

Prey-predator relationship between *Lipaphis erysimi* Kalt. (Hom., Aphididae) and *Coccinella septempunctata* L. (Col., Coccinellidae). II. Effect of host plants on the functional response of the predator

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Abstract: The present paper examines the effect of the host plants *Brassica oleracea*, *Raphanus sativus* and *Brassica campestris* on which *Lipaphis erysimi* was reared, on the functional response of the grub of *Coccinella septempunctata*. The functional response of the grub of *C. septempunctata* is of type II. The amount of prey consumption increases significantly with the increase of prey density and is maximum in *B. oleracea*-reared aphids, followed by those reared on *R. sativus* and *B. campestris*. The percentage prey consumption declined throughout. This decrease was a maximum for aphids reared on *B. campestris* followed by *R. sativus*- and *B. oleracea*-reared aphids. Analysis of variance also confirmed that the number and percentage prey consumption was significantly influenced between the three host plants and between 12 prey densities. Results show that *C. septempunctata* has a greater liking for aphids reared on *B. oleracea* rather than those reared on the other plants that were tested.

1 Introduction

Lipaphis erysimi Kalt. is the most damaging pest of a major oil-seed crop *Brassica campestris*. *Coccinella septempunctata* has been reported to be an effective biocontrol agent against *L. erysimi* (SINHA et al., 1982; PANDEY et al., 1984). The grubs of *C. septempunctata* are voracious feeders and consume more aphids than the adults (ANTHONY et al., 1993; HENRIK and EKBOM, 1994; PHOOFULO and OBRYCKI, 1995) and play an important role in decimating the prey population.

A predator can respond in many ways to changes in the density of its prey. One of the most widely investigated responses has been the consumer's 'functional response' (SOLOMON, 1949), which is a short-term behavioural phenomenon defined in terms of the relationship between the number of prey consumed per predator and the prey density (SHIPP and WHITFIELD, 1991; WIEDENMANN and SMITH, 1993; FAN and PETITT, 1994). HOLLING (1959, 1966) proposed three types of functional response (fig. 1): type I, a linear rise to a plateau; type II, a curvilinear rise to a plateau; and type III, a sigmoid curve rising to a plateau. A type II response is normally exhibited by arthropod predators but this type of response has also been observed in entomophagous invertebrates (HOFSVANG and HAGVAR, 1983).

Differences in the quality of host plants and the texture of their leaves have been reported to influence the consumption rate of the predators (WOETS and VAN LENTEREN, 1976; ZHU and HIGGINS, 1994; GIROUX et al., 1995), but little information is available on the role of host plants and their impact on the predation rate

of predators (KUMAR and TRIPATHI, 1987; KUMAR et al., 1988). The present study aimed to investigate this further.

2 Materials and methods

The aphid *L. erysimi* and the predator, *C. septempunctata* were reared in the laboratory on the fresh foliage of *B. campestris* (host plant) at $27 \pm 4^\circ\text{C}$ and $75 \pm 12\%$ RH by adopting the technique of WHEELER (1923) and SINGH and MALHOTRA (1979), respectively. Laboratory-cultured nymphs of the aphids reared on *B. campestris* were transferred to potted plants of *Raphanus sativus* and *Brassica oleracea* for rearing. Third instar nymphs [the stage most preferred by the predators (SINHA et al., 1982)] were drawn from the maintained culture and were utilized as prey. Third instar grubs of *C. septempunctata* that had been starved for 24 h were used as predators in the experiment.

All the experiments were performed in Petri dishes (15×2 cm) with moistened filter paper on their bottoms. Counted numbers of aphids (*L. erysimi*) reared on *B. campestris* were kept on fresh and tender *B. campestris* leaves which was then placed over the filter paper. The aphids were then allowed to settle down. The functional response was observed at varying prey densities, namely 2, 5, 10, 20, 40, 80, 100, 200, 400, 600, 800 and 1000 aphids. One 24-h-starved predator was introduced into each Petri dish for 24 h. After 24 h the predators were withdrawn from each Petri dish and the unconsumed aphids left over in the Petri dishes were counted and the total used to calculate the number consumed. The same experiment was repeated using the aphids that had been reared on *B. oleracea* and *R. sativus*. All the experiments were replicated 10 times with fresh hosts and new 24-h-starved predators and the data obtained were analysed statistically.

