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Comparative Functional and Numeric Response of Two Coccinellids (*Coccinella septempunctata* and *Cheilomenes sexmaculata*) Preying Cowpea Aphid (*Aphis craccivora*)

Gaurang Chhangani, M.K. Mahla, R. Swaminathan, Lekha, H. Swami, N.L. Dangi 10.18805/LR-4697

ABSTRACT

Background: The cowpea aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae), a plant lice known to commonly attack plants that causes loss by sucking sap from phloem and act as vector for viruses. The aphidophagous coccinellids are efficient in controlling the pestiferous population of aphids. The two coccinellid *Coccinella septempunctata* and *Cheilomenes sexmaculata* are efficient in predation of cowpea aphid, *Aphis craccivora* in southern Rajasthan. The present study determined the response of prey consumption at different prey densities.

Methods: To compute the functional and numeric response of the lady bird beetle on cowpea aphid, experiment was conducted *in vitro* by using cowpea potted plant in caged conditions at Department of Entomology, Rajasthan College of Agriculture during 2019-20. The cowpea pea plants were sown in small pots and were placed in aluminium insect cages having 15 cm × 15 cm × 15 cm size. The predatory potential of coccinellid grubs and adults were evaluated at six different prey densities (aphids per arena): 25, 50, 75, 100, 125, 150 and 200 with 5 replications.

Result: The grub and adults of *C. septempunctata* consumed more prey as compared to *C. sexmaculata*. Both the coccinellid showed Type II functional response when functional curve was plotted. The linear regression method suggested that *C. septempunctata* required less time to act upon prey as compared to *C. sexmaculata*. The *C. septempunctata* also showed more numeric response in terms of ECI [conversion efficiency of prey consumption (ECI) into biomass (egg)] at different prey densities. The fecundity in both the cases increased with the increased prey densities that eventually decreased after reaching the maximum egg laying capacity at prey density of 125 aphids. In all the cases it was found that consumption rate of predaceous beetle increased with increasing aphid population.

Key words: ECI, Hollings disc equation, Prey predator relationship, Type II response.

INTRODUCTION

The cowpea aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae), a plant lice known to commonly attack plants from bean family (Minks and Harrewijn, 1987; Sadeghi *et al.,* 2009). It is one of the important pestiferous hemipteran insect that causes loss by sucking sap from phloem (Chhangani *et al.,* 2021). They also act a vector for many viral diseases *via* faba bean necrotic yellow virus, broad bean yellow mosaic virus and bean leaf roll virus (Weigand and Bishara, 1991). The fungus developed on aphids' honeydew secretion also hinders the photosynthesis process, resulting in severe damage to the plant (Klingler *et al*., 2001, Smith and Boyko, 2007). The parthenogenetic development coupled with high fecundity and short generation resulted in increased biotic potential of the pest (Klingler *et al*., 2001), which makes it important to control the enormous population damaging the crop. The fortunate increased awareness towards environmental and human health hazards from chemicals has prevailed upon biological control of the insect pests.

The common predaceous coleopteran coccinellids are most efficient aphidophagous predators for the biological control of the aphids. In nature, they play a maleficent role in controlling the prolific aphid population. They are the most successful and pioneer agent of the biological control with use of Australian ladybird beetle *Rhodolia cardinalis* in California in 1888 against scale insect, devastating Californian citrus industry (Dixon, 2000). Both grubs and adults voraciously feed primarily on aphids and other soft bodied insects, which in turn makes them important key in suppressing the aphid population in field. From India, 57 genera comprising of 261 species of predaceous

Department of Entomology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur-313 001, Rajasthan, India.

Corresponding Author: Gaurang Chhangani, Department of Entomology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur-313 001, Rajasthan, India. Email: gaurangchhangani@gmail.com

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coccinellids have been catalogued (Omkar and Pervez, 2004); out of which 12 genera of aphidophagous coccinellids have been reported from Southern Rajasthan (Jat, 2008). *Coccinella septempunctata* Linnaeus and *Cheilomenes sexmaculata* Fabricius were the relatively more dominant in the different cropping patterns in Udaipur region of Southern Rajasthan (Swaminathan *et al*., 2016)

