of crowding on some biological aspects of A. bipunctata larvae

In this respect, the first instar larvae were reared individually and in groups of 2, 4, 8, 16 and 32 in glass jars 15 × 20 cm. The larvae were supplied daily with new aphids cemented on the lower surface of brussels leaves. First and second instar larvae received 25 aphids of the first and second instar per individual, larvae of the third and fourth instar, however received 60 aphids of third and fourth instar per individual. Observations were carried out daily to detect the mortality rate. The daed larvae were microscopically examined to differentiate between the normal mortality and cannibalism. The total number of aphids offered within the jar was reduced according to larval mortality. The resulting pupae were weighed. The results obtained are shown in table 1 from which it is evident that larval crowding had a remarkable effect on the larval duration. The length of the larval period varied in average between 8.0 ± 0.20 and 12.8 ± 0.29 days. When the number of larvae increased, the larval duration decreased and this may be

Table 1. The effect of larval crowding at constant predator-prey ratio on some biological aspects of *Adalia bipunctata* (L.) in glass jars (average number of 10 replicates)

No of larvae	Larval duration in days	Pupal wt in mg	Survival No	%	Cannibalism No	%	Other mortality No	%
1	12.7 ± 0.26	9.6 ± 0.0	1.0 ± 0.0	100	0.0 ± 0.0	0	0.0 ± 0.0	0
2	12.8 ± 0.29	9.5 ± 0.58	1.8 ± 0.13	90	0.0 ± 0.0	0	0.2 ± 0.1	10
4	10.8 ± 0.35	10.6 ± 0.73	3.0 ± 0.25	75	0.6 ± 0.14	15	0.4 ± 0.14	10
8	10.2 ± 0.28	10.2 ± 0.68	5.3 ± 0.18	66	1.6 ± 0.22	20	1.1 ± 0.16	14
16	9.2 ± 0.20	10.2 ± 0.65	8.2 ± 0.20	51	5.4 ± 0.16	34	2.4 ± 0.16	15
32	8.8 ± 0.21	10.0 ± 0.69	6.5 ± 0.34	20	16.1 ± 0.17	50	9.4 ± 0.26	30

attributed to the aggregation character of the coccinellids. On the other hand, pupal weight slightly increased with increasing number of larvae and aphids to a maximum at 8 larvae and then decreased again. This decrease may be due to competition for space in the larvae instars.

The percentage of larval survival was greatly decreased with increasing number of larvae. This is partly due to the increasing normal mortality and mostly to the increasing of cannibalism in spite of the greater number of aphids available. Maximum cannibalism occurred during the fourth instar as this instar is the most voracious one.

3.2 Effect of crowding on the percentage of cannibalism of A. bipunctata larvae

Leaves of brussels sprout (appr. 51 cm^2) were cemented with its upper surface on sheets of paper. Definite numbers of aphids (25 first and second instars for an individual first and second instar larvae) were cemented on the lower surface of the leaves, which was directed upwards and 65 aphids (third and fourth instar for the third and fourth instar larvae). Each leaf was applied with 4, 8, 16 and 32 newly hatched larvae of *A. bipunctata* and covered by a plastic Petri-dish that was fixed on the paper by modelling

Table 2. Effect of crowding at constant predator-prey ratio on cannibalism between *A. bipunctata* larvae on a definite brussels sprouts leaf area (average number of 10 replicates)

Larval density	Survival No	%	Cannibalism No	%	Other mortalities No	%
4	3.5 ± 0.22	88	0.3 ± 0.09	7	0.2 ± 0.08	5
8	6.0 ± 0.16	75	1.9 ± 0.15	24	0.1 ± 0.1	1
16	11.3 ± 0.21	70	4.7 ± 0.21	30	0.0 ± 0.0	0
32	15.9 ± 0.28	50	15.1 ± 0.37	47	1.0 ± 0.21	3

clay. Plant leaves and aphids were renewed daily. The results obtained are shown in table 2 from which it is evident that the percentage of cannibalism in the less crowded conditions (4 larvae) was very low but the percentage

of normal mortality was high in comparison with that of 8, 16 and 32 larvae because the aphids were cemented away from each other and so the larvae may lost its way in finding the aphids. In the more crowded conditions 16 and highly crowded conditions 32 larvae, the aphids were cemented very near each other and this gave the opportunity of nearly each larva to find its way to the prey aphid and as a result the normal mortality was 0 in 16 larvae but it was 3 % in case of 32 larvae. It can be concluded that the normal mortality occurs in this case may be not from starvation but from the direct effect of crowding. The percentage of cannibalism increased with increased larval density.

