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Biology and foraging behaviour of *Oenopiakirbyi* Mulsant (Coleoptera: Coccinellidae) on melon aphid, *Aphis gossypii* Glover

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Abstract

Oenopia kirbyi Mulsant is an important naturally occurring predator of *Aphis gossypii* Glover in cucumber. Before recommending the natural enemy against any pest it is important to investigate the feeding efficiency and density responsiveness of the given natural enemy. We, therefore, studied the biology and predatory potential of *O. kirbyi* against this aphid in the laboratory at 25 ± 0.5 °C, 70 ± 5% RH and 12L: 12D photoperiod. Incubation, total larval, pre pupal and pupal period of *O. kirbyi* was 3.40, 15.26, 1.30 and 4.80 days, respectively. Females on an average laid 177.60 ± 6.38 eggs. Pre oviposition, oviposition and post oviposition period of *O. kirbyi* was 6.92, 23.22 and 5.48 days, respectively. Adult female and adult male consumed an average of 2634.78 and 2012.52 aphids in their life span of 38.50 and 31.38 days, respectively, whereas, total prey consumption during the larval stages was 535.90 aphids/ predator. All the predator stages exhibited a type II functional response to the aphid. Based on Rogers's random predator equation, the attack rate was lowest (0.065) in the first-instar and highest (0.171) in the adult stage. Handling times of the adult and the fourth-instar stages (0.237 and 0.263 h, respectively) were much shorter than other stages. Study indicates that the adults and the fourth-instar grubs were the most voracious stages and could be considered for the biological control of the aphid after field evaluation.

Keywords: biocontrol, attack rate, handling time, predator, functional response

Introduction

The melon aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) is a cosmopolitan, polyphagous pest infesting 569 host plants in tropical, subtropical and temperate regions [32, 38, 40]. Heavy infestation reduces the yield and fruit quality of cucumber. The aphids also secrete honeydew which encourages sooty mould that disturbs the normal physiology of the leaves and transfer 76 plant viruses [5, 28, 39, 2]. For the control of thisaphid, many insecticides have been recommended [22, 23] but, the indiscriminate use of synthetic pesticides leads to the development of insecticide resistance [41, 4, 34], pest resurgence, insecticide residue, environmental pollution and killing of natural enemies. Melon aphid, *A. gossypii* developed resistance against many insecticides [8, 35, 25]. Insecticide resistance forces the farmers to increase the dose and frequency of pesticide application which further aggravates the problem [4]. Therefore, there is a need to find out some alternatives of chemical pesticides to protect cucumber from infestation of melon aphid [16]. Under such circumstances, biological control can be alternative, ecofriendly and sustainable approach to control this pest [14]. Coccinellid beetles are important predators of aphids and other hemipterans [27, 33, 1, 24, 17, 36] . But before the use of a predator in a biological control programme, the study of biology and foraging efficiency against the target species is necessary. Foraging efficiency of a given natural enemy can be assessed by studying its functional response to the target pest [7, 29]. Functional response is the number of prey eaten per predator as a function of prey density [13]. According to Holling (1959) functional response have been categorized into a linear relationship between prey density and the number of prey consumed (type I), a curvy linear relationship (type II), and a sigmoidal relationship (type III). In addition, dome shaped response (type IV) and negative exponential response (type V) [20, 31] have also been reported. Functional response studies are used to estimate the attack rate (*a*) and handling time (*Th*) of the predator. The natural enemies with high attack rate(*a*) and low handling time (*Th*) are known as effective biocontrol agents [2, 40].The present study was, therefore, conducted with a aim to study the biology and foraging behaviour of *O. kirbyi* against *A. gossypii* so that it can be utilized in pest management programme of the target pest.

Materials and Methods

The stock culture of *A. gossypii* was maintained on cucumber plants raised in the greenhouse. For the experimental studies aphid colonies were also maintained in the laboratory on cucumber seedlings at 25 ± 0.5 °C, 70 ± 5% RH and 12 L: 12D h photoperiod. The culture of *O. kirbyi* was maintained from field collected beetles on *A. gossypii* in the biological control laboratory at previously described environmental conditions. The beetle was reared for one generation before using for the experiment.