Bio- ecological studies are pre-requisite for maximum and efficient utilisation of the aphidophagous beetle in the arena of biological control. Predatory potential is the basic factor regulating population dynamics of predator-prey system. Function response curve helps to workout basic mechanism governing their interaction and thus enhance biological control strategies. To emphasis the predator effects into action threshold, it requires the estimation of functional response for predator species. Functional response is estimated by establishing the linear regression relationship between the number of prey consumed per predator and the prey densities (Solomon, 1949). Handling time and attack rate, which infers the foraging efficiency are the key parameters for describing the response curve (Hassell, 1978). The fundamental aspect of the study is to further evaluate and compare the predatory traits of *Coccinella septempunctata* Linnaeus and *Cheilomenes sexmaculata* Fabricius under insitu condition through assessment of: (i) Functional response of the coccinellids to increasing prey densities (ii) Numeric response of the coccinellids to prey densities.

MATERIALS AND METHODS

Rearing of *Coccinella septempunctata* Linnaeus and *Cheilomenes sexmaculata* Fabricius

The nucleus culture of the aphidophagous coccinellids was maintained under laboratory conditions at Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan for the experiment. The field collected adult predators were brought to the laboratory to maintain a stock culture under ambient conditions of temperature and humidity (25±2°C, 70±5%).

The mating pairs were kept in glass jars (500ml capacity) covered with muslin cloth and fastened with rubber bands. The predators were reared on leaves of cowpea infested with aphids. The eggs laid on cowpea leaves (20) were transferred onto fresh leaves in separate glass jars till the first instar grubs emerge, which were then be provisioned cowpea aphids as food daily. The leaves were changed every two days to maintain succulence for aphid growth. The cowpea pea plants were sown in small pots and were placed in aluminium insect cages having 15 cm × 15 cm × 15 cm size.

Experimental conditions

The predatory potential of coccinellid grubs and adults were evaluated at six different prey densities (aphids per arena): 25, 50, 75, 100, 125, 150 and 200 with 5 replications. Healthy second instar grubs were separated with the help of a camel hair brush after the first moult and transferred on to tender cowpea plants grown in small pots kept under caged condition individually. To evaluate the predation potential, adult coccinellid beetles, were starved for 6h and individually transferred to the pot plants with known numbers of aphid prey at different aphid prey densities. Observations on the consumption of aphids were recorded in each replicate under the different treatments after 24 h. The experiment continued for one week; wherever required, aphids will be replenished. The functional response at different prey densities computed using the linear interpretation of Holling's Equation (Holling, 1959) for the grubs and adult coccinellid beetles; likewise, the numerical response was analyzed for the adult coccinellids by observing the fecundity at different prey densities.

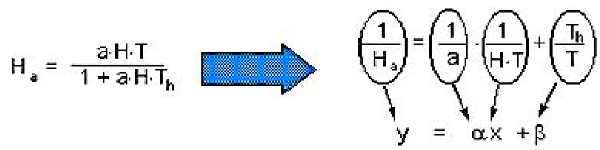
Data analyses

The proportion of prey killed at different densities were plotted to evaluate the type of response curve using logistic regression (by SAS software). As Type I and Type II responses are difficult to distinguish as articulated by most of the researchers (Trexler *et al*. 1988); makes it necessary to determine the functional curve by considering the proportion of prey eaten (N_a/N_o) as a function of prey offered (N_o) (Juliano 2001). Once the functional curve were plotted, coefficients for Type II response were calculated using the linear interpretation of Holling's Equation (Holling, 1959):

$$Ha = \frac{a.H.T}{1 + a.H.T_h}$$

Where,
H = Number of prey consumed.
Ha= Average prey killed.
a= Attack rate.
T= Exposure time for predation and
T_h= Handling time associated with each prey consumed.

After using the above Hollings equation for Type II response, it was subject to linear regression to work out the intercept and slope to estimate time for prey handling and area examined by the predator.



Numeric response was also observed at different prey densities 25, 50, 75, 100, 125, 150 and 200 with 5 replications in a completely randomised design. The equation suggested by Omkar and Pervez (2004) was used to determine the conversion efficiency of prey consumption (ECI) into biomass (egg) at different densities.

$$ECI = \frac{\text{Number of eggs laid}}{\text{Number of prey consumed}} \times 100$$

RESULTS AND DISCUSSION

Functional response of *C. septempunctata* and *Ch. sexmaculata* with respect to their prey, *A. craccivora*

During our study the prey consumption varied with prey densities. The prey consumption by grubs of *C. septempunctata* ranged from 23.71 to 85.17 cowpea aphid (Table 1); whereas, grubs of *Ch. sexmaculata* consumed an average of 20.8 to 71.94 aphids (Table 3). The consumption by adult *C. septempunctata* ranged from 23.02 to 87.82 (Table 2); whereas, for adult *Ch. sexmaculata* it ranged from 20.6 to 71.28 aphids (Table 4). In all the cases the maximum predation was observed at prey density of 150 cowpea aphids per experimental arena. From the observations presented in Tables (1) to (4), it can be inferred that in general cowpea aphid consumption increased with increasing prey densities up to the density of 150 aphids, but the mean consumption, expressed as a per cent value, showed a decreasing rate of increase.

