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INTERFERENCE AND COMPETITIVE BEHAVIOUR OF THE APHID PREDATORS, *CHRYSOPERLA CARNEA* AND *COCCINELLA SEPTEMPUNCTATA* IN THE LABORATORY*

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Interference and competition between *Chrysoperla carnea* (Stephens) and *Coccinella septempunctata* L. was investigated in the absence and presence of aphid prey. When larvae of similar vigour encountered each other, *C. carnea* larvae were superior to *C. septempunctata*. Otherwise the larger of 2 individuals always killed the smaller. In the absence of prey *C. carnea* adults were attacked by their own 2nd and 3rd instar larvae as well as by 3rd instar larvae of *C. septempunctata*. In all encounters the adults of *C. septempunctata* were superior. Since the eggs of *C. carnea* are protected to some extent by being on egg stalks, they were less susceptible to cannibalism and predation than *C. septempunctata* eggs which are deposited in batches directly on plant leaves. In the presence of prey cannibalism and predation were reduced, especially between larvae. Only eggs and 1st instar larvae were endangered. In the present experiments *C. carnea* showed a slight superiority over *C. septempunctata*.

KEY-WORDS : *Chrysoperla carnea, Coccinella septempunctata,* Interference, Competitive behaviour.

Many factors affect the efficiency with which natural enemies suppress pest populations. Two factors are the interference and competition from the same or other species.

Arzet (1972) and **Duelli** (1981) observed the occurrence of cannibalism in the predator *Chrysoperla carnea* (Stephens) and studies by **Bänsch** (1964) and **Egger** (1974) revealed that *C. carnea* larvae cannibalized eggs. It was found also that hunger influenced the extent of cannibalism (**Arzet,** 1972 ; **Bond,** 1978 ; **Baumgärtner** *et al.,* 1981).

Cannibalism among larvae of *Coccinella septempunctata* L. was reported by **Jöhnssen** (1930). Several authors observed egg cannibalism by larvae (**Dixon,** 1959 ; **Shah,** 1980 ; **Basedow,** 1982 ; **Mills,** 1982) and **Banks** (1955) also observed adults feeding on eggs. In *C. septempunctata* the extent of cannibalism was also dependent on hunger (**Bänsch,** 1964 ; **Kehat,** 1968). The competitive interactions between *C. carnea* and *C. septempunctata* were studied by **Bänsch** (1964) and **Ickert** (1968).

This paper presents studies on the interference and competition between *C. carnea* and *C. septempunctata*. The interactions between different larval instars and between larvae,

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eggs, and adults were investigated both within and between the 2 species. All experiments were conducted in the absence and presence of prey to take into consideration the hunger of the predator.

MATERIALS AND METHODS

The stock cultures of *C. carnea* and *C. septempunctata* were maintained in a controlled-environment cabinet at 25 ± 1°C and 65-70 % relative humidity. A 16 h photophase was maintained with a light intensity of approximately 1500 Lux.

The stock culture of *C. carnea* was reared following the method of **Hassan** (1975). The adults of *C. septempunctata* were kept in glass cylinders containing several leaves of broad-bean (*Vicia faba*). The cylinders were covered with a piece of gauze. The egg batches of 1 day were placed in Petri dishes (9 cm in diameter) with a screened hole in the lid. Live aphids of the species *Acyrthosiphon pisum* (Harris) and *Aphis fabae* (Scop.) were used as food for the larvae of both predators.

The experiments were conducted in insectary rooms at 25 ± 1°C and 35-40 % relative humidity. A 16 h photophase was maintained with a light intensity of ca. 8500 Lux.

Petri dishes each 9 cm in diameter and 3 cm deep were used as arenas throughout the experiments. Each Petri lid had a 2 cm diam. hole punched in its centre and a piece of gauze placed over the hole. A leaflet of broadbean, set into a small glass vial containing a piece of wet cotton wool to keep the leaflet turgid, was placed in every Petri dish. This leaflet served as food for the prey. In every experiment the interaction between 2 individual predators was observed and 6 replications were conducted for each experiment. Results were recorded every 24 h with further observations made at irregular intervals.