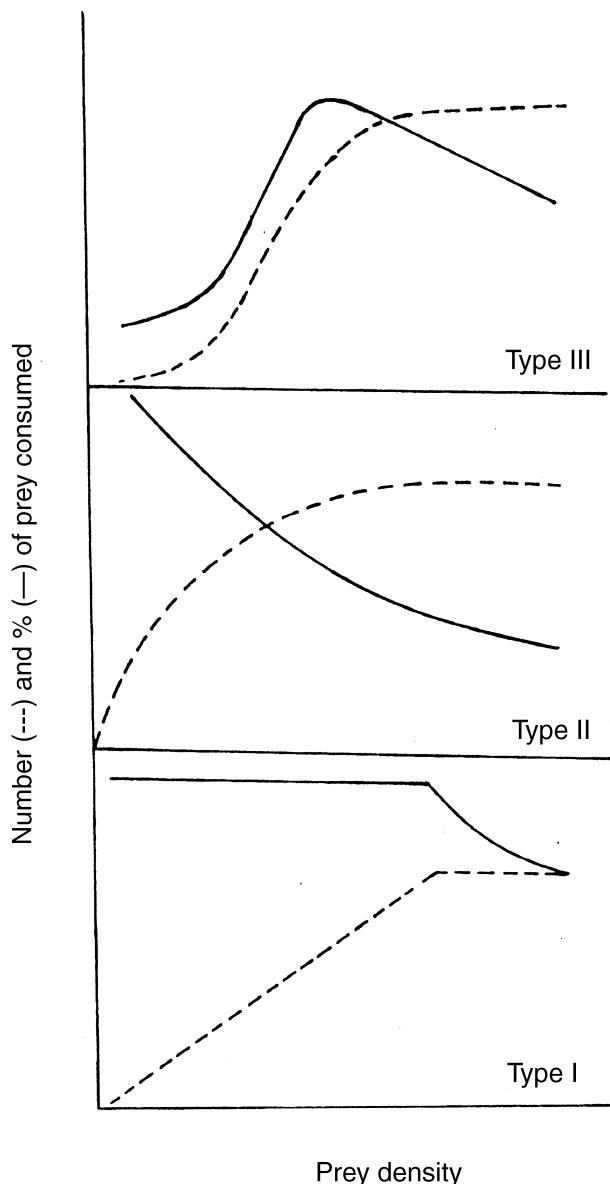


Fig. 1. Three types of functional responses suggested by HOLLING (1959). For each type the number and percentage per unit time by a single predator is graphed against prey density

3 Results

As the prey density increased the number of prey consumed by the predator increased significantly for aphids reared on all three selected host plants (figs 2, 4), whereas the percentage of prey consumed decreased (figs. 3, 5). The functional response of the grub of *C. septempunctata* for aphids reared on all three selected host plants was of type II of HOLLING (1959) and can be explained by a linear relationship between the log of number of prey consumed and log of initial number of prey (fig. 4), and between the percentage prey consumed and the log of initial number of prey (fig. 5). As the prey density increased the amount of prey consumed by the predator increased significantly and was a maximum for aphids reared on *B. oleracea*, followed those reared on *R. sativus* and *B. campestris* (fig. 4). The percentage

prey consumption decreased with the increase of prey density for aphids reared on all the three tested host plants.

This decrease was a maximum for aphids reared on *B. campestris*, followed by those reared on *R. sativus* and *B. oleracea* (fig. 5). Initially the number of prey consumption increased (figs 2, 4), whereas the percentage prey consumption decreased (figs 3, 5) until the number of prey had increased to 600, thereafter the number of prey consumed tend to level, whereas, the percentage of prey consumed declined throughout. This was common for aphids reared on all three selected host plants. For aphids reared on *B. oleracea* the grub consumed 100% prey at a density of 10 and only 34.64% at a prey density of 1000, whereas for aphids reared on *R. sativus* and *B. campestris* the grub consumed 91 and 86% prey at a density of 10, and 28.67 and 26.91%, respectively, at a prey density of 1000. Analysis of variance shows that the number (table 1) and percentage (table 2) of prey consumed by the predator was significantly influenced between the three selected host plants and between 12 prey densities.

