

THE EFFECT OF PREY DENSITY ON FOOD INTAKE BY ADULT
CHEILOMENES SULPHUREA [COL. : COCCINELLIDAE] ⁽¹⁾

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The feeding rate of males of the coccinellid *Cheilomenes sulphurea* (Ol.) was checked in 3 types of exposure arenas of 210, 476 and 2973 cm², at 3 levels of prey offered daily (40, 80, 120 *Aphis fabae* Scopoli aphids per arena). Prey numbers affected the feeding rate much more than the size of the exposure arena. *C. sulphurea* males thus showed a rather high searching efficiency. The data are apparently near to the satiation threshold where **Holling's** functional response curves of type II and III resemble each other.

The consumption (or killing) of prey by predators per time unit usually grows along with an increase in prey density. The increase levels off when a saturation threshold is attained. This relation was described as a functional response of the predator to its prey (**Solomon**, 1949). The 3 types of response curves were introduced by **Holling** (1959) and graphically compared by **Huffaker et al.** (1968).

The phenomenon is important in evaluating the efficiency of a predator in biological control, despite the limitations rightly mentioned by **Murdoch** (1973). We checked the functional response in a coccinellid intended for use in glasshouses to control aphids.

METHODS

Cheilomenes sulphurea (Ol.) was imported from Angola, Africa, to the Laboratoire E. Bi-liotti, Station de Zoologie et de Lutte Biologique, I.N.R.A., Antibes-Valbonne, France. We are very much obliged to G. **Iperti** of this laboratory for allowing us to use his strain of *C. sulphurea* in our experiments.

⁽¹⁾ The experiments were performed when the 2nd author worked as a participant in a UNESCO course at the Czechoslovak Academy of Sciences, Prague.

Murdoch (1973) rightly criticized that only a short time of a predator's life is covered by most experiments and that too simple and small environments are used as experimental arenas. We therefore observed the predators for 10 consecutive days and repeated the experiments in arenas of different search surfaces and complexity. The total experimental time was similar to that used in a recent study on functional response in *Phytoseiidae* where the numbers of killed prey were recorded for 5 days at low prey densities and for 10 days at high prey densities (Eveleigh & Chant, 1981). Only 4 beetles were used with each prey density because of limited possibilities of aphid production. This is not much different from similar studies: 5 individuals of the predatory mite *Pergamasus crassipes* (L.) were used by Longstaff (1980). Sinha *et al.* (1982) repeated the experiment 10 times with a single starved larva of *Coccinella septempunctata* L..

Four series of experiments were conducted in arenas of 3 sizes (table 1), in a room with controlled temperature (exp. C and RH: $25 \pm 2^\circ/\text{day}$, $23 \pm 1^\circ/\text{night}$; Exp. A and B: $27 \pm 2^\circ/\text{day}$, $24 \pm 1^\circ/\text{night}$) and photoperiod (16 L : 8 D). The internal surface area was increased by folded paper sheets and 1, 2 and 4 bean seedlings (*Vicia faba* L.). Only male coccinellids ($n = 4$ to 6) were used to avoid variations in food intake caused by oogenesis and oviposition. The beetles were not starved before the beginning of the experiment. Adult apterous *Aphis fabae* Scopoli females were used as prey. One male was introduced to each container with a counted number of aphids on bean seedlings. The beetle was transferred to another container after 24 h. The living or naturally dead aphids were counted and the number subtracted from the provided amount; thus the actual number of consumed aphids was determined. While in exp. A, B, C, RHa the relative humidity was not modified (55 - 80 %) it was artificially increased to 100 % (or almost 100 %) with a large piece of moistened cotton in exp. RHb.

The results were evaluated by 2-way analysis of variance and by non-linear regression analysis (see Sokal & Rohlf, 1981).

TABLE 1

Experimental conditions

Exp.	Container	Searched area (sq. cm)	Temperature ($^\circ\text{C}$)	Relative humidity (%)	Bean seedlings (n)	Cover	Age of beetles (days)	n (c)
RH $\frac{a}{b}$	round glass container	2973 (a)	day 27 ± 2	55-80	4	nylon cloth partially glass	12-15	6
	20 x 20 cm		night 24 ± 1	100	4			6
A	20 x 20 cm			55-80	4			4
B	round glass container 9.5 x 8.5 cm	476 (a)	day 25 ± 2	55-80	2			4-5
C	Petri dish 10 x 1.5 cm	210 (b)	night 23 ± 1	55-80	1	Petri dish	4-6	4

(a) paper and plants included; (b) plant included; (c) repeated per 10 days.

