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Predation rate of *Hippodamia variegata* (Coleoptera: Coccinellidae) feeding on different densities of *Aphis gossypii* (Hemiptera: Aphididae)

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Abstract

Predation rate is basic to any investigation of prey-predator interaction and a major component in the selection of predators for biological control. The predation rate of variegated lady beetle, *Hippodamia variegata* (Goze), fed on different densities (20, 40, 60, 80 and 100) of third instar nymphs of cotton aphid, *Aphis gossypii* Glover, was studied under laboratory conditions (25 ± 1 °C, 65 ± 5% RH and a photoperiod of 16L: 8D h). The net predation rates (C_0) using age-stage, two sex life tables for 20, 40, 60, 80 and 100 aphids were calculated as 1547.50, 4011.91, 4450.78, 5300.20, 5305.73 prey nymphs, respectively. The mean consumption rates for male and female predators increased as prey density increased. The predation rate for both sexes also increased with increasing prey density. The lowest and highest predation rates for female were 1547.50 and 5305.73 prey nymphs at densities of 20 and 100 aphids, respectively. The transformation rate from prey population to predator offspring (Q_p) decreased as prey density increased. It was concluded that any increase in the density of third instar nymphs of *A. gossypii* will result in significant effects on predation parameters of *H. variegata*.
Key words: age-specific survival rate, net consumption rate, *Aphis gossypii*, transformation rate

چکیده

نرخ شکارگری *Hippodamia variegata* (Coleoptera: Coccinellidae) با تغذیه از تراکم‌های مختلف شته جالیز (Hemiptera: Aphididae)

سوده داودی دهکردی و احد صحراگرد

نرخ شکارگری اساس هر پژوهش در برهم‌کنش شکار-شکارگر است و یکی از اجزای مهم در انتخاب شکارگران در کنترل بیولوژیک به‌شمار می‌رود. نرخ شکارگری کفشدوزک *Hippodamia variegata* (Goeze) با تغذیه از تراکم‌های مختلف (20، 40، 60، 80 و 100) عدد از پوره‌های سن سوم شته پنبه *Aphis gossypii* Glover در شرایط آزمایشگاهی (25±1 درجه سلسیوس، رطوبت نسبی 5 ± 65 درصد و دوره نوری 16 ساعت روشنایی و 8 ساعت تاریکی) بررسی شد. نرخ خالص شکارگری (C_0) با استفاده از جدول زندگی دوجنسی سنی-مرحله‌ی رشدی در تراکم‌های 20، 40، 60، 80 و 100 شته به‌ترتیب 1547/50، 4011/91، 4450/78، 5300/20 و 5305/73 شته طعمه بود. میانگین نرخ‌های مصرف برای نر و ماده با افزایش تراکم طعمه افزایش یافت. نرخ شکارگری برای هر دو جنس نر و ماده نیز با افزایش تراکم طعمه افزایش یافت. پایین‌ترین و بالاترین نرخ‌های مصرف برای ماده‌ها 1547/50 و 5305/73 پوره طعمه به‌ترتیب در تراکم‌های 20 و 100 شته پنبه بود. نرخ تبدیل از جمعیت طعمه به نتاج شکارگر (Q_p) با افزایش تراکم طعمه کاهش پیدا کرد. نتیجه‌گیری شد که افزایش تراکم پوره‌های سن سوم شته پنبه، تأثیرمعنی‌داری روی پارامترهای شکارگری *H. variegata* داشت.

واژگان کلیدی: نرخ بقای ویژه سنی، نرخ خالص مصرف، شته جالیز، نرخ تبدیل

Introduction

Aphids are a diverse group of plant feeding insects belonging to the family Aphididae of order Hemiptera. They are often found in temperate regions such as North America, Europe, Central and Eastern Asia (Nelson and Rosenheim, 2006). Their damage is directly by sucking cell sap, secrete honeydew resulting in development of sooty mould on leaves and shoots and indirectly as vectors of certain plant viruses (Kennedy *et al.*, 1962; Raboudi *et al.*, 2002). The melon aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae) is a worldwide, polyphagous species widely distributed in tropical, subtropical and temperate regions (Leclant and Deguine, 1994). One of its dominant coccinellid predators is *Hippodamia variegata* (Goeze), the variegated lady beetle. This ladybeetle, an important predator of aphids in Europe (Hodek and Honek, 1996), is widely distributed in a large area of the Palearctic regions (Obrycki and Orr, 1990). In Australia, the lady beetle was recorded preying on 12 aphid species and one psyllid species feeding on various crops, weeds and ornamental plants (Franzmann, 2002).