4 Discussion

The functional response is one of the most important aspects in the dynamics of predator-prey interaction (HASSELL, 1978; BERRYMAN, 1992). It has been used to infer the basic mechanisms underlying the interactions of predator-prey behaviour, to enhance practical predictive powers for biological control, and even to clarify co-evolutionary relationship (FAN and PETITT, 1994). The grub of *C. septempunctata* is unable to detect its prey either by vision or by olfaction (MCCONNELL and KRING, 1990) and the search is random (HEIMPEL, 1991; HEIMPEL and HOUGH-GOLDSTEIN, 1994). The probability of contact with the prey at higher density would tend to increase per unit area. The functional response of *C. septempunctata* resembles type II as defined by HOLLING (1959) which is considered to be a typical functional response and is characterized by a predation rate that increases at a decreasing level with increasing prey density until a plateau is reached (WIEDENMANN and O'NEIL, 1991; HEIMPEL and HOUGH-GOLDSTEIN, 1994).

The number of prey attacked by *C. septempunctata* was significantly influenced by the host plants and prey abundance. *Coccinella septempunctata* consumed the greatest proportion of prey reared on *B. oleracea* followed by *R. sativus* and *B. campestris*. The interaction between the plant species and prey abundance indicates that the response of the predator was significantly influenced by the host plants (BLODGETT and HIGGINS, 1988; CARRELL et al., 1993). Further, as *C. septempunctata* has a greater liking for aphids reared on *B. oleracea* rather than the other two host plants tested, the predator *C. septempunctata* should be reared on *B. oleracea*-reared aphids.

The differences in the amount of predation in aphids reared on different host plants might be due to the presence of volatile or contact chemicals (allomones) in varying quantities on the host plants; the kairomones

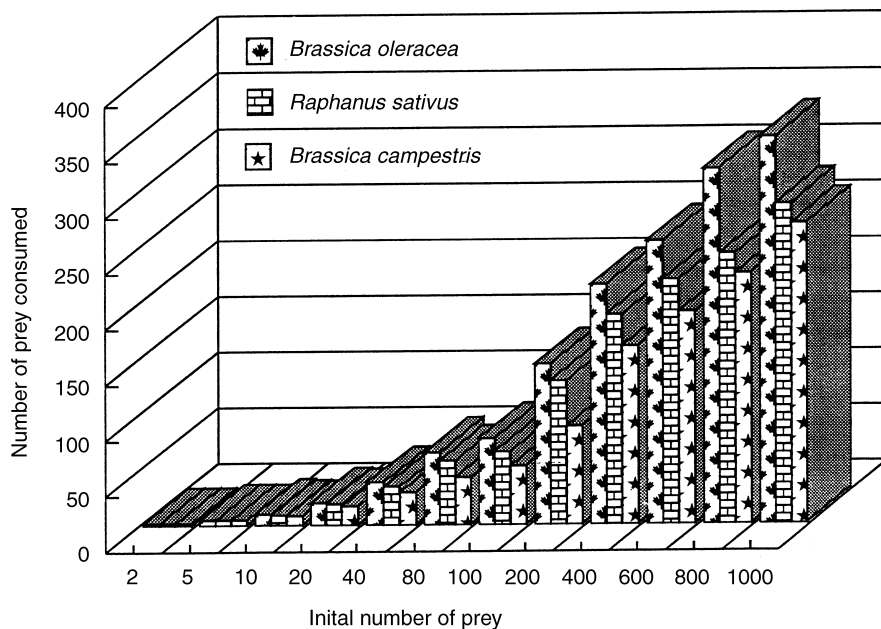


Fig. 2. Relationship between the initial number of *L. erysimi* on the average consumption caused by the individual *C. septempunctata* reared on different host plants

