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Research Article

Host stage preference and age-specific functional response of *Praon volucre* (Hymenoptera: Braconidae, Aphidiinae) a parasitoid of *Acyrthosiphon pisum* (Hemiptera: Aphididae)

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Abstract: The pea aphid, *Acyrthosiphon pisum* (Harris) is one of the most important pests of pea throughout the world. Host stage preference under choice and no-choice tests and age-specific functional response of *Praon volucre* (Haliday) parasitizing *A. pisum* were investigated. The experiments were carried out under laboratory conditions at 25 ± 1 °C, 60 ± 5% RH and a photoperiod of 14: 10 h (L: D). Functional response of *P. volucre* was evaluated in adult lifetime at seven host densities (2, 4, 8, 16, 32, 64 and 128). *Praon volucre* strongly preferred to oviposit into first and second instar nymphs in both choice and no-choice conditions. Parameter estimation of logistic regression revealed type III functional response for *P. volucre* in first and second days and type II from third to the end of parasitoid lifetime. The handling time (T_h) and searching efficiency (*a* or *b*) were estimated using the Rogers equation. The shortest and longest handling times were at fourth day (T_h = 0.19 ± 0.04) and 8th day (T_h = 0.94 ± 0.15), respectively. The highest searching efficiency (*a*) was 0.048 ± 0.007 h^{-1} on third day and lowest searching efficiency was observed at the end of parasitoid lifetime (6th day-8th days). The maximum attack rate ranged from 126.31 nymphs/24 h on fourth day to 25.53 nymphs/24 h on 8th day. The results of this study revealed that the age of adult parasitoid can change the functional response from type III to type II, indicating that this factor may contribute to stabilization of parasitoid–prey dynamics.

Keywords: Behavioral characteristics, pea aphid, parasitoid wasp, biological control

Introduction

The pea aphid, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae), is a cosmopolitan species and attacks different legume host plants including pea, broad bean, the red clover and alfalfa (Ciocoiu *et al.*, 2009; Peccoud *et al.*, 2009 a, b). The pea aphid is one of the most important pests of the pea and alfalfa in higher altitudes of Iran (Moravvej and Hatefi, 2008; Rakhshani *et al.*, 2009). *Acyrthosiphon pisum* affects plant growth not only directly through feeding on phloem sap but also by transmitting more than 30 viruses, including bean yellow mosaic virus (BYMV), red clover vein mosaic virus (RCVMV) and pea streak virus (PeSV) (Jones and Proudlove, 1991; Dixon, 1998), all of which reduce the yield of legume crops (Garlinge and Robartson, 1998).

The subfamily Aphidiinae (Hymenoptera: Braconidae) includes important biological

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control agents against aphids (Stary, 1988). *Praon volucre* is one of the most frequent species in the world including Iran (Stary, 1976; Kavallieratos *et al*., 2003, 2004; Rakhshani *et al*., 2007). This aphid parasitoid wasp was reported as the main parasitoid of *A. pisum* from Iran (Rakhshani *et al*., 2007).

In biological control, host stage preference is one of the most important factors that affects the potential of a parasitoid in suppressing an aphid population (Hagvar and Hofsvang, 1991). The optimal host selection aims to maximize the profits of the next parasitoid generation (Pyke, 1984; Pandey and Singh, 1999). The size of the host aphid influences its selection by parasitoids (Hagvar and Hofsvang, 1991; Sequeira and Mackauer, 1992). The functional response of natural enemies is also one of the main features for the selection of biological control agents (Wiedenmann and Smith, 1997). The functional response is defined as any change in the number of hosts attacked per parasitoid (or predator) as host density changes (Holling, 1968). The type of functional response and their parameters such as handling time and searching efficiency are affected by many factors such as the temperature and age of adult parasitoid (Hassell *et al*., 1977; Bellows and Hassell, 1988; Kidd and Jervis, 1989; Gitonga *et al*., 2002; Asadi *et al*., 2012).

The behavioral characteristics including host stage preference and functional response are key factors to determine efficiency of biological control agents. No data are available on the host stage preference and functional response of *P. volucre* on *A. pisum*. Therefore the objectives of this research were to evaluate the host stage preference and effect of different ages of *P. volucre* on its searching efficiency and its functional response at different densities of *A. pisum* as prey.

Materials and Methods

Plant and insect culture

Acyrthosiphon pisum and its parasitoid were collected from alfalfa fields on the campus of the Faculty of Agriculture, Tarbiat Modares University in Tehran, Iran (35°44´28.99″ N, 51°09´50.07″ E, 1205 m), during May and June 2012. The aphids were reared on broad bean seedlings, *Vicia faba*, (Barakat variety) grown in plastic pots (15 cm diameter and 15 cm height) and covered with transparent cylindrical plastic containers (13 cm diameter and 30 cm height). The colony of *P. volucre* was reared on different nymphal instars of *A. pisum* for one generation before starting the host stage preference and functional response experiments. All experiments were carried out on broad bean plants with 10-12 leaves at 25 ± 1 °C, 60 ± 5% relative humidity and a photoperiod of 14: 10 h (Light : Dark).