To be successful in biological control program, it is necessary to determine the growth, stage structure and predation rate of the predators. Data analysis of

predation rate plays major roles in this process. Chi and Yang (2003) explained the age-stage, two-sex life table to the predator, *Propylaea japonica* (Col.: Coccinellidae) and demonstrated that it can properly include the variable predation rate of different predator stages. The age-stage, two-sex life table and predation rate of the predator, *H. variegata* (Col.: Coccinellidae) fed on *Aphis fabae* was also studied by Farhadi *et al*. (2011). In addition, life table parameters and predation rate of *Typhlodromus bagdasarjani* Wainstein & Arutunjan were calculated on two-spotted spider mite reared on susceptible and resistant eggplant varieties (Khanamani *et al*., 2015). These studies showed the advantages of incorporating the predation rate into the age-stage, two-sex life table.

Due to the adverse effects of increased use of different insecticides on the environment, using natural enemies in biological control of insect pests has become an important component in pest control programs (Hodek and Honek, 1996; Atlihan and Bora Kaydan, 2010). To increase the impact of natural enemies in a prey population, it is necessary to realize the interaction components between natural enemies and their preys (Rabb, 1974).

The predation rate of *H. variegata* feeding on different densities of *A. gossypii* based on the age-stage two-sex life table was the aim of this study. Therefore, the net predation rate as a population parameter of predator by combining the survival rate and age-stage specific predation rate were calculated.

Materials and methods

Rearing prey and predator

Adults of *H. variegata* were collected from an alfalfa field in the Shahrekord region, Chaharmahal, and Bakhtiari Province, Iran. Nymphs of *A. gossypii* were collected from a cucumber field on the outskirts of the city of Rasht. They were reared on potted (20 cm in diameter) cucumber varieties such as Super dominus and US Agriseeds in a greenhouse (at average temperature of 26 ± 1 °C with the range of 18-35 °C) in order to have access to a steady supply of prey for experiments.

Predation rate

To study the predation rate, it was necessary to collect equal numbers of aphid nymphs for beetles. Initially, 100 adults of *A. gossypii* were placed on an individual *Cucumis sativus* plant and allowed to produce progeny. After two days, the adult aphids were removed and the newborn nymphs were kept under constant temperature (25 ± 1 °C). After three days, all aphids were in the third instar nymphs, and used in the predation study.

Newly emerged 1st instar larvae of *H. variegata* were released individually in transparent plastic containers (15 ×1 3× 3 cm) and offered densities of 20, 40, 60, 80 and 100 *A. gossypii* to study their predation rate parameters. The number of consumed prey was recorded daily at each prey density level to determine the total number of consumed prey (from 1st instar larva to adult). After adult emergence, the lady beetles from the same prey densities were allowed to mate, and then transferred to individual experimental arenas as described earlier. The dishes contained the same prey densities that the beetles had been fed in their immature stage. The number of prey consumed was recorded daily at each prey density until all adults died. The number of replicates was between 20 and 30 for both larval and adult stage at each prey density. The daily predation rate of larvae, males and females of *H. variegata* were calculated at different prey densities separately.

Statistical analysis

The methodology of Chi and Yang (2003) was used to analyze predation rates. This method takes into account the variable predation rates among stages. The raw data of predation rates for the 120 individuals in the predation study were grouped according to age and stage of the predator. The age-stage specific predation rate (C_{xj}) gives the mean number of *A. gossypii* consumed by individual *H. variegata* of age x and stage j. In the age-stage, two-sex life table (Chi and Liu 1985), the age-specific survival rate (l_x) and the age-specific fecundity (m_x) for individuals aged x was calculated as:

$$l_x = \sum_{j=1}^{\beta} = s_{xj}$$

and

$$m_x = \frac{\sum_{j=1}^{\beta} s_{xj} f_{xj}}{\sum_{j=1}^{\beta} s_{xj}}$$

Where β is the number of life stages and S_{xj} is the age-stage specific survival rate, i.e., the probability that a neonate survives to age x and stage j and fxj is the age-stage specific fecundity.