RESULTS

When the impact of prey density and arena size on the food intake are assessed by the 2-way analysis of variance, the effect of prey density is much more important ($F = 7.21$, $p < 0.005$) than the effect of arena size ($F = 3.61$, $p < 0.05$). A similar analysis indicated that the effect of prey density was significant ($F = 4.14$, $p < 0.05$) while the effect of air moisture was not significant ($F = 1.12$, $p \leq 0.25$).

Also a simple tabular comparison of the mean voracity in individual experiments shows that the prey consumption slightly increased with the rise in prey density - with the only exception of the [A 80] replicate (table 2). In the largest exposure arena, a significant difference between replicates 40 and 80 was found neither in exp. A nor in exp. RHa. A small decrease in food intake was produced by high relative humidity in the replicate with 40 aphids, but not with 80 aphids.

TABLE 2

Number of aphids (apterous females of Aphis fabae) consumed by Cheilomenes sulphurea males at various prey densities

Exp.	Searched area (sq. cm)	Aphids offered per day			
		40	80	120	
		Daily prey consumption			
RH $\frac{a}{b^{(1)}}$	2973	average	20.9	22.5	
		range	(19.6 - 23.0)	(18.9 - 26.6)	
		%	52.2	28.2	
		average	18.1	22.3	
		range	(16.4 - 19.6)	(20.3 - 24.1)	
		%	45.3	27.8	
A	2973	average	22.5	21.7	27.8
		range	(22.1 - 23.0)	(16.8 - 25.6)	(22.0 - 32.8)
		%	56.3	27.2	23.2
B	476	average	19.3	24.5	28.3
		range	(14.3 - 23.7)	(22.5 - 24.9)	(25.9 - 31.6)
		%	48.3	30.6	21.5
C	210	average	24.7	29.2	30.2
		range	(23.2 - 27.4)	(23.1 - 38.9)	(20.1 - 35.3)
		%	61.8	36.5	25.2

1) Relative humidity in exp. RH b was 100 %.

FUNCTIONAL RESPONSE

Holling's type II response equation (Holling, 1959) was used for the assessment of functional response :

$$N_a = aN / (1 + aT_hN)$$

Here, N_a is the number of prey eaten per predator per day ; a is the instantaneous attack rate ; T_h is the "handling time" associated with each prey eaten, and N is the density of prey. The fitting of data by non-linear regression analysis is presented in figure 1. The decrease in the instantaneous attack rate, a , with the increase in prey density (smaller arenas) is in keeping with some results presented by Hassell *et al.* (1977, fig. 6) for high prey densities.

DISCUSSION

In a small experimental area which is optimal for an easy search the consumption of prey equals or almost equals that offered, and thus the numbers of captured prey do not indicate the searching efficiency of the predator. We have therefore used only the higher population densities of prey, chosen according to the previously ascertained voracity of *C. sulphurea* adults (Okrouhla, 1983).

Also at high densities of prey, used in our experiments, the dependence of the increase in captured prey on the increase in prey densities was significant at the level of $p < 0.005$ ascertained by means of the F-test. Evidently, our data are near to the satiation threshold where the functional response curves of type II and III resemble each other. Our results thus do not contribute much to the recent intensive discussion of the occurrence of the sigmoid type of functional response in entomophagous insect predators (Hassell *et al.*, 1977 ; Takafuji & Deguchi, 1980 ; Collins *et al.*, 1981 ; Eveleigh & Chant, 1981 ; Sinha *et al.*, 1982). The shape of the decrease in the proportion of captured prey (fig. 2) indicates that the functional response found might be close to type II. However, the predator was confined with its prey in our experiments ; such experimental design produced the functional response of type II in *Aphelinus thomsoni* Graham which otherwise exhibited type III when the predator was free to leave at any time (Collins *et al.*, 1981).

Our principal aim was to check the searching capacity at different aphid densities of a coccinellid which is likely to be used in aphid pest management in glasshouses. Curve A (fig. 1) markedly differs by its steepness from curves B and C ; high prey consumption even at very low aphid densities thus indicates a very high searching efficiency. Also the only slight difference between the small and large arenas in the proportion of captured prey demonstrated a rather high searching efficiency of *C. sulphurea* males.