The linear regression trend line showed an intercept of 32.15 with a slope of 0.030 for the adult, while an intercept of 30.54 with a slope of 0.032 for the grubs of *C. septempunctata* (Fig 1 and 3). Similarly, an increasing rate of feeding at decreasing rate was observed for grubs and adults of *C. septempunctata* (Fig 2 and 4). In case of *Ch. sexmaculata*, for the adults the intercept was 35.54 with a slope of 0.034 and for the grubs the intercept was 35.19 having a slope of 0.034 (Fig 5 and 7). The graphs between feeding propensity and prey density for grubs and adults of *Ch. sexmaculata* also showed an increasing trend with prey density (Fig 6 and 8).

The intercept and slope values were used to calculate the handling time for predation and area of predation corresponding to it. The handling time ranged from 5.04 h to 5.71 h, calculated by linear regression method. Adults of *C. septempunctata* required minimum time to act upon their prey (5.04 h) searching an area of 6.99 sq. m.; while, the

Table 1: Functional response at different prey densities computed using the linear interpretation of Holling's equation for grubs of *C. septempunctata*.

Prey density / day (H)	Total prey consumed (Weekly)	Mean prey consumed (Ha)	Inverse mean consumption (1/Ha)	Inverse prey density over time (1/HT)	Feeding (%)
25	118.55	23.71	0.042	0.005714	94.84
50	216.10	43.22	0.023	0.002857	86.44
75	295.25	59.05	0.017	0.001905	78.73
100	342.85	68.57	0.015	0.001429	68.57
125	377.55	75.51	0.013	0.001143	60.41
150	425.85	85.17	0.012	0.000952	56.78
200	369.25	73.85	0.014	0.000714	36.93

Table 2: Functional response at different prey densities computed using the linear interpretation of Holling's equation for adults of *C. septempunctata*.

Prey density / day (H)	Total prey consumed (Weekly)	Mean prey consumed (Ha)	Inverse mean consumption (1/Ha)	Inverse prey density over time (1/HT)	Feeding (%)
25	115.10	23.02	0.0434	0.005714	92.08
50	209.40	41.88	0.0239	0.002857	83.76
75	290.40	58.08	0.0172	0.001905	77.44
100	340.55	68.11	0.0147	0.001429	68.11
125	376.10	75.22	0.0133	0.001143	60.18
150	439.10	87.82	0.0114	0.000952	58.55
200	380.10	76.02	0.0132	0.000714	38.01

Table 3: Functional response at different prey densities computed using the linear interpretation of Holling's equation for grubs of *Ch. sexmaculata*.

Prey density / day (H)	Total prey consumed (Weekly)	Mean prey consumed (Ha)	Inverse mean consumption (1/Ha)	Inverse prey density over time (1/HT)	Feeding (%)
25	104.00	20.80	0.0481	0.005714	83.20
50	197.00	39.40	0.0254	0.002857	78.80
75	258.25	51.65	0.0194	0.001905	68.87
100	316.40	63.28	0.0158	0.001429	63.28
125	341.40	68.28	0.0146	0.001143	54.62
150	359.70	71.94	0.0139	0.000952	47.96
200	352.40	70.48	0.0142	0.000714	35.24

Table 4: Functional response at different prey densities computed using the linear interpretation of Holling's Equation for adults of *Ch. sexmaculata*.