The age-stage specific predation rate (k_x) is the mean number of prey consumed by *H. variegata* at age x and was calculated by the following formula proposed by Chi and Yang (2003):

$$k_x = \frac{\sum_{j=1}^{\beta} S_{xj} C_{xj}}{\sum_{j=1}^{\beta} S_{xj}}$$

According to Chi and Yang (2003), the age-specific net predation rate (q_x) gives the weighted number of *A. gossypii* consumed by a predator of age x and was calculated as

$$q_x = l_x k_x$$

or:

$$q_x = \sum_{j=1}^{\beta} S_{xj} C_{xj}$$

The net predation rate (C_0) is the summation of the q_x over all age groups giving

$$C_0 = \sum_{x=0}^{\delta} \sum_{j=1}^{\beta} S_{xj} C_{xj}$$

Where δ is the last age of the population. Although the net reproduction rate (R_0) that is estimated by life table MSChart program represents the mean number of offspring produced by an individual during its life span, the parameter C_0 gives the mean number of prey consumed by an individual during its life span. It is a demographic parameter that represents the predation capacity of the predator population including all individuals of both sexes and those that died before the adult stage. The ratio of the net predation rate to the net reproductive rate gives the transformation rate from prey population to predator offspring. This ratio is defined as (Q_p) according to Chi and Yang (2003):

$$Q_p = \frac{C_0}{R_0}$$

Q_p is the number of prey needed for the production of an offspring from a predator. The net reproductive rate (R_0) of this predator preying on different densities of *A. gossypii* was derived from its life table parameters (Davoodi *et al*., 2013). Predation rate data were analyzed using the computer program CONSUME-MSChart as designed by Chi (2014). The CONSUME-MSChart is also available for download at http://140.120.197.173/Ecology/prod02.htm (Chung Hsing University) and http://nhsbig.inhs.uiuc.edu/wes/chi.html (Illinois Natural History Survey). Means comparison were done using Tukey Cramer procedure. The curves were drawn using Excel software.

Results

The age-stage predation rate (C_{xj}) of *H. variegata* on third instar nymphs of the cotton aphid is shown in Figure 1. It illustrates the trend in age-stage specific predation rate, i.e., the mean number of aphids eaten by a predator of age x and stage j.

The age-specific survival rate (l_x), the age-specific predation rate (k_x), and age-specific net predation rate (q_x) at different prey densities are shown in Figure 2. Because eggs and pupae of *H. variegata* do not consume prey, there are some obvious gaps in k_x and q_x. The age-specific net predation rate (q_x) of the larvae increases at first, and then gradually decreases with the age-specific survival rate (l_x).

The mean consumption rate of *H.variegata* fed on different densities of cotton aphids increased with increasing prey density up to 100 aphids /day for both sexes. The lowest consumption rate was obtained at a prey density of 20 aphids /day (Female: 1547.50 and Male: 1314.88 nymphs) and the highest consumption rate was obtained at a prey density of 100 aphids /day (Female: 5305.73and Male: 3324 prey nymphs).

The net reproductive rate (R_0), the net predation rate (C_0), the transformation rate from prey population to predator offspring (Q_p) and mean total number of prey eaten by different life stages of *H. variegata* at different densities of prey are shown in Table 1. It is obvious that Q_p decreased significantly with increasing prey density. In addition, the trend of net predation rate (C_0) of *H. variegata* at different densities of *A. gossypii* is shown in Figure 3. It illustrates the mean number of aphids consumed by a predator at different densities of prey. As it is shown, the net predation rate (C_0) increases with the increasing prey density.