Developmental biology of *O. kirbyi*

Developmental biology of the *O. kirbyi* was studied on the melon aphid, *A. gossypii* at 25 ± 0.5 ºC, 70± 5% RH and 12 L: 12D h photoperiod. For this purpose, one pair of newly emerged adults was released in the Petriplate containing wet blotting paper on the base. Cucumber leaves (6×6cm) having mixed population of second and third instar of *A. gossypii* were placed on the wet blotting paper in the Petriplate. Each set was replicated 10 times. The food was changed daily and the Petriplates under observation were examined at 24 h interval for egg laying and moulting of the grubs until pupation. Pupae obtained were collected and kept for adult emergence. The duration of egg, each larval instar, total larval duration, pre pupal, pupal and egg to adult emergence was recorded. After emergence, the adults were sexed under a stereozoom microscope and kept in pairs in Petriplates with ample supply of food. Observations on pre-oviposition period, oviposition period, post-oviposition period, male longevity and female longevity were recorded.

Feeding potential of *O. kirbyi*

Feeding potential of different developmental stages of *O. kirbyi* was studied against *A. gossypii*. Newly emerged larvae of the desired stage were shifted individually to a petri plate with counted number of aphids of same instra. In order to select the aphids of the desired age, the cucumber leaves were carefully examined under the stereo zoom binocular microscope and the unwanted stages were removed carefully with the help of camel hair brush. The experiment was carried out in the insect culture room fixed at 12:12 h photoperiod, 25 ± 0.5ºC and 70± 5 per cent relative humidity. The data on aphid consumption by the predator was recorded after every 24 h untilthey enter the next stage and the food was changed daily. The experiment was replicated ten times. The number of aphids consumed per day by each larval instar was calculated.

Foraging behaviour of *O. kirbyi* to *A. gossypii*

Functional response of first, second, third and fourth instar, and adult female of *O. kirbyi* was studied by offering varying densities of the second/third instar nymphs of the aphid on a cucumber leaf disc (6 cm diameter) placed in a Petri plate with moist filter paper. The prey densities offered were 10, 15, 20, 25 and from 10, 15, 30, 45, 60 and 75; 20, 40, 60, 80 and 100 and 25, 50, 75, 100 and 125 for the first, second, third and fourth instar as well the adult female of *O. kirbyi*, respectively. The prey densities for each stage were decided based on a preliminary experiment carried to study their feeding over a 24 h period. After allocating the prey at different densities, one predator was confined into each arena. The Petri plates were kept in a culture room at 25 ± 0.5 °C, 70 ± 5% RH and 12 L: 12D h photoperiod. Each prey density was replicated 10 times simultaneously for each stage. The data on the number of prey eaten by each predator was recorded after 24 h.

Data analysis

Analysis of variance was performed to test differences in daily prey consumption at different prey densities and means were separated using the least significant difference. The functional response was analyzed from prey consumption data over a period of 24 h. The logistic regression was fit to the prey density offered (N) and the proportion of prey consumed (Na/N) to distinguish between Type II and Type III functional response was:

$$N_a/N = \exp(p_0 + p_1 N + p_2 N^2 + p_3 N^3) / (1 + \exp(p_0 + p_1 N + p_2 N^2 + p_3 N^3))$$

Where, Na is the prey density eaten, N is the prey density offered, and p_0, p_1, p_2 and p_3 are constant, linear, quadratic and cubic coefficients. Significant negative p1 indicates Type II, whereas, a significant positive p_1 and negative p_2 indicates Type III response [15]. Because the cubic polynomial fit indicated the Type II response, further analysis was applied for Type II response. Rogers's random predator equation, $N_a = N[1 - \exp\{a(T_h N - T)\}]$ [30] was used to estimate the predator's attack rate (a) and predator's handling time (T_h). Predator's attack rate per handling time (a/T_h) and maximum theoretical predation rate per day ($K = T/T_h$) was also calculated [6]. Analysis of variance was applied to test differences in a and T_h values, and means were separated by least significant difference.

Results

Developmental biology

The mean duration of the egg, larval, prepupal and pupal stage was 3.4, 15.26, 1.4 and 1.3 days, respectively. The time taken from egg to adult emergence was 24.82 days. Female and male longevity of *O. kirbyi* reared on *A. gossypii* was 38.50 and 31.38 days, respectively. Pre-oviposition, oviposition and post-oviposition period was 6.92, 23.22 and 5.48 days, respectively. The female of *O. kirbyi* laid on an average 177.60 eggs/female.

Feeding potential

The number of aphids consumed increased with the advancement of developmental stages of the predator (Table 2). The average number of aphids consumed by the first, second, third and fourth instar of the predator was 32.40, 73.52, 171.06 and 252.80, respectively. Whereas, the average number of aphids consumed per day by these stages was 11.58, 22.28, 43.86 and 56.18 aphids, respectively. To complete the larval development, *O. kirbyi* consumed 535.90 aphids at the rate of 35.12 aphids/ day (Table 2). The adult female and male consumed on an average 2634.78 and 2012.52 aphids, respectively, during their life span.