C. carnea and *C. septempunctata* larvae and adults were removed 2 days after eclosion or molting from the stock cultures for use in the experiments. However, 1st and 2nd instar larvae of *C. septempunctata* were removed after 1 day because of the short duration of these immature stages. In experiments concerning adults of the 2 predators, 3 males and 3 females of each were observed. In experiments using eggs, 5 eggs of *C. carnea* deposited on a piece of paper and hung to the stalks were placed on to a broadbean leaflet inside a Petri dish. Five eggs of *C. septempunctata* were also transferred to the leaflet with a fine camel hair brush.

For investigations with prey present, 10 aphids were placed daily into Petri dishes containing 1st and 2nd instar larvae. In contrast, Petri dishes containing 3rd/4th instar larvae or adults each received 15 aphids per day. Wilting broadbean leaflets were replaced. Experiments were terminated when 1 of the individuals in the test had been killed or molted to the next stage.

RESULTS

For a clearer presentation of the results the following abbreviations will be used for the respective predators and their stages :

C. carnea		*C. septempunctata*	
1st stage larva	C_1	1st stage larva	S_1
2nd stage larva	C_2	2nd stage larva	S_2
3rd stage larva	C_3	3rd stage larva	S_3
		4th stage larva	S_4
Pupa	C_P	Pupa	S_P
Adult	C_A	Adult	S_A
Egg	C_E	Egg	S_E

CANNIBALISM IN *C. CARNEA*

In the absence of prey cannibalism was high among the larvae (table 1). All 6 C_1-larvae were killed in the experiments where they were confined with C_1, C_2 and C_3 larvae. In 5 instances C_2 was killed by C_2, whereas only 4 C_2 were killed by C_3. In the experiment with 2 C_3-larvae 1 was killed after 1 day in each replicate. Except for C_1 the larvae also attacked adults and C_2 and C_3 killed 4 and 5 C_A, respectively. All larval instars cannibalized the eggs. C_1 and C_2 ate the eggs within 2 days whereas all eggs were consumed by C_3 within 1 day.

Cannibalism was reduced when prey was present. In the experiments with C_1-larvae only 1 was killed by C_1, C_2 did not kill any C_1 and C_3 cannibalized 1 C_1. C_2 attacked 1 C_2 whereas C_3 killed 3 C_2. Also 1 C_2 ate a C_3. In the experiments with competing C_3-larvae, no cannibalism occured and all larvae reached the pupal molt. Cannibalism between adults and larvae was observed only once, when a C_3 killed an adult. While no eggs were consumed by C_1, all eggs were eaten in 5 and 4 of the replicates by C_2 and C_3 respectively. In the other replicates no eggs were eaten. In no experiment, whether in the absence or presence of prey, did larvae attack pupae.

TABLE 1

Interference among the different stages of Chrysoperla carnea *in the absence and presence of aphid prey*

Stage of Attacker	Number of individuals of *C. carnea* killed											
	Prey absent						Prey present					
	C_E	C_1	C_2	C_3	C_P	C_A	C_E	C_1	C_2	C_3	C_P	C_A
C_1	25	6	0	0	0	0	0	1	0	0	0	0
C_2	30	6	5	0	0	4	25	0	1	1	0	0
C_3	30	6	4	6	0	5	20	1	3	0	0	1
C_A	0	0	0	0	0	0	0	0	0	0	0	0

The number of eggs offered was 30 (6 Reps of 5), the number of the other stages 6 (6 Reps of 1).