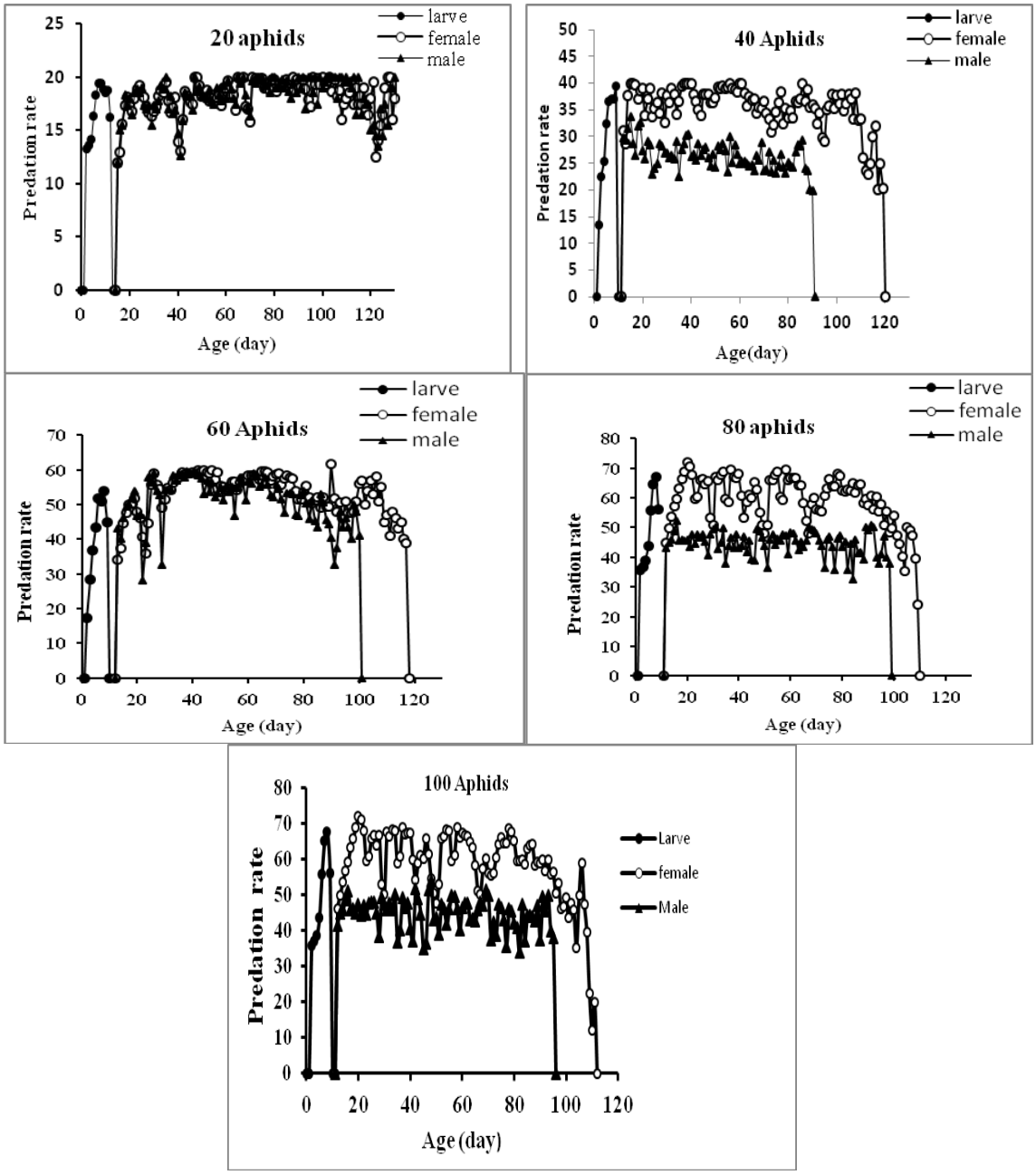

Fig. 1. Age-stage predation rate (c_{xj}) of *Hippodamia variegata* feeding on different densities of cotton aphids.