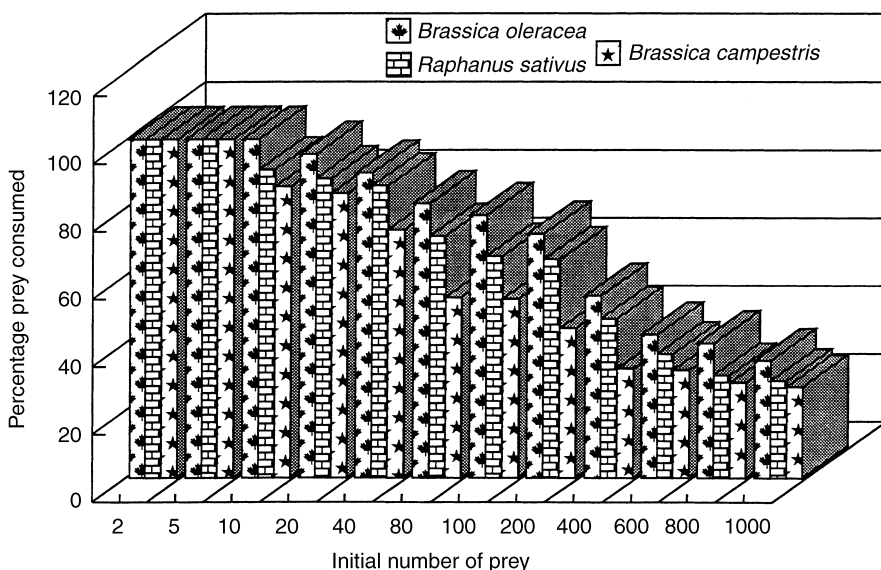


Fig. 3. Relationship between the initial number of *L. erysimi* on the percentage consumption caused by the individual *C. septempunctata* reared on different host plants

of the prey with varying attractive potentials for the predators (TAMAKI et al., 1981; ELZEN et al., 1983); quality and quantity of honey dew excreted by the aphid prey (KUMAR and TRIPATHI, 1988); haemolymph of the aphids reared on the tested host plants and the texture of their leaves (WOETS and LENTEREN, 1976; MILLER and PAUSTIAN, 1992; GIROUX et al., 1995). The leaf surfaces of host plants are covered with hairs (SIDDIQUI et al., 1998) which may obstruct the movement of the predator resulting in lesser consumption of prey in *R. sativus*- and *B. campestris*-reared aphids rather than *B. oleracea*-reared aphids.

The results discussed so far reveal that the functional response of *C. septempunctata* resembles the type II of HOLLING (1959) which is considered to be a typical

functional response that reflects the suitability of the predator, *C. septempunctata* as a potential biocontrol agent against the prey *L. erysimi*. Furthermore, the aphids should be reared using *B. oleracea* as the host plant rather than other two tested host plants because *C. septempunctata* has a greater liking for aphids reared on *B. oleracea*. However, during the off season *R. sativus* can be used as an alternative host plant.