CANNIBALISM IN *C. SEPTEMPUNCTATA*

All larval stages killed S_1 when aphid prey was absent (table 2). In the experiment with 2 competing S_1, 4 S_1 were killed. Similar numbers were also killed by S_2. Five S_1 were consumed by S_3 and 4 by S_4. In 5 of the 6 replicates S_2 was killed by S_2, whereas S_3 and S_4 consumed all S_2. Five S_3 larvae were killed in those experiments where S_3-larvae competed against each other or against S_4-larvae. Only 3 S_4 were eaten by S_4. The adults of *C. septempunctata* ate all S_1 and S_2-larvae, but only 5 S_3 and 4 S_4-larvae. Neither larvae nor adults attacked pupae, whereas eggs were quickly consumed. S_1 killed the eggs in 4, and S_2 and S_3 in all 6 replicates. The somewhat slower moving S_4 as well as the adults ate the eggs from only 3 of the replicates.

In the presence of prey cannibalism did not occur between competing S_1-larvae or between S_1 and S_2-larvae. Only S_3 and S_4 killed S_1. Cannibalism was not observed between other larvae. The adults however were cannibalistic, even when prey was present. They killed S_1 3 times. Egg cannibalism by S_1 and S_2 was reduced considerably. S_1 ate the eggs from only 1, S_2 from 2, S_4 from 4 and both S_3 and S_A from all 6 Petri dishes.

TABLE 2

Interference among the different stages of Coccinella septempunctata *in the absence and presence of aphid prey*

Stage of Attacker	Number of individuals of *C. septempunctata* killed													
	Prey absent							Prey present						
	S_E	S_1	S_2	S_3	S_4	S_P	S_A	S_E	S_1	S_2	S_3	S_4	S_P	S_A
S_1	20	4	0	0	0	0	0	5	0	0	0	0	0	0
S_2	30	4	5	0	0	0	0	10	0	0	0	0	0	0
S_3	30	5	6	5	0	0	0	30	6	0	0	0	0	0
S_4	15	4	6	5	3	0	0	20	6	0	0	0	0	0
S_A	15	6	6	5	4	0	0	30	3	4	2	3	0	0

The number of eggs offered was 30 (6 Reps of 5), the number of the other stages 6 (6 Reps of 1).

TABLE 3

Competition between the different stages of Chrysoperla carnea *and* Coccinella septempunctata *in the absence and presence of aphid prey*

Stage of Attacker	Number of individuals of *C. septempunctata* killed													
	Prey absent							Prey present						
	S_E	S_1	S_2	S_3	S_4	S_P	S_A	S_E	S_1	S_2	S_3	S_4	S_P	S_A
C_1	30	6	0	0	0	0	0	25	0	0	0	0	0	0
C_2	30	5	6	6	0	0	0	30	0	1	0	0	0	0
C_3	30	5	4	4	3	0	0	30	4	3	1	0	0	0
C_A	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Stage of Attacker	Number of individuals of *C. carnea* killed													
	Prey absent							Prey present						
	C_E	C_1	C_2	C_3	C_P	C_A		C_E	C_1	C_2	C_3	C_P	C_A	
S_1	25	0	0	1	0	0		0	1	1	0	0	0	
S_2	10	5	0	0	0	0		0	0	0	0	0	0	
S_3	20	6	0	0	0	5		20	3	0	0	0	0	
S_4	10	4	4	1	0	0		5	1	2	0	0	1	
S_A	15	6	6	1	0	0		19	5	2	0	0	0	

The number of eggs offered was 30 (6 Reps of 5), the number of the other stages was 6 (6 Reps of 1).