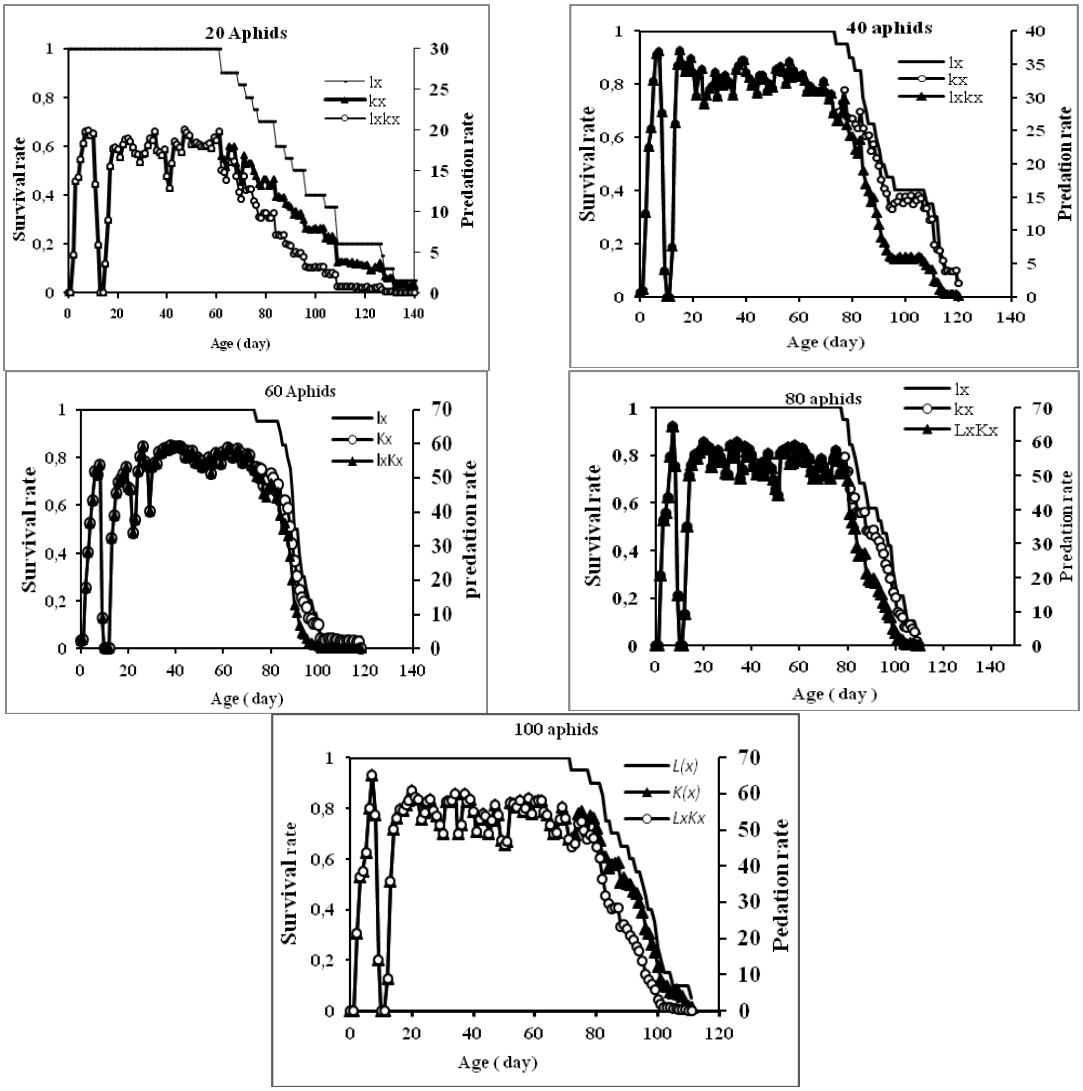

Fig. 2. Age specific survival rate (l_x), predation rate (k_x) and age specific net predation rate (q_x) of *Hippodamia variegata* fed on different densities of cotton aphids.

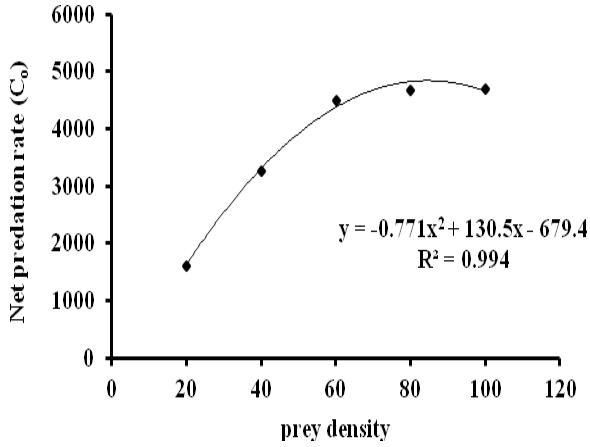

Fig. 3. The net predation rate (C_0) of *Hippodamia variegata* feeding on different densities of *Aphis gossypii*.