The response of coccinellids to aphid density has hitherto been studied only in larvae of 3 species : *Harmonia axyridis* Pallas (Mogi, 1969), *Propylea japonica* (Thunberg) (Kawauchi, 1979) and *C. septempunctata* (Sinha *et al.*, 1982). The results indicate type II functional response in all 3 cases.

However, Hassell *et al.* (1977) reported an example of type III functional response for *C. septempunctata*, based on Cock's unpublished data. The prey they used, *Brevicoryne brassicae* (L.) was not very suitable.

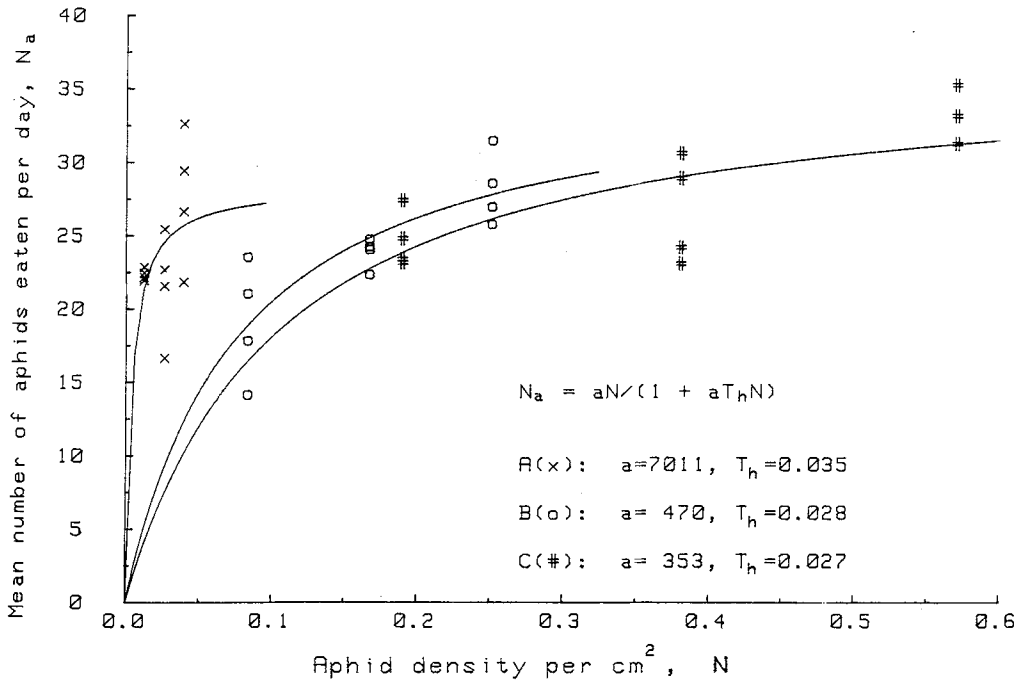


Fig. 1. Functional response of *Cheilomenes sulphurea* preying on *Aphis fabae* with curves of the best fit for Holling's disc equation. A (x) - 2973 cm² arena, B (o) - 476 cm² arena, C (#) - 210 cm² arena. Parameter a is the instantaneous attack rate and T_h is the handling time associated with each prey item eaten.