Host stage preference

Host-stage preference was determined by both choice and no-choice experiments. In the no-choice tests, 100 individual aphids of a same stage separately (first, second, third, and fourth nymphal instars and adult) were reared on a broad bean seedling and were exposed to a pair of male and female parasitoids aged maximum 36 hours. After 24 h, the parasitoids were removed. The aphids were reared on broad bean seedlings until mummies appeared. In the choice tests, all nymphal instars were established on a broad bean seedling (20 aphids from each nymphal instar on each seedling) and were then exposed to a pair of maximum 36-hours-old male and female parasitoids for 24 h. Then each instar was held separately until the aphids mummified. Both the choice and the no-choice preference tests were replicated 10 times. Experiments were carried out on braod bean seedlings, were planted in plastic pots (7.5 cm diameter and 8 cm height) in the same conditions as above. Plastic pots were placed in cylindrical plastic containers (30 cm diameter and 17cm height). Two holes (3 cm in diameter) covered with fine nylon mesh were prepared on two sides of the containers for ventilation. A streak of honey-water solution (20%) was placed inside cylindrical plastic containers as a source of carbohydrates and water for the adult parasitoids. Data from the prey stage preference experiments were first tested for normality using Kolmogrov-Smirnov test (SPSS ver.18, 2009). The data were then analyzed using one-way ANOVA. If significant differences were detected, the means were compared by Tukey's test (SAS Institute 2003).

Functional response

The effect of different host densities on rate of parasitism was determined during adult lifetime. A pair of male and female of newly emerged adult of parasitoid was transferred into container at seven host density levels (2, 4, 8, 16, 32, 64 and 128) of the second instar nymphs (as preferred host stage) of *A. pisum*. The parasitoid wasp was removed after 24 h and transferred into a new container of the same aphid group. This procedure was continued until the death of the female parasitoid. The experiments were replicated 15 times for each density. The experimental arena consisted of plastic pots (7.5 cm diameters and 8 cm height) that contained broad bean seedlings (6-8 leaf stages) which were covered with cylindrical plastic containers (9 cm diameter and 11.5 cm height). Honey-water solution (20%) was provided for adult parasitoids.

Data analysis

Type of functional response was determined using a logistic regression model (Messina and Hanks, 1998; De Clercq *et al.*, 2000; Juliano, 2001). The data were fitted to the logistic regression which describes the relationship between N_a / N_0 and N_0 (Juliano, 2001):

$$\frac{N_a}{N_0} = \frac{\exp(P_0 + P_1 N_0 + P_2 N_0^{\ 2} + P_3 N_0^{\ 3})}{1 + \exp(P_0 + P_1 N_0 + P_2 N_0^{\ 2} + P_3 N_0^{\ 3})}$$

Where P_0, P_1, P_2, and P_3 are the intercept of linear, quadratic and cubic coefficients, respectively and estimated using the method of maximum likelihood. N_a is the number of aphid nymphs which is parasitized, N_o is the number of hosts available. Significant negative or positive linear coefficients (*i.e.*, P_1) from the logistic regression model indicate Type II or Type III, respectively (Juliano, 2001). A type II functional response is declining (*i.e.*, P_1 is negative), whereas the type III response is sigmoid and accelerating (*i.e.*, P_1 is positive). After defining the type of functional response the handling time (T_h) and searching efficiency (a) of a type II and instantaneous attack rate (b) and handling time (T_h) of type III were estimated by random parasitoid equation (Rogers, 1972).

The Rogers' type II random parasitoid model is:

$$N_a = N_0\left[1 - \exp\left(-\frac{aT\,Pt}{aT_h N_0}\right)\right]$$

The Rogers' type III random parasitoid model is:

$$N_a = N_0\left[1 - \exp\left(\frac{bT\,P_t}{1 + bT_h N_t}\right)\right]$$

Where N_a is the number of host parasitized, N_0 is the density of host available, T is the total time of the experiment (=24 h), a is the searching efficiency (h^{-1}), P_t is the number of parasitoid and T_h is the handling time (h). The searching efficiency (a) in type III functional response was calculated by formula: $a = bN_0$

b is instantaneous attack rate in Rogers' type III equation N_0 is the density of host available.

The functional response parameters were estimated with nonlinear regression (the least square technique with DUD initialization). Statistical analysis of functional response was performed using the SAS software (SAS Institute, 2003). The mean numbers of host that were parasitized by *P. volucre* at different host densities were compared using one-way ANOVA (SPSS ver.18, 2009).

Results

Host stage preference

In the no-choice experiment *P. volucre* parasitized all nymphal instars and adults of *A. picum*. There was significant difference among the numbers of mummified aphids at different aphid instar nymphs ($F = 42.411$; d.f. = 4, 45; $P < 0.05$). The mean numbers of aphid parasitized at each nymphal instar (1^{st} to 4^{th}) and the newly emerged adults of *A. pisum* were 51 ± 6.64, 49.2 ± 3.83, 19.5 ± 3.21, 2.3

± 0.83 and 1.1 ± 0.55, respectively. The female parasitoid preferred to oviposit into the first and second instar nymphs with no significant difference between these two nymphal instars. In the choice experiment, *P. volucre* females did not parasitize adult aphids ($F = 11.66$; d.f. = 3, 36; $P < 0.05$) but the obvious preference for the first and second instar nymphs were also reflected in the results for the choice