Table 1. The net reproductive rate (R_0), net predation rate (C_0) and transformation rate (Q_p) and mean total consumption rate of *Hippodamia variegata* feeding on different densities of *Aphis gossypii.*

Prey density	20	40	60	80	100
R_0 (female offspring/individual)	42.76 ± 7.55^{e}	196.62 ± 39.8^{d}	337.57 ± 67.6^{c}	587.74 ± 117.82^{b}	621.09 ± 116.56^{a}
C_0 (preys/predator)	1547.50 ± 122.36^{d}	4011.91 ± 383.27^{c}	4450.78 ± 161.09^{b}	5300.20 ± 167.71^{a}	5305.73 ± 144.4^{a}
Q_p (preys/predator)	37.80^{a}	16.68^{b}	13.32^{bc}	7.98^{d}	7.57^{d}
Mean total consumption rate	1616.75 ± 102.169^{c}	3281.5 ± 317.935^{b}	4499.1 ± 109.527^{a}	4691.37 ± 257.606^{a}	4707.05 ± 258.543^{a}

Within rows, values followed by the same letter do not differ significantly ($p < 0.05$) using Tukey Cramer procedure.

Discussion

The consumption rates increase with increasing prey density up to 100 aphids /day for both sexes. The minimum consumption rate was obtained at a prey density of 20 aphids/day (females higher than males) and the maximum consumption rate was obtained at a prey density of 100 aphids /day (female higher than males). Because of the larger body size of females and requiring more energy for egg production, they consumed more number of aphids than the males.

The net predation rate (C_0) increased with increasing prey density. For example, the lowest and highest net consumption rate were 1547.50 and 5305.73 prey nymphs at densities of 20 and 100 *A. gossypii.* The net predation rate (C_0) increased with the increasing prey density. Mean total consumption rate of the predator at different prey densities also showed an increasing trend as the net predation rate.

The age-specific net predation rate (q_x) of the larvae increased at first, and then gradually decreased with the age-specific survival rate (l_x). However, the predator survived longer at different densities of prey in the ages of 6o to 80 days. Isenhour and Yeargan (1981) reported that adult females of *Orius insidiosus* Say (Het.: Anthocoridae) killed more soybean thrips, *Sericothrips variabilis* Beach (Thysanuptera: Thripidae) than adult males. Milne and Walter (1997) also reported that second-instar larvae of *Frankliniella schultzei* Trybom devoured significantly more eggs than any other life stage. In another study, significant differences were also observed between the number of nymphs and adult aphids consumed by *Coccinella septempunctata* L. (Col.: Coccinellidae) (McConnell and Kring, 1990). Chi and Yang (2003) reported that the net predation rate for *Propylea japonica* Thunberg (Col.: Coccinellidae) fed on *M. persicae* was 1199.5 aphids which is lower than what was obtained in this study at density of 20 *A. gossypii*.

Yu *et al.* (2005) studied life table and predation rate of *Lemnia biplagiata* (Col.: Coccinellidae) fed on *A. gossypii*. They found that the net consumption rate was 3,022 aphids per individual during the total life span. Farhadi *et al.* (2011) studied the predation rate of *H. variegata* feeding on *A. fabae*. Their study indicated that males consumed fewer prey than the females that is in accordance with our current results.

The transformation rate from prey population to predator offspring (Q_p) by feeding on different prey densities was decreased by increasing prey density. Q_p indicates transformation rate from prey population to predator offspring. For example, if Q_p is 37 at density of 20 *A. gossypii*, this means that *H. variegata* requires approximately 37 preys to produce an egg. The Q_p gives a demographic estimation for the relationship between the reproduction rate and predation rate of predator. However, Q_p of *H. variegata* feeding on *A. fabae* was 3 nymphs (Farhadi *et al.*, 2011).

A lower transformation rates of *L. biplagiata* feeding on *A. gossypii* and *P. japonica* on *M. persicae* were found to be as 10.4 and 17.7 preys, respectively (Chi and Yang, 2003;Yu *et al*., 2005). Khodaverdi *et al.* (2012) obtained a lower Q_p of *Andrallus spinidens* Fabricius (Het: Pentatomidae) fed on fourth instar

larvae of *Spodoptera littoralis* Boisduval (Lep: Noctuidae) as 4.15 preys. It can be concluded that different densities of *A. gossypii* influenced the predation and transformation rate of *H. variegata*.

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References

Atlihan, R. & Bora Kaydan, M. (2010) Functional response of the coccinellid predator, *Adalia Fasciatopunctata revelierei* to walnut aphid (*Callaphis juglandis*). *Phytoparasitica* 38, 23-29.

Chi, H. & Yang, T. C. (2003) Two-sex life table and predation rate of *Propylaea japonica* Thunberg (Coleoptera: Coccinellidae) fed on *Myzus persicae* (Sulzer) (Homoptera: Aphididae). *Environmental Entomology* 32, 327-333.