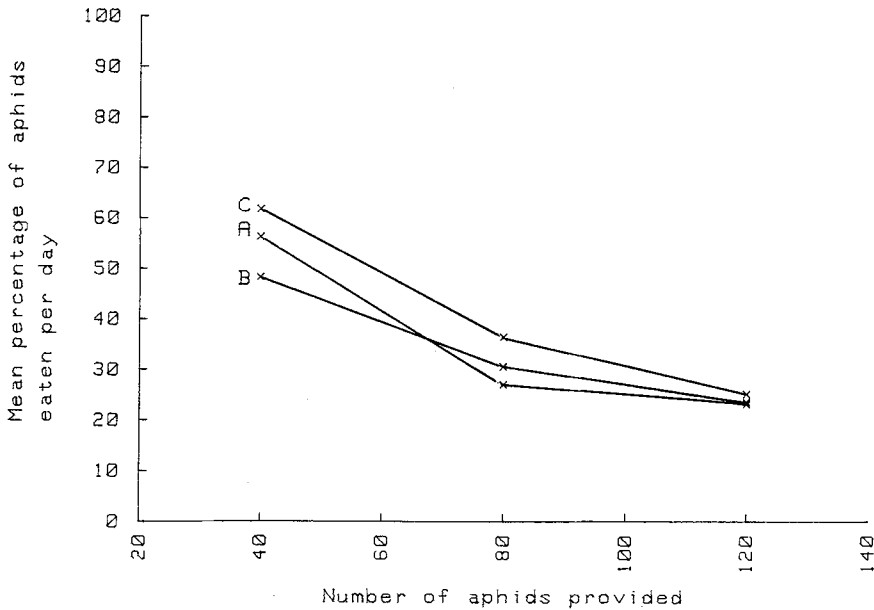


Fig. 2. The dependence of the mean percentage of aphids eaten per day on the number of aphids provided in 3 arenas of different sizes (see fig. 1).

RÉSUMÉ

Effet de la densité en proies sur l'alimentation de l'imago de *Cheilomenes sulphurea*
[Col. : Coccinellidae]

La consommation de proie par les mâles de *Cheilomenes sulphurea* (Ol.) est étudiée dans 3 types d'enceintes dont l'espace expérimental est de 210, 476 et 2973 cm², avec 3 densités de proie offerte chaque jour : 40, 80 et 120 individus du puceron *Aphis fabae*, Scopoli.

La quantité de proies a modifié la consommation de manière plus importante que la taille de l'espace expérimental utilisé. Les mâles de *C. sulphurea* ont démontré ainsi une capacité à trouver la proie très élevée. Les niveaux de densité de proie sont évidemment près du seuil de saturation définis dans les courbes II et III de la réaction fonctionnelle de Holling.

REFERENCES

- Collins, M.D., Ward, S.A. & Dixon, A.F.G. — 1981. Handling time and the functional response of *Aphelinus thomsoni*, a predator and parasite of the aphid *Drepanosiphum platanoides*. — *J. Anim. Ecol.*, 50, 479-487.
- Eveleigh, E.S. & Chant, D.A. — 1981. Experimental studies on acarine predator - prey interactions : effects of predator age and feeding history on prey consumption and the functional response [Acarina : Phytoseiidae]. — *Can. J. Zool.*, 59, 1387-1406.
- Hassell, M.P., Lawton, J.H. & Beddington, J.R. — 1977. Sigmoid functional responses by invertebrate predators and parasitoids. — *J. Anim. Ecol.*, 46, 249-262.
- Holling, C.S. — 1959. The components of predation as revealed by a study of small mammal predation of the European pine sawfly. — *Can. Entomol.*, 91, 293-320.
- Huffaker, C.B., Kennett, C.E., Matsumoto, B. & White, E.G. — 1968. Some parameters in the role of enemies in the natural control of insect abundance. In : *Insect Abundance* (Southwood T.R.E. ed.). — *Blackwell*, Oxford, 59-75.
- Kawauchi, S. — 1979. Effect of prey density on the rate of prey consumption, development and survival of *Propylea japonica* Thunberg [Coleoptera : Coccinellidae]. — *Kontyû*, 47, 204-212.
- Longstaff, B.C. — 1980. The functional response of a predatory mite and the nature of the attack rate. — *Austral. J. Ecol.*, 5, 151-158.
- Mogi, M. — 1969. Predation response of the larvae of *Harmonia axyridis* Pallas [Coccinellidae] to the different prey density. — *Jap. J. Appl. Entomol. Zool.*, 13, 9-16.
- Murdoch, W.W. — 1983. The functional response of predators. — *J. Appl. Ecol.*, 10, 335-342.
- Okrouhla, M. — 1983. Potravne-ekologická studie slunéčka *Cheilomenes sulphurea*. — *C.Sc. Thesis, Inst. Entomol., Czechoslovak Academy of Sciences*, Praha.
- Sinha, T.B., Pandey, R.K., Singh, R., Tripathi, C.P.M. & Kumar, A. — 1982. The functional response of *Coccinella septempunctata* Linn., a coccinellid predator of mustard aphid, *Lipaphis erysimi* Kalt. — *Entomon*, 7, 7-10.
- Sokal, R.R. & Rohlf, F.J. — 1969. Biometry. — *W.H. Freeman & Co.*, San Francisco, 776 pp.
- Solomon, M.E. — 1949. The natural control of animal populations. — *J. Anim. Ecol.*, 18, 1-35.
- Takafuji, A. & Deguchi, K. — 1980. Functional responses of a predacious Phytoseiid mite in different sizes of experimental universe. — *Appl. Entomol. Zool.*, 15, 355-357.