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Full Length Research Paper

Feeding ability of *Hippodamia variegata* (Coleoptera: Coccinellidae) on *Aphis fabae* (Hemiptera: Aphididae)

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Consumption rate and starvation tolerance of larvae and adult of *Hippodamia variegata* (Goeze) were studied on *Aphis fabae* Scopoli under laboratory conditions (25±1°C, 60±5% RH and 16h L: 8h D). The average daily feeding of different larval stages: 1st, 2nd, 3rd, 4th instars and adults were 12±0.47, 22.1±1, 32±0.47, 48.7±1 and 58.2±0.55 aphids, respectively. The average total feeding of larval stages 1st, 2nd, 3rd and 4th instars were 42.03±1.65, 67.41±1.58, 105.6±1.51 and 177.76± 1.65 aphids per day, respectively. The predation rate of 4th instar larva of *H. variegata* was the highest whereas the 1st instar larva consumed the lowest number of prey. Mean of feeding in male, virgin female and mated female per hour was 2.1±0.1, 1.2±0.13 and 4.3±0.15 respectively. Average of starvation tolerance in larval instars 1st, 2nd, 3rd, 4th, male adult and female adult were 2.3, 2.95, 3.95, 5.35, 4.6 and 8.1 respectively. A linear correlation curve showed the dependency of predation on the developmental stages of *H. variegata*. The results obtained here provide information about the consumption of *H. variegata* that might be useful for IPM programs.

Key words: Predation, consumption rate, variegated lady beetle.

INTRODUCTION

Pests hamper and destroy standing and stored foods reserves in every part of the world (Kring, 1998). Aphids (Hemiptera: Aphididae) is one of the most important pest found more in plants (Nelson and Rosenheim, 2006).

Aphids cause damage by sucking nutrients from plants, vectoring viruses, causing deformation at the growing tips, and producing honeydew (Kennedy et al., 1962; Difonzo et al., 1997).

Aphids are difficult to control due to their extremely high fecundity. Aphids can reproduce females without fertilization. A female aphid produces 50 to 100 daughters in her life span, with each daughter reproducing in 6 to 8 days (Grigorov, 1977).

Aphis fabae Scopoli 1846, commonly known as black bean aphid, is the most important polyphagous species of pest and attacks the bean, sugar beet and over hundred of host plants. Nymphs and the adults of *A. fabae* cause damage by sucking the sap from the tender shoots, pods, flowers and reduce the market value (Volkl and Stechmann, 1998).

In the western part of Iran, *A. fabae* is the predominant pest species in agro-ecosystems (Jafari, 2009, 2011). Scientists are trying to develop and apply different techniques to control and reduce loss of these pests on agriculture and garden products. Chemical control methods are frequently applied as it is an easy and prompt way to directly kill or repel the pests from crops and fruit tree (Katsarou, 2005). But it is reported in many experiments that pesticides has not only hazardous effects on human life by increasing pollution but also it has indirect impact by disturbing ecosystems (Luckman and Metcalf, 1978).

Recently, it is reported that biological control is a better technique to control different types of pests (Habeck et al., 1990; Murario and Andriev, 2008). Lady beetles (Coleoptera: Coccinellidae) are known to be voracious predators of plant pests such as aphids (Hodek, 1973; Gordon, 1985). Coccinellids, the most widespread and abundant predator in many agricultural regions, are known to have the strongest impact on aphid species (Hodeck, 1962; Hodek and Honek, 1996; Grigorov, 1977).

Aphidophagous lady beetles are highly polyphagous, consuming most (if not all) aphid species that they

encounter (Pedigo and Rice, 2006). Lady beetles have long attracted the attention of the applied entomologist for they are good candidates for use in IPM (Integrated Pest Management) programs. They are distributed worldwide, and they have a wide host plant and prey range (Bianchi et al., 2004; Allawi, 2006).

The species of the genus *Hippodamia* have been identified so far in the world and are reported as aphid predators in all agro-ecosystems. Several of them have been identified as potential biological control agents of bean aphid in agricultural crops (Fan and Zhao, 1988). In many studies, it is known that *Hippodamia variegata (*Goeze) 1977 is a capable predator and can be used for the biological control of aphids (Franzman, 2002).

Hippodamia variegata is native to palaearctic (Eurasia, Africa and India) region, but is now found throughout many parts of the world (Franzmann, 2002). *H. variegata* has several favorable characteristics that would make it a useful biological control agent. Firstly, the widespread distribution of *H. variegata* throughout Europe and most parts of Asia. Secondly, it occurs on a variety of host plants (Hurst et al., 1999; Franzmann, 2002).