Chi, H. (2014) TWOSEX-MSChart: Computer program for age-stage, two-sex life table analysis. Taichung, Taiwan: National Chung Hsing University http://140.120.197.173/Ecology/prod02.htm.

Davoodi, D. S., Sahragard, A., & Hajizadeh,J. (2013) The effect of prey density on life table parameters of *Hippodamia variegata* (Coleoptera: Coccinellidae) fed on *Aphis gossypii* (Hemiptera: Aphididae) under laboratory conditions. *ISRN Entomology*. Article ID 281476, 7 pages.

Farhadi, R., Allahyari, H., & Chi, H. (2011) Life table and predation capacity of *Hippodamia variegata* (Col.: Coccinellidae) feeding on *Aphis fabae* (Hem.: Aphididae). *Biological Control* 59, 83-89.

Franzmann, B. A. (2002) *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae), a predacious ladybird new in Australia. *Australian Journal of Entomology* 41, 375-377.

Hodek, I., & Honek, A. (1996) Ecology of Coccinellidae. Dordrecht, the Netherlands: Kluwer Academic. pp. 464.

Isenhour, D. J., & Yeargan, K. V. (1981) Predation by *Orius insidiosus* on the soybean thrips, *Sericothrips variabilis*: effect of prey stage and density. *Environmental Entomology* 10, 496-500.

Kennedy, J. S., Day, M. F., & Eastop, V. F. (1962) A conspectus of aphids as vectors of plant viruses. London, Eastern, UK, 114 pp.

Khanamani, M., Fathipour, Y., & Hajiqanbar, H. (2015) Assessing compatibility of the predatory mite *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) and resistant eggplant cultivar in a tritrophic system. *Annals of the Entomological Society of Americ*a 108(4), 501-512.

Khodaverdi, H., Sahragard, A., Amir-Maafi, M., & MohagheghNeyshabouri, J. (2012) Biological and predation characteristics of *Andrallus spinidens* (Heteroptera: Pentatomidae) fed on fourth instar larvae of *Spodoptera littoralis* (Lepidoptera: Noctuidae) under laboratory conditions. *Journal of Entomological Society of Iran* 32 (1), 1-19.

Leclant, F., & Deguine J. P. (1994) Aphids (Homoptera: Aphididae). pp. 285-323In: Matthews, G. A. & Tunstall, J. P. (eds). *Insect Pests of Cotton*. CAB International, Wallingford.

McConnell, J. A., & Kring, T. J. (1990) Predation and dislodgment of *Schizaphis graminum* (Homoptera: Aphididae), by adult *Coccinella septempunctata* (Coleoptera: Coccinellidae). *Environmental Entomology* 19, 1798-1802.

Milne, M., & Walter, G. H. (1997) The significance of prey in the diet of the phytophagous thrips, *Frankliniella schultzei*. *Ecological Entomology* 22, 74-81.

Nelson E. H., & Rosenheim, J. A. (2006) Encounters between aphids and their predators: The Relative frequencies of disturbance and consumption. *Entomologia Experimentalis et Applicata* 118, 211-219.

Obrycki, J. J., & Orr, C. J. (1990) Suitability of three prey species for Nearctic populations of *Coccinella septempunctata*, *Hippodamia variegata* and *Propylea quatrodecimpunctata* (Coleoptera: Coccinellidae). *Journal of Economic Entomology* 83, 1292-1297.

Rabb, R. L. (1974) Naturally occurring biological control in the eastern United States, with particular reference to tobacco insects. pp. 294-309. In: Huffaker, C. B. (ed.) *Biological Control*. 539 pp. Plenum Publ. Co. New York.

Raboudi, F., Ben Moussa, A., Makni, H., Marrakchi, M., &Makni, M. (2002) Seriological detection of plant viruses in their aphid vectors and host plants in Tunisia. *EPPO Bulletin* 32, 495-498.

Yu, J. Z., Chi, H., & Chen, B. H. (2005) Life table and predation of *Lemnia biplagiata* (Coleoptera: Coccinellidae) fed on *Aphis gossypii* (Homoptera: Aphididae) with a proof on relationship among gross reproduction rate, net reproduction rate, and pre adult survivorship. *Annals of the Entomological Society of America* 98, 475-482.

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