3.3 Effect of crowding on the food consumption of A. bipunctata larvae

The feeding capacity was determined by rearing 4, 8, 16 and 32 newly hatched predator larvae in cages of the same kind. The number of aphids given daily to the predator larvae were the same as in the previous experiment. The rate of prey consumption was recorded under all conditions of larval density. The total number of aphids consumed and the daily rate of feeding increased with increased age of the larva. Aphids partially eaten

Table 3. Effect of larval crowding on the food consumption of *A. bipunctata* larvae

Larval density	No of aphids consumed/larva Instars				Total
	1st	2nd	3rd	4th	
4	21	41	68	100	230 ± 16.2
8	25	57	76	127	285 ± 12.9
16	19	46	71	181	317 ± 20.1
32	20	35	70	205	330 ± 16.8

or killed but not eaten were considered consumed. The fourth instar larva was the most voracious, this was due to an increase in the daily rate of consumption and the number of feeding days. In highly crowded conditions i.e. 32 larvae, the total number of aphids consumed was very high (average 330 ± 16.8). When the density of larvae was low (4), the total number of aphids consumed decreased to 230 ± 16.2 in an average. Thus, the predatory activity is therefore host density dependent.

3.4 The functional response of predators to prey density

As seen in the foregoing experiments, each cage was provided with 16 newly hatched larvae which were daily supplied with different number of aphids (table 4). If larvae died during the experiment, the number of aphids given daily to the cage was reduced in the same ratio. The results obtained showed that the percentage of cannibalism increased greatly in low aphids density. The larval duration was lengthend, the number of feeding days increased, the mortality rate rose and the total food consumption dropped.

Table 4. The functional response of predator to prey density

No of aphids offered daily to 1 + 2 instars	No of aphids offered daily to 3 + 4 instars	Larval duration in days	Pupal wt in mg	Survival		Cannibalism		Other mortality	
				No	%	No	%	No	%
50	100	26.3 ± 0.49	5.7 ± 0.16	0.3 ± 0.02	2	10.5 ± 0.35	66	5.2 ± 0.35	32
100	200	18.0 ± 0.24	7.9 ± 0.30	2.5 ± 0.28	16	9.0 ± 0.20	56	4.5 ± 0.24	28
200	400	9.8 ± 0.25	9.4 ± 0.37	7.0 ± 0.28	44	7.0 ± 0.24	44	2.0 ± 0.14	12
400	800	9.0 ± 0.20	10.5 ± 0.66	12.0 ± 0.24	75	4.0 ± 0.25	25	0.0 ± 0.0	0

A comparison of the results of the scarcity and plenty of food reveals the following interesting points, the greater the population density of the prey, the fewer will be the number of larvae starved to death. In a high population density of the prey, a greater percentage of larvae survive and complete their development sooner and produce larger, stronger adults which undoubtedly are more fecund. Thus a variation in the population density of the prey has an immediate and striking effect on the population density of the predator.

3.5 The percentage of cannibalism when a constant number of aphids (200) was offered

Again 4, 8, 16 or 32 newly hatched larvae were confined in cages of the same kind. Two hundred aphids in the third instar were offered daily, independently of the number and the increasing age of the larvae. The number of aphids given daily remained constant, even when some of the larvae died.

It has been observed that the percentage of larval survival decreased with the increase of the initial larval density (table 5) which is partly due to the increase of normal mortality but mainly to the sudden increase in cannibalism. This could be explained by the fact that the increasing chance of meeting is no longer compensated by increasing prey density. With initial density of 8, 16, or 32 larvae, nearly the same number of larvae survived. It seems that under the present conditions, the experimental cage has the capacity for only 7 larvae of *A. bipunctata* to complete their development. Perhaps food supply is the limiting factor as 200 aphids were insufficient as a food supply for 16 or 32 larvae in their last instar. Therefore, only reduction of the larval density due to cannibalism insured the complete development of the remaining larvae.