Prey density / day(H)	Total prey consumed (Weekly)	Mean prey consumed (Ha)	Inverse mean consumption (1/Ha)	Inverse prey density over time (1/HT)	Feeding (%)
25	103.00	20.60	0.0485	0.005714	82.40
50	196.25	39.25	0.0255	0.002857	78.50
75	255.10	51.02	0.0196	0.001905	68.03
100	312.85	62.57	0.0160	0.001429	62.57
125	340.25	68.05	0.0147	0.001143	54.44
150	356.40	71.28	0.0140	0.000952	47.52
200	350.85	70.17	0.0143	0.000714	35.09

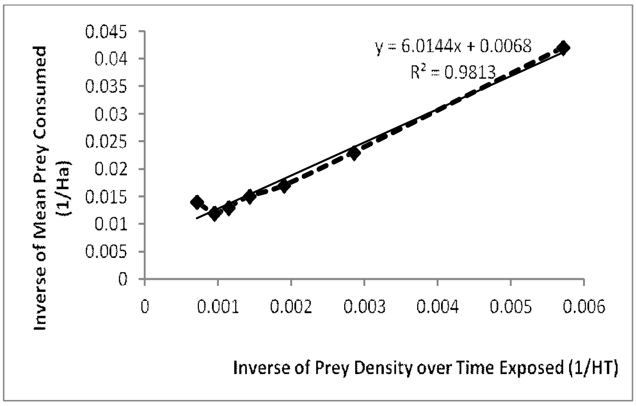


Fig 1: Linear regression of Type-II functional response for predatory *C. septempunctata* grubs on aphid prey.

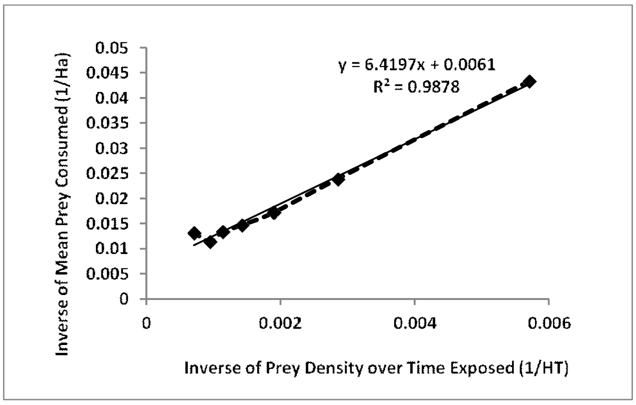


Fig 3: Linear regression of Type-II functional response for predatory *C. septempunctata* adults on aphid prey.

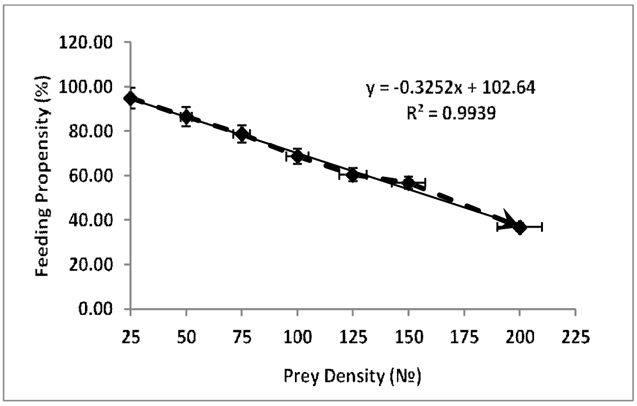


Fig 2: Feeding behaviour of the predatory *C. septempunctata* grubs on aphid prey.

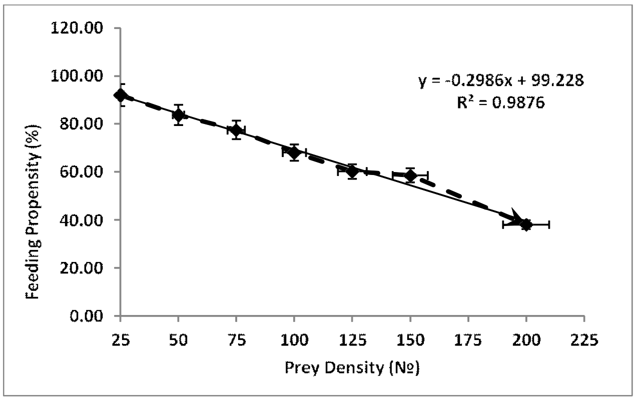


Fig 4: Feeding behaviour of predatory *C. septempunctata* adults on aphid prey.

grubs needed 5.3 h to search an area of 7.36 sq m. The adults and grubs of *Ch. sexmaculata* required somewhat similar time (5.71 h) to search an arena of 6.33 and 6.39 sq m area respectively; however, the time required for consumption happened to be relatively more for *Ch. sexmaculata* in comparison to that for *C. septempunctata*.