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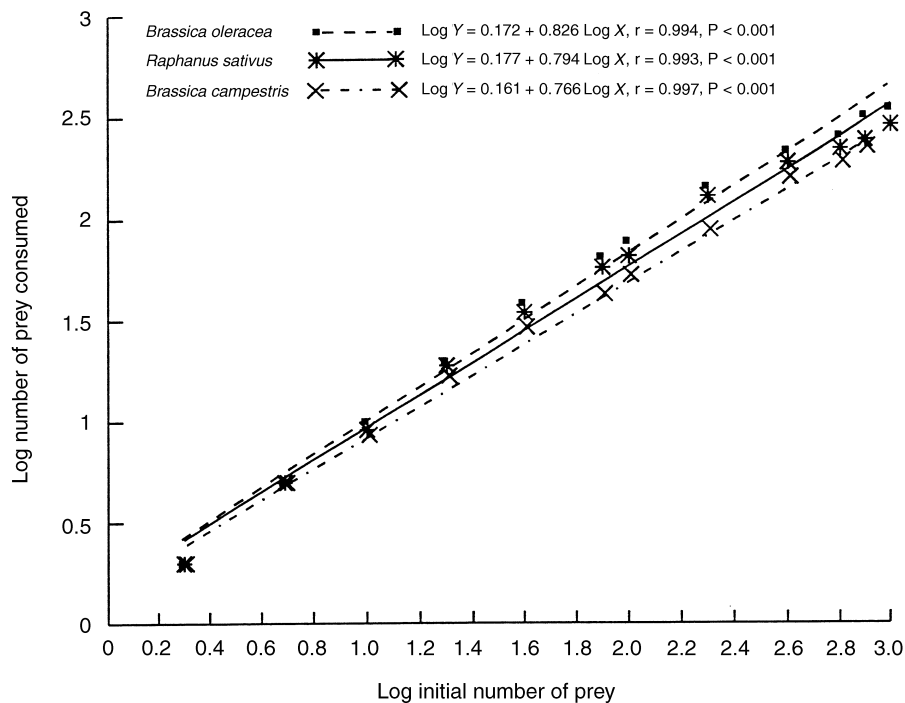


Fig. 4. Relationship between log of initial number of *L. erysimi* and the log of their consumption caused by *C. septempunctata* reared on different host plants

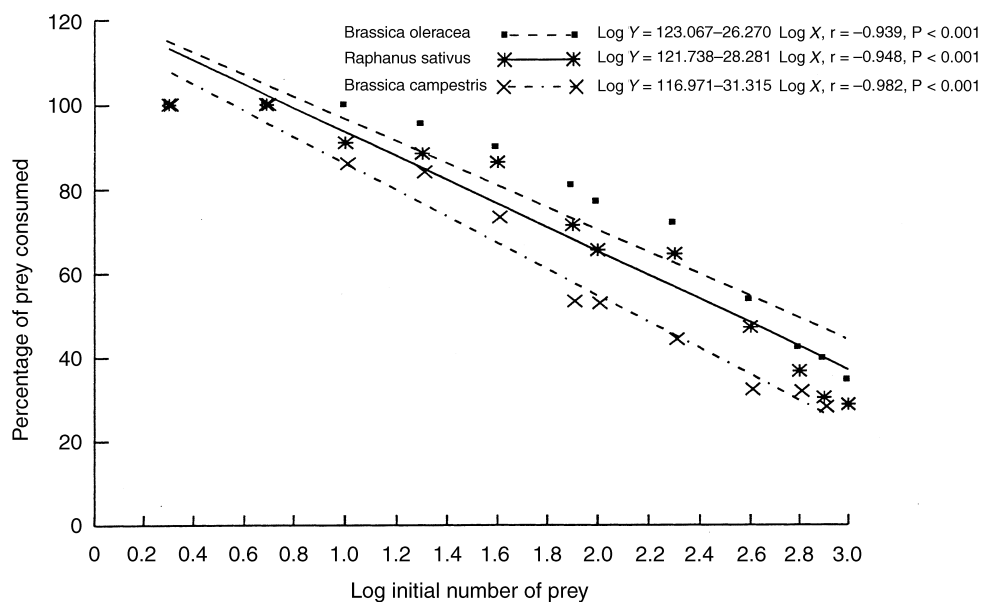


Fig. 5. Relationship between log of initial number of *L. erysimi* and their percentage consumption caused by *C. septempunctata* reared on different host plants

Table 1. Summary of Computation for Analysis of Variance of number of prey (*L. erysimi*) consumed by predator *C. septempunctata*

Source of variation	d.f.	Sum of squares	Mean squares	F-Value	P
Between 3 host plants*	2	7969.021	3984.510	11.015	0.001
Between 12 prey density	11	388649.181	35331.744	97.678	0.001
Total interactions	22	7957.759	361.716		
Total	35	404575.961	11559.313		

**Brassica oleracea*, *Raphanus sativus*, *Brassica campestris*.

Table 2. Summary of Computation for Analysis of Variance of per cent prey (*L. erysimi*) consumed by predator *C. septempunctata*