The study of the feeding ability of *H. variegata* under laboratory conditions may evaluate its predatory impacts on black bean aphid pest for better utilization in integrated aphids control program.

MATERIALS AND METHODS

The present experiments were conducted during the year 2010 in entomological laboratory (at 25±1°C of temperature, 60±5% of relative humidity and photoperiod of 16 L:8 h D) in College of Agricultural Sciences, Boroujerd Islamic Azad University, Boroujerd, Iran.

Collection and mass culture of *H. variegata* and *A. fabae*

To maintain the culture of black bean aphid (*A. fabae*), sugar beet (*Beta vulgaris*) and common bean (*Phasaeolus vulgaris*) were grown in the micro-plots sized 2x3 m, plants were maintained at experimental field of the university. *A. fabae* and *H. variegata* were collected from unsprayed sugar beet fields and reared on planted beets and beans in micro-plots. Population of aphids and lady beetles increased rapidly. Then some pairs of ladybirds were selected for oviposition. The selected pairs were kept in separate Plexiglas cage (6x11x23 cm^3) to get the batches of eggs for single cohort offspring to minimize the variation in the experiments. The bottom of the cages was covered with blotting paper.

Study of the feeding ability of *H. variegata*

After hatching of eggs, daily and total feeding of *H. variegata* were studied. Different larval stages were transferred individually in Petri dishes (15 cm in diameter) and reared on black bean aphids. Fresh beet leaves infested with aphids were placed in each Petri dish to provide food for the larvae every day. The larvae were observed daily at 6 h interval until pupation. The exuvae found in each Petri dish was removed when the larva entered into the next instar. Total number of aphid consumed by each larval instar, dead and unconsumed aphids were counted daily and were replaced by fresh ones. Each larval instar was checked and aphid consumption was recorded. These experiments were carried out in 10 replications.

In other cages, one male, mated female and virgin female of lady beetle were placed separately. These adults were fed by 100 adult aphids. The numbers of aphids eaten by each adult after 24 h were counted. Average daily and total feeding of lady beetles were analyzed using Analysis of Variance (ANONA) and thereafter compared with Duncan test.

The starvation tolerance of larvae and adults (*H. variegata*) in the absence of prey (*A. fabae*) was investigated. To do this during intensive observation of the blotting paper containing *H. variegata*, eggs were collected with a fine brush immediately after they were laid and were placed in Petri dishes (15 cm in diameter) on sugar beet leaves. After egg hatching, 1st instars larvae (newly emerged larvae) were transferred individually into Petri dishes without prey on a piece of sugar beet leaf.

The larvae were observed daily at 6 h interval until end of the larval period. The same experiment was carried out on 2nd, 3rd, 4th larval instars and adults (male and female). Thus from each stage, 10 individuals were selected and placed in Petri dishes (15 cm in diameter) without aphid separately. Regular observations were made and total time of each larva period was measured and recorded.

RESULTS

The mean daily consumption of different developmental stages is presented in Table 1. Average daily feeding of different larval stages 1st, 2nd, 3rd, 4th and adults of these lady beetles were 12.0, 22.1, 32.0, 48.7 and 58.2 aphids per day respectively. By increase of larval instar, the number of daily feeding increased (Table 1). Adult consumed more aphids than the larval stages. The ANOVA analysis showed a significant difference among feeding rate of different stages of ladybird beetles ($P< 0.01$). Duncan test also showed that the average daily and total feeding in developmental stages of *H. variegata* on *A. fabae* were at different levels.

Average total feeding rate of larval stages were 42.03, 67.41, 105.6 and 177.76 aphids per day respectively (Table 2). The last larval instar (4th instars grub) consumed more aphids than the other grub stages. Adults consumed more aphids than the larval stages.

Table 1. Comparative feeding rate of adult *H. variegata* and its larvae on *A. fabae*.

Growth stages	Mean	SE.
First larval instar	12.0	0.47a
Second larval instar	22.1	1.00b
Third larval instar	32.0	0.47c
Fourth larval instar	48.7	1.00d
Adult	58.2	0.55e

Mean within column followed by the same letter are not statistically different by Duncan test (p=0.01).

Table 2. Comparison of total predation rate of adult *H. variegata* and its larvae on *A. fabae*.

Growth stages	Mean	SE.
First larval instar	42.03	1.65a
Second larval instar	67.41	1.58b
Third larval instar	105.60	1.51c
Fourth larval instar	177.76	1.65d

Mean within column followed by the same letter are not statistically different by Duncan test (p=0.01).