COMPETITION BETWEEN *C. CARNEA* AND *C. SEPTEMPUNCTATA*

The results of competition between the different stages of the 2 predators are shown in table 3. When prey was absent, all S_1 were killed by C_1. However, older *C. septempunctata* larvae preyed upon C_1, as S_2, S_3 and S_4-larvae killed C_1 in 5, 6 and 4 of the replicates respectively. The S_A also killed the C_1 in all 6 replicates. In 5 instances C_2 was superior to S_1, and in 6 cases to both S_2 and S_3. Only S_4 killed 2 of the C_2 whereas S_A consumed all 6. In the experiment with C_3 5 S_1 were killed whereas the remaining C_3 was killed by the S_1. C_3 preyed upon S_2 and S_3 4 times each and was superior to S_4 3 times. The eggs of *C. carnea* were consumed from 5, 2, 4, 2 and 3 of the replicates by S_1, S_2, S_3, S_4 and S_A, respectively. Frequently not all of the eggs in each batch were killed. In particular S_A consumed only some of the eggs, leaving others intact.

In the presence of prey, 1, 0, 3, 1 and 5 C_1 were killed by S_1, S_2, S_3, S_4 and S_A, respectively. One C_2 was killed by an S_1, and 1 C_2 killed an S_2. No predation occurred in experiments where C_2 and S_3 competed, whereas 2 C_2 were killed by both S_4 and S_A. C_3 killed 4 S_1, 3 S_2 and 1 S_3-larva. Predation did not occur between C_3 and S_4 or between C_3 and S_A. The egg batches of *C. septempunctata* were consumed in 5, 6 and 6 of the replicates by C_1, C_2 and C_3-larvae, respectively. The eggs of *C. carnea* were not attacked by S_1 and S_2 larvae though eggs were eaten by the other instars. Only S_4 preyed upon 1 C_A.

DISCUSSION

The cannibalistic behaviour of *C. carnea* larvae was studied by **Arzet** (1972), who reported that *C. carnea* upon contacting a larvae of its own species usually turned back. However, with increasing hunger this behaviour became less pronounced. In our studies the turning back of the larvae was observed between larvae of the same age but not in encounters between young and old larvae. Several factors determine the occurrence and extent of cannibalism. **Duelli** (1981) stated that the most important factor determining whether an attacked individual will be killed or not is the response by the individual itself. According to our observations, however, hunger seemed to be the most important influence, since it produced increased, and more aggressive, attacks thereby enhancing cannibalism. The observed reductions of cannibalism in the experiments where prey was present are evidence of this (table 1). According to **Arzet** (1972) the density of the predator is another factor determining the level of cannibalism, but the state of predator hunger was not considered in his study.

It is known that food scarcity may induce a premature pupal molt (**Pariser,** 1919). This occurred in several C_3-larvae when prey was absent. In 2 instances C_3-larvae were killed by younger larvae which had climbed on their backs and were feeding directly behind the prothorax, at a position where the attacked C_3-larvae could not dislodge them.

With 1 exception, larvae attacked adults only when prey was absent. Pupae were never attacked in any experiment. C_3 were attacked shortly before or during the pupal molt confirming earlier findings of **Alderson** (1907). **Bänsch** (1964) and **Ickert** (1968) reported that hatching larvae occasionally cannibalized eggs, whereas **Egger** (1974) found 43 % of the eggs were killed by hatching larvae. In the present study, approximately 77 % of the eggs were killed by C_1-larvae. In some instances the hatching larvae climbed up the eggs stalks and in others the eggs were knocked over and then also eaten by C_2- and C_3-larvae. Frequently C_2 and C_3 passed the eggs several times before starting to feed on them.

Bänsch (1964) observed cannibalism by *C. septempunctata* only when prey was scarce since no cannibalism occurred when larvae were placed in an aphid colony. According to **Hawkes** (1920) *Adalia bipunctata* L. is cannibalistic even in the presence of an adequate food

supply. The present experiments revealed that cannibalism by *C. septempunctata* was reduced when prey was present. While, in the absence of prey, older larvae cannibalized younger larvae as well as larvae of the same age, only S_1-larvae were killed by S_3 and S_4 when prey was present. Cannibalism of pupae by *C. septempunctata* was never observed in this study, confirming earlier findings (**Jöhnssen,** 1930 ; **Hagen,** 1962). The extent of egg cannibalism in *C. septempunctata* has been discussed by several authors. **Dixon** (1959) and **Shah** (1980) reported that egg cannibalism was carried out mainly by newly hatched 1st instar larvae. **Basedow** (1982) indicated that only infertile eggs were attacked and thus by providing the 1st food for young larvae this cannibalism could be beneficial when prey density is low. Studies by **Banks** (1955) and field observations by **Mills** (1982) revealed that eggs were attacked by all larval stages and adults. This is in agreement with our observations where all stages cannibalized eggs (table 2).