Source of variation	d.f.	Sum of squares	Mean squares	F-Value	P
Between 3 host plants*	2	1500.672	750.336	17.646	0.001
Between 12 prey density	11	22978.586	2088.962	49.127	0.001
Total interactions	22	935.478	42.521		
Total	35	25414.736	726.135		

**Brassica oleracea*, *Raphanus sativus*, *Brassica campestris*.

References

- ANTHONY, R. I.; KAREIVA, P.; PERRY, R., 1993: Response of a predator to variation in prey density at three hierarchical scales: lady beetles feeding on aphids. *Ecology* **74**, 1929–1939.
- BERRYMAN, A. A., 1992: The origins and evolution of predator-prey theory. *Ecology* **73**, 1530–1535.
- BLODGETT, S. L.; HIGGINS, R. A., 1988: Blister beetles (Coleoptera: Meloidae) in Kansas: historical perspective and results of an intensive alfalfa survey. *J. Econ. Entomol.* **81**, 1456–1462.
- CARRELL, J. E.; MCCAIREL, M. H.; SLAGLE, A. J.; DOOM, J. P.; BRILL, J.; MCCORMICK, J. P., 1993: Cantharidin production in a Blister beetle. *Experientia* **49**, 171–174.
- ELZEN, G. W.; WILLIAMS, H. J.; VINSON, S. B., 1983: Response by the parasitoid *Campoletis sonorensis* (Hymenoptera: Ichneumonidae) to chemicals (Synomones) in plants: implications for host-habitat location. *Environ. Entomol.* **12**, 1873–1877.
- FAN, Y.; PETITT, F. L., 1994: Parameter estimation of the functional response. *Environ. Entomol.* **23**, 785–794.
- GIROUX, S.; DUCHESNE, R. M.; CODERRE, D., 1995: Predation of *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) by *Coleomegilla maculata* (Coleoptera: Coccinellidae): comparative effectiveness of predator developmental stages and effect of temperature. *Environ. Entomol.* **24**, 748–754.
- HASSELL, M. P., 1978: The Dynamics of Arthropod Predator Prey System. Princeton, NJ: Princeton University Press.
- HEIMPEL, G. E., 1991: Searching behaviour and functional response of *Perillus bioculatus*, a predator of the Colorado potato beetle. M. S. Thesis. New York: University of Delaware.
- HEIMPEL, G. E.; HOUGH-GOLDSTEIN, J. A., 1994: Components of the functional response of *Perillus bioculatus* (Hemiptera: Pentatomidae). *Environ. Entomol.* **23**, 855–859.
- HENRIK, W.; EKBOM, B., 1994: Influence of hunger level and prey densities on movement patterns in three species of *Pterostichus* beetles (Coleoptera: Carabidae). *Environ. Entomol.* **23**, 1171–1181.
- HOFVANG, T.; HAGVAR, E. B., 1983: Functional responses to prey density of *Ephedrus cerasicola* (Hymenoptera: Aphididae), an aphidiid parasitoid of *Myzus persicae* (Homoptera: Aphididae). *Entomophaga* **28**, 317–324.
- HOLLING, C. S., 1959: Some characteristics of simple types of predation and parasitism. *Can. Ent.* **91**, 385–398.
- HOLLING, C. S., 1966: The functional response of invertebrate predators to prey density. *Mem. Ent. Soc. Can.* **48**, 1–86.
- KUMAR, A.; TRIPATHI, C. P. M., 1987: Parasitoid–host relationship between *Trioxyys (Binodoxys) indicus* Subba Rao & Sharma (Hymenoptera: Aphidiidae) and *Aphis craccivora* Koch (Hemiptera: Aphididae). IV. Effect of host plants on the sex ratio of the parasitoid. *Entomon* **12**, 95–99.
- KUMAR, A.; TRIPATHI, C. P. M., 1988: Parasitoid–host relationship between *Trioxyys (Binodoxys) indicus* Subba Rao & Sharma (Hymenoptera: Aphidiidae) and *Aphis craccivora* Koch. (Hemiptera: Aphididae). V. Allomones and kairomones involved in the parasitoid–host-plant interaction. *Mitt. Zool. Mus. Berl.* **64**, 331–337.