4 Discussion

Crowding was considered as a factor inducing cannibalism between predaceous Coccinellidae. As in polyphagous insects studied by HODJAT (1970) on *Spodoptera littoralis* and LEONARD (1968) on the gypsy moth *Porthetria dispar*,

Table 5. The percentage of cannibalism between *A. bipunctata* larvae when offered a constant number of aphids (200)

No of larvae	Survival		Cannibalism		Other mortalities	
	No	%	No	%	No	%
4	3.6 ± 0.16	90	0.3 ± 0.15	8	0.1 ± 0.1	2
8	6.9 ± 0.18	86	1.0 ± 0.20	13	0.1 ± 0.1	1
16	6.3 ± 0.26	39	8.0 ± 0.21	50	1.7 ± 0.22	11
32	6.8 ± 0.25	21	21.2 ± 0.39	66	4.0 ± 0.21	13

crowding has a remarkable effect on the physiology, biology and behaviour of the predaceous Coccinellidae.

In the experiments, both larval crowding and prey density influenced the degree of cannibalism between the larvae of *A. bipunctata*. However, only the influence of prey density could be tested independently. The remarkable decrease of cannibalism with increasing number of aphids can possibly traced back to different causes: If the activity of the larvae decreases with increasing number of prey (decreasing area traversed) the number of encounters per unit of time will also decrease; therefore, the probability of cannibalism is reduced. On the other hand, agressivity and ability for defence or escape may also depend on the degree of hunger.

The effect of crowding on cannibalism could not be tested without interference by changing prey quantity. If prey number per vial was constant with increasing larval density cannibalism was enhanced by growing competition for food. However, if prey number was proportional to the number of *Adalia* larvae, food consumption per larva increased with increasing density: obviously, at higher density food was found more easily. In this way, cannibalism probably increased more slowly.

Nevertheless, cannibalism increased very much under these conditions. Thus it is influenced by factors that are correlated with population density, such as number of encounters per unite of time. If a is the number of encounters between 2 larvae there are a (1 + 2) encounters between 3 larvae. Generally the number of encounters between n larvae would be

$$e_n = a\,(1 + 2 + 3 + \ldots + [n - 1]) = \frac{a}{2}\,n\,(n - 1)$$

if the number of larvae would not decrease by cannibalism. Of course, a cannot expected to be constant. It probably changes with age and population density and is dependent also on the duration of development of observation covers the whole period of larval development. From the degree of density dependent increase of cannibalism in the experiments, however, a rough estimate does not reveal significant changes of a. Thus additional influences on cannibalism cannot be proved from these data. At present, further experiments are conducted to reveal such influences.

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Zusammenfassung

Zur Beeinflussung der Lebens- und Verhaltensweise von Adalia-bipunctata-Larven durch Räuber- und Beutedichte

Bei hoher Dichte (im Labor) entwickelten sich die Larven von *A. bipunctata* schneller als einzelne lebende Larven. Das Puppengewicht aus Zuchten sowohl bei hoher Larvendichte als auch bei Einzelzucht war geringer als bei Aufzucht in mittlerer Dichte. Das Überlebensprozent nahm ab, wenn sich die Zahl der Larven verringerte. Andererseits stiegen die Mortalität und der Kannibalismus mit der Larvendichte. Es wurden die Auswirkungen von Mangel und Überfluß an Beute auf den Kannibalismus näher untersucht.

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Action of juvenoids on the honey bee colony

By J. Žďárek, O. Haragsim and V. Veselý

With 1 figure

Abstract

Topical application of a great dose (1 mg) of potent juvenoids has no negative effects on the reproduction processes in the honey bee queen. When these compounds are introduced to the hive with food the queen continues laying eggs, but both unsealed and sealed brood are destroyed and removed by worker bees. No mortality in adults was observed. Topical

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