Functional response

Mean number of aphids consumed by different developmental stages of *O. kirbyi* differed significantly among different prey densities. Logistic regression fit between prey density offered (N) and proportion of prey eaten (Na/N) by all the stages of the predator resulted in significant negative linear coefficients confirming a type II functional response for all the developmental stages of the predator (Table 3). The parameters of functional response i.e. predator's attack rate

(a) and handling time (T_h) obtained after fitting Rogers's random predator equation are presented in Table 4. The predation efficiency of *O. kirbyi* against *A. gossypii* increased with the advancement of the developmental stage of the predator which is numerically illustrated by parameters of attackrate (a) and handling time (T_h). Predator's attack rate was lowest (0.065) in the first-instar and highest (0.171) in the adult stage. Handling time of the adult beetle (0.237 h) and the fourth-instar larva (0.263 h) was much shorter than that of other stages (Table 4). The maximum number of aphids that could be consumed over a period of 24 h by the first, second, third and fourth instargrubs and adult of *O. kirbyi* was estimated to be 20.70, 28.60, 60.00, 92.30 and 100.00 aphids/predator, respectively.

Discussion

In the present study, *O. kirbyi* exhibited a Type II functional response in all the developmental stages to *A. gossypii*. The proportion of prey consumed at higher density decreased which may be due to satiation of the predator at the increased prey density. Similar to the present study, Kumari *et al.* (2020) [18] reported with same prey but with different predator (*C. septempunctata*). The present findings corroborate with the findings of Pervez and Omkar, (2005) [27] but with different predator and aphids which reported that the number of the aphids consumed increased with the increase in prey densities for all the developmental stages of the predator and when satiation was attained by the predator there was no significant increase in the number of aphids consumed and there was no effect of the prey density. The proportion of aphids consumed was maximum at the lowest density and minimum at the highest prey density.

In the present findings, a type-II functional response was observed. Similar to present findings, *Harmonia axyridis* exhibited a Type II functional response at all growth stages against *A. gossypii*, though type I (Lou, 1987) [21] or Type III (Hu *et al.* 1989) [11] response has also been reported for adult *H. axyridis* against different prey species (*Rhopalosiphum prunifoliae* and *Cinara* sp., respectively). Similar to present findings, a type II functional response is reported in many coccinellids by previous workers [19, 27, 26, 43, 12, 1, 36, 17, 24, 18] . A predator with a type II functional response has an inverse density-dependent action against its prey, whereas, a predator with a type III functional response acts as a positive density dependent mortality factor [27, 3, 42]. Sharma *et al.* (20l7) [37] and Kumari *et al.* (2020) [18] also observed that the attack rate of *Harmonia dimidiata* and *Coccinella septempuncta* increased with the advancement of stages against *A.gossypii* and handling time shortened with the increase in stages of the predator. The predation efficiency of *O. kirbyi* against *A. gossypii* increased with the advancement of the developmental stages of the predator which is numerically illustrated by parameters of attack rate (a) and handling time (T_h). This is because the fourth instar and the adult beetles arebigger in size and capable of moving faster than the other stages. In coccinellids, the fourth instar is generally responsible for approximately 60–80% of total prey consumption by larvae (Hodek and Honek, 1996) [10]. Asimilar trend was observed in our study. These proportions are similar to those of *H. axyridis* preying on *Myzus persicae* (Sulzer) (Hodek and Honek, 1996) [10]. The low predation rates observed in the first and second instars of *O. kirbyi* were due to their low attack rates and longer prey handling times (Table 4). This may be due to the reason that the first and second instar larvae are small in size and their movements are slow. In the present study, third instar had the highest attack rate, but the maximum mean aphid consumption was lower than the fourth instars and female adults, which may be due to a longer handling time of the third instar (Table 4). Low variation in prey consumption, high attack rate, and short handling time in fourth instars indicated that thefourth instar is the most voracious stage. Similar to present findings, Lee and Kang (2004) [19] reported that all stages of *Harmonia axyridis* showed a type II functional response against *A.gossypii* on cucumber leaves and attack rates of *H. axyridis* at 24 h were 0.0037, 0.0442, 0.3590, 0.3228, and 0.1456, and estimated handling times were 4.1001, 2.4575, 0.7500, 0.2132, and 0.1708 h for the first, second, third, and fourth instars, and female adult, respectively.

Conclusion

The adults and the 4th instar grubs were the voracious feeders of the melon aphid and could be important for the biological control of the aphid. Hence it can be utilized as one of the components of the integrated pest management programme of the aphid

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