- KUMAR, A.; SHANKER, S.; PANDEY, K. P.; SINHA, T. B.; TRIPATHI, C. P. M., 1988: Parasitoid–host relationship between *Trioxyys (Binodoxys) indicus* Subba Rao & Sharma (Hymenoptera: Aphidiidae) and *Aphis craccivora* Koch. (Hemiptera: Aphididae). VI. Impact of males on the number of progeny of the parasitoid reared on certain host plants. *Entomophaga* **33**, 17–23.
- MCCONNELL, J. A.; KRING, T. J., 1990: Predation and dislodgment of *Schizaphis graminum* (Homoptera: Aphididae), by adult *Coccinella septempunctata* (Coleoptera: Coccinellidae). *Environ. Entomol.* **19**, 1798–1802.
- MILLER, J. C.; PAUSTIAN, J. W., 1992: Temperature-dependent development of *Eriopsis connexa* (Coleoptera: Coccinellidae). *Environ. Entomol.* **21**, 197–201.
- PANDEY, K. P.; KUMAR, A.; SINGH, R.; SHANKER, S.; TRIPATHI, C. P. M., 1984: Numerical response and area of discovery of a predator, *Coccinella septempunctata* L. *Z. ang. Ent.* **97**, 418–423.
- PHOOFOLO, M. W.; OBRYCKI, J. J., 1995: Comparative life history studies of Neartic and Palearctic populations of *Coccinella septempunctata* (Coleoptera: Coccinellidae). *Environ. Entomol.* **24**, 581–587.
- SHIPP, J. L.; WHITFIELD, G. H., 1991: Functional response of the predatory mite, *Amblyseius cucumeris* (Acari: Phytoseiidae), on western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae). *Environ. Entomol.* **20**, 694–699.
- SIDDIQUI, A.; KUMAR, A.; KUMAR, N.; TRIPATHI, C. P. M., 1999: Prey–predator relationship between *Lipaphis erysimi* Kalt. (Homoptera: Aphididae) and *Coccinella septempunctata* Linn. (Coleoptera: Coccinellidae). I. Effect of host plants on the searching strategy, mutual interference and killing power of the predator. *Biol. Agric. Hortic.* **17**, 11–17.
- SINGH, R.; MALHOTRA, R. K., 1979: Bionomics of *Coccinella septempunctata* Linn. *Ind. J. Ent.* **41**, 244–249.
- 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.
- SOLOMON, M. E., 1949: The natural control of animal populations. *J. Anim. Ecol.* **18**, 1–35.
- TAMAKI, G.; WEISS, M. A.; LONG, G. E., 1981: Evaluation of plant density and temperature in predator–prey interactions in field cages. *Environ. Entomol.* **10**, 716–720.

- WHEELER, E. W., 1923: Some braconids parasitic on aphids and their life history. *Ann. Ent. Soc. Am.* **16**, 129.
- WIEDENMANN, R. N.; O'NEIL, R. J., 1991: Laboratory measurement of the functional response of *Pediscus maculiventris* (Say) (Heteroptera: Pentatomidae). *Environ. Entomol.* **20**, 610–614.
- WIEDENMANN, R. N.; SMITH, J. W. JR, 1993: Functional response of the parasitic *Cotesia flavipes* (Hymenoptera: Braconidae) at low densities of the host *Diatraea saccharalis* (Lepidoptera: Pyralidae). *Environ. Entomol.* **22**, 849–858.
- WOETS, J.; VAN LENTEREN, J. C., 1976: The parasite–host relationship between *Encarsia formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). VI. The influence of host plant on the green-house white fly and its parasite *Encarsia formosa*. *Progress in integrated control in glasshouses. Bull. S.R.O.P.* **4**, 151–169.
- ZHU, Y. C.; HIGGINS, R. A., 1994: Host plant influences on feeding, survivorship, population, distribution and management of Blister beetles (Coleoptera: Meloidae) in Kansas. *Environ. Entomol.* **23**, 1472–1479.
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