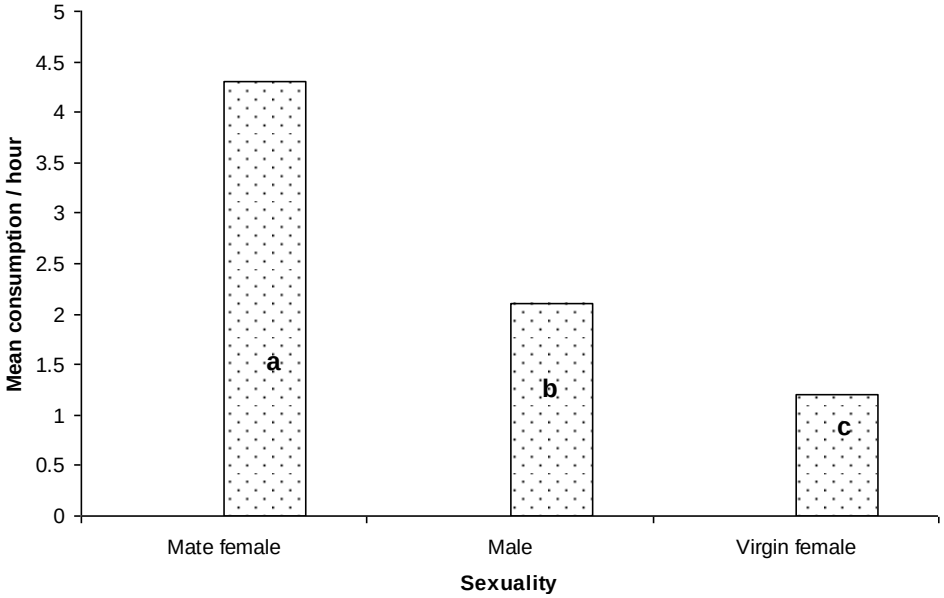

Figure 1. Comparison of the effect of sex status on the feeding rate of *H. variegata*.

The average feeding of male, virgin female and mated female per hour was 2.1±0.10, 1.2±0.13 and 4.3±0.15 nymphs per hour, respectively (Figure 1). Duncan test results also showed that the average feeding was located at different levels. The results of the ANOVA showed that a significant difference exists between the amount fed and gender (P< 0.01).

Average of starvation tolerance in larval instars 1st, 2nd, 3rd, 4th, male adult and female adult was 2.30, 2.95, 3.95, 5.35, 4.60 and 8.10 respectively (Table 3). The results showed that younger larvae are less tolerant of food and soon died. Thus, fourth instars larvae are most tolerant and least tolerant to the first instars larvae which were starved. The results in Table 3 show that the duration of starvation tolerance between 4th larval instars and other larval instars show significant differences.

Table 3. Mean of starvation adult and larvae of *H. variegata* with *A. fabae*.

Growth stages	Min	Max	Mean	SE
Female	5.0	12.0	8.10	0.84[a]
Fourth instar	4.0	6.0	5.35	0.26[b]
Male	3.0	6.0	4.60	0.27[bc]
Third instar	3.5	4.0	3.95	0.05[cd]
Second instar	2.5	3.5	2.95	0.12[de]
First instar	2.0	3.0	2.30	0.11[e]

Mean within column followed by the same letter are not statistically different by Duncan test (p=0.01).

There was no significant difference between the first and second larval instars. However, significant difference was not observed for starvation tolerance between the second and third larval instars.

DISCUSSION

Advancement in the instars of *H. variegata* clearly showed the increase in the consumption of *A. fabae* and has been well supported by the findings of other workers (Cottrell, 2005; Elhabi et al., 2000).

H. variegata adult devoured more aphids than larvae, such investigations are in consonance with the finding of Mohamed et al. (2000).

Results showed that the 4th larvae eat 48 aphids each 24 h. These results are in line with the findings of other researches (Franzman, 2002; Fan, 1988). The amount of consumption depend on aphid species, the fourth age larva eat 29 of *Diuraphis noxia* and 32 of *Schizaphis graminis* each day (Michels and Flanders, 1992; Wang et al., 2004). The consumption of mated-female was higher in contrast to male and virgin female. However, between sexes, females consumed more aphids than the males (Elhabi et al., 2000; Hatami et al., 2000; Lanzoni et al., 2004; Kontodimas and Stathas 2005). In present studies, it was also found that the female adults consumed more aphids as compared to male adults. Kontadimas and Stathas (2005) and Fan and Zhao (1998) also held the same opinion. Tolerance to starvation in females fed the diet was significantly higher than that in males. Experiments by Wang et al. (2004) on *H. variegata* were revealed that adults can continue to live without food for 72 h.

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