Our results with regard to the predator-prey relationship of the adults and grubs of both the coccinellids: *C. septempunctata* and *Ch. sexmaculata*, showed an increasing prey consumption rate by the respective predators reaching a level of satiation at a prey density of 150 aphids per day, where the rising graph levelled between the prey density provided and the mean prey consumed. This typically showed the Type II functional response of predator-prey relationship as explained by Holling (1959).

Omkar and Pervez (2004) observed that prey consumption per predator significantly decreased with an increase in a constant prey density in case of a ladybeetle, *Propylea dissecta*. The decrease in prey consumption per predator was curvilinear when fitted with predator density. Type II functional responses are evidenced by an initial decrease in the proportion of prey eaten with increasing

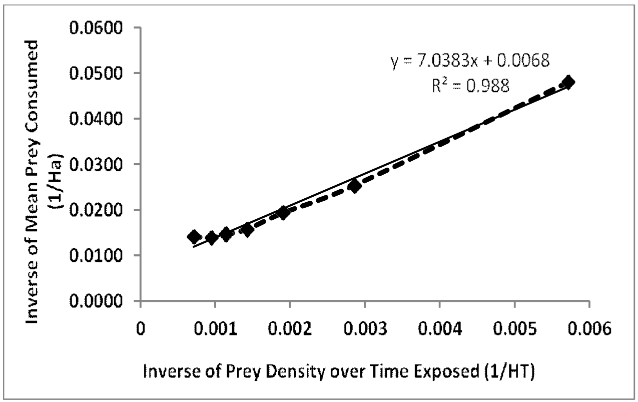


Fig 5: Linear regression of Type- II functional response for predatory *Ch. sexmaculata* grubs on aphid prey.

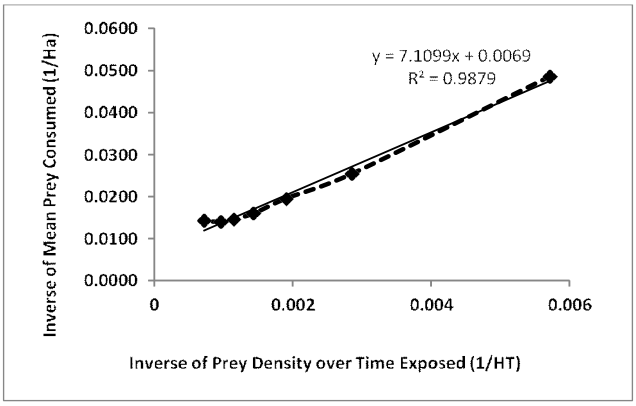


Fig 7: Linear regression of Type- II functional response for predatory *Ch. sexmaculata* adults on aphid prey.

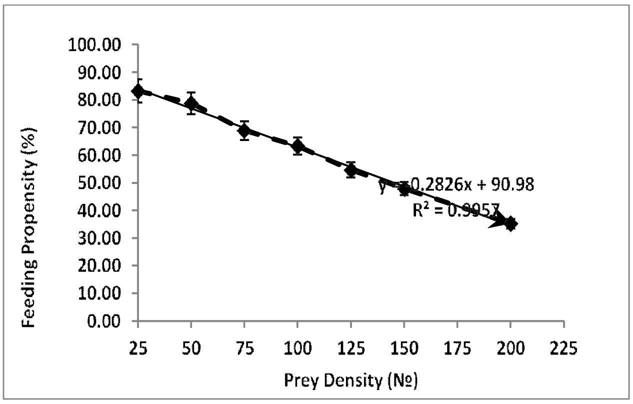


Fig 6: Feeding behaviour of predatory *Ch. sexmaculata* grubs on aphid prey.