In comparison with *C. carnea* the extent of cannibalism by *C. septempunctata* was less dependent on the absence or presence of prey (table 1 and 2).

The competition between *C. carnea* and *C. septempunctata* was studied by **Bänsch** (1964), who after observing *C. carnea* preying upon *Coccinella* larvae in an aphid colony, considered *C. carnea* to be superior. The present study revealed that *C. septempunctata* attacked *C. carnea* in the absence as well as in presence of prey. *C. carnea* larvae were superior when the 2 larvae were of similar vigour, whereas in encounters between larvae of different ages the larger one always ate the smaller. In the presence of prey these relations were not so evident, since a C_1 and C_2 were killed by a S_1 (table 3). Thus the inhibition to contact an attacker decreased with increasing hunger.

The adults of *C. septempunctata* proved to be very aggressive and, with the exception of C_3-larvae, attacked all larval stages of *C. carnea* in the absence and presence of prey.

Pariser (1919) stated that the egg stalks of the Chrysopid eggs did not help to protect the eggs from predation. In the present study, however, a higher percentage of *C. septempunctata* eggs than *C. carnea* eggs were killed. The *C. carnea* eggs first had to be knocked over before they could be consumed, whereas the eggs of *C. septempunctata* are deposited in batches and this type of egg placement was conducive to predation.

The present study revealed that the interference and competitive behavior of the 2 predators might be an important factor limiting population development and efficiency.

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ZUSAMMENFASSUNG

Das Interferenz- und Konkurrenzverhalten von *Chrysoperla carnea* und *Coccinella septempunctata* unter Laborbedingungen

Bei den räuberischen Arten *Chrysoperla carnea* und *Coccinella septempunctata* wurde das Interferenz- und Konkurrenzverhalten bei An- und Abwesenheit von *Acyrthosiphon pisum* und *Aphis fabae* als Beute untersucht.

So konnte beobachtet werden, daß beim Aufeinandertreffen zweier gleich großer Individuen von *C. carnea* und *C. septempunctata* in der Regel *C. carnea* überlegen war. Ansonsten siegte immer die größere über die kleinere Larve. Die Imagines von *C. carnea* wurden in den Versuchen ohne Beute von den eigenen Larven des zweiten und dritten Stadiums, aber auch vom dritten Larvenstadium von *C. septempunctata* angegriffen und ausgesaugt. Die Imagines von *C. septempunctata* erwiesen sich in allen Versuchen als Überlegen. Der Vergleich zwischen der Fraßaktivität gegenüber den Eiern beider

Arten ergab, daß die Eier von *C. carnea* durch ihre Stielchen besser geschützt waren. Sie wurden oft erst zufällig durch die Larven beider Prädatoren umgestoßen und teils nach mehrmaligem Überlaufen gefressen. Dagegen waren die in Paketen abgelegten Eier von *C. septempunctata* rasch gefunden und gefressen.

Alle diese Vorgänge waren bei Anwesenheit von Beutetieren reduziert, vor allem die Aktivitäten zwischen den Larvenstadien, und die Räuber entwickelten sich meist unbehelligt. Gefährdet waren in dieser Versuchsreihe die ersten Larvenstadien sowie die Eier. Insgesamt gesehen zeigte *C. carnea* in den Versuchen eine geringe Überlegenheit gegenüber *C. septempunctata*.

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