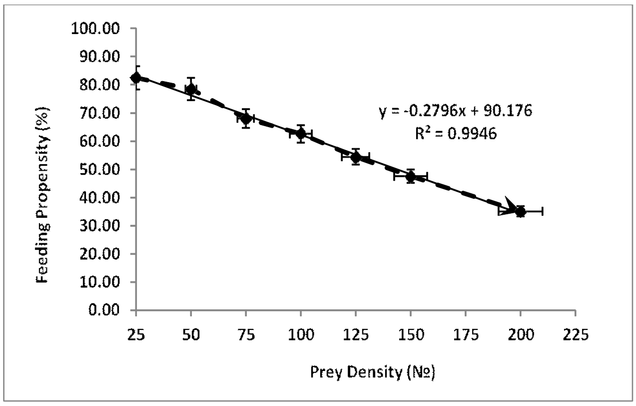


Fig 8: Feeding behaviour of predatory *Ch. sexmaculata* adults on aphid prey.

prey offered (Trexler *et al*., 1988 and Juliano, 1993). Although three types of functional responses described by Holling (1959) may occur in coccinellids (Hodek and Honek, 1996), but it is evident that Type II response is a more common predatory response reported for many coccinellids, such as *Cheilelomenes vicina* Mulsant (Ofuya, 1988), *Scymnus hoffmanni* (Ding-Xin, 1986), *C. septempunctata* (Kumar *et al*., 2001), *S. levaillanti* Mulsant (Uygum and Athhan 2000), *S. creperus* Mulsant (Wells *et al*., 2001), *Harmonia axyridis* (Lee and Kang 2004), *P. dissecta* (Omkar and Pervez, 2004; Pervez and Omkar, 2005), *C. sexmaculata*, *C. transversalis* (Pervez and Omkar, 2005) and *Hippodamia variegata* (Goeze) (Farhadi *et al*., 2010).

Table 5: Numerical response of aphidophagous coccinellids preying at different aphid density.

Prey density / day(H)	Conversion efficiency of prey consumption (%)	
	C. septempunctata	*Ch. sexmaculata*
25	80.00	76.00
50	84.00	78.00
75	86.70	84.00
100	89.00	86.00
125	94.40	92.80
150	84.70	82.00
200	71.50	69.00

Numerical response of *C. septempunctata* and *Ch. sexmaculata* on cowpea aphids

The numerical response in terms of conversion efficiency was observed to be more in case of *C. septempunctata* (71. 5% to 94.4%) as compared to that for *Ch. sexmaculata* (69% to 92.8%). The fecundity in both the cases increased with the increased prey densities that eventually decreased after reaching the maximum egg laying capacity at prey density of 125 aphids (Table 5).

Hodek and Honek (1996) observed a decreased ECI at higher prey densities with a possible suggestion that well-fed females laid large number of eggs, besides investing much in maintenance and metabolic costs. Previous studies explain the efficient fitness of the predator exposed to high prey densities in terms of growth. Besides prey density, other factors such as temporary prey isolation (Evans and Dixon, 1986) and body size (Agarwala and Yasuda, 2000) also influence egg production.

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REFERENCES

Agarwala, B.K. and Yasuda, H. (2000). Competitive ability of ladybird predators of aphids: A review of *Cheilomenes sexmaculata* (Fabr.) (Coleoptera: Coccinellidae) with a worldwide checklist of preys. Journal of Aphidology. 14:1-20.

Ding-Xin, Z. (1986). Studies on predation of the coccinellid beetle, *Scymnus hoffmanni* Weise to cotton aphid, *Aphis gossypii* Glover I. Functional response of *Scymnus hoffmanni* to cotton aphid. Contributions from Shanghai Institute of Entomology. 6: 43-57.

Dixon, A.F.G. (2000). Insect Predator Prey Dynamics, Ladybird Beetles and Biological Control, Cambridge: Cambridge University Press.

Evans, E.W. and Dixon, A.F.G. (1986). Cues for oviposition by ladybird beetles (Coccinellidae): Response to aphids. Journal of Animal Ecology. 55: 1027-1034.

Farhadi, R., Allahyari, H. and Juliano, S.A. (2010). Functional response of larval and adult stages of *Hippodamia variegata* (Coleoptera:Coccinellidae) to different densities of *Aphis fabae* (Hemiptera:Aphididae). Environment Entomology. 39: 1586-1592.

Chhangani, G., Mahla, M.K., Swaminathan, R., Jain, H.K., Ahir, K.C., Sharma, K. (2021). Diversity of insect fauna associated with summer and monsoon cowpea [*Vigna unguiculata* (L.) Walp.]. Legume Research. DOI: 10.18805/LR-4529.

Hassell, M.P. (1978). The Dynamics of Arthropod Predator Prey Systems, Monographs in Population Biology 13. Princeton, NJ: Princeton University Press, 237 pp.

Hodek, I. and Honek, A. (1996). Ecology of Coccinellidae. Dordrecht, Boston, London: Kluwer Academic Publishers, 464.

Holling, C.S. (1959). Some characteristics of simple types of predation and parasitism. The Canadian Entomologist. 91: 385-398.

Jat, G.C., Swaminathan, R, Yadav, P.C, Deshwal, H.L., Dotasara, S.K., Choudhary, S. and Choudhary, H.S. (2008). Effect of natural enemies on the population dynamics of insect-pest of cabbage ecosystem. International Journal of Current Microbiology and Applied Sciences. 6(6): 696-708.

Juliano, S.A. (1993). Nonlinear Curve Fitting: Predation and Functional Response Curves. In: Design and Analysis of Ecological Experiments [S.M. Scheiner, J. Gurevitch, (eds.)]. Chapman and Hall, New York, 432 pp. p. 159-182.

Juliano, S.A. (2001). Non-linear Curve Fitting: Predation and Functional Response Curves. In: Design and Analysis of Ecological Experimentsm, 2nd edition, [(eds) S.M. Scheiner and J. Gurevitch], New York: Chapman and Hall, pp. 178-196.

Klingler, J., Kovalski, I., Silberstein, L., Thompson, G.A. and Perl-Treves, R. (2001). Mapping of cotton-melon aphid resistance in melon. Journal of the American Society Horticultural Sciences. 126: 56-63.

Kumar, A, Kumar, N, Siddiqui, A and Tripathi, C P M. (2001). I. Prey predator relationship between *Lipaphis erysimi* Kalt. (Hemiptera: Aphididae) and *Coccinella septempunctata* L. (Coleoptera: Coccinellidae). II. Effect of host plants on functional response of the predator. Journal of Applied Entomology. 123: 591-601.

Lee, J.H. and Kang, T.J. (2004). Functional response of *Harmonia axyridis* (Coleoptera: Coccinellidae) on *Aphis gossypii* Glover (Homoptera: Aphididae) in the laboratory. Biological Control. 31: 306-310.

Minks, A.K. and Harrewijn, P. (1989). Aphids, their Biology, Natural Enemies and Control. Vol. C. Elsevier Science Publishers B.V. Amsterdam, 322 pp.

Ofuya, T.I. and Akingbohungbe, A.E. (1988). Functional and numerical responses of *Cheilomenes lunata* (Fabricius) (Coleoptera: Coccinellidae) feeding on cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae). Insect Science Application. 9: 543-546.

Omkar and Pervez, A. (2004). Predaceous coccinellids in India: Predator-prey catalogue. Oriental Insects. 38: 27-61.

Pervez, A. and Omkar, (2005). Functional and numerical responses of *Propylea dissecta* (Mulsant) (Coleoptera: Coccinellidae). Journal of Applied Entomology. 128: 140-146.

Sadeghi, A., Van-Damme, E.J.M. and Smagghe, G. (2009). Evaluation of the susceptibility of the pea aphid, *Acyrthosiphon pisum*, to a selection of novel biorational insecticides using an artificial diet. Journal of Insect Science. 9: 65.

Smith, C.M. and Boyko, E.V. (2007). The molecular bases of plant resistance and defense responses to aphid feeding: Current status. Entomologia Experimentalis et Applicata. 122: 1-16.

Solomon, M.E. (1949). The natural control of animal populations. Journal of Animal Ecology. 18: 1-35.

Swaminathan, R., Meena, A. and Meena, B.M. (2016). Diversity and predation potential of major aphidophagous predators in maize. Applied Ecology and Environmental Research. 13(4): 1069-1084.

Trexler, J.C., McCulloch, C.E. and Travis, J. (1988). How can the functional response best be determined? Oecology. 76: 206-214.

Uygun, N. and Atlihan, R. (2000). The effect of temperature on development and fecundity of *Scymnus levaillanti*. Biocontrol. 45: 453-462.

Weigand, S. and Bishara, S I. (1991). Status of Insect Pests of Faba Bean in the Mediteranean Region and Methods of Control. In: Present Status and Future Prospects of Faba Bean Production and Improvement in the Mediterranean Countries. [Cubero J.I., Saxena M.C. (eds.)]. Zaragoza: CIHEAM pp 67-74.

Wells, M.L., McPherson, R.M., Ruberson, J.R. and Herzog, G.A. (2001). Coccinellids in cotton: Population response to pesticide application and feeding response to cotton aphids (Hemiptera: Aphididae). Journal of Environmental Entomology. 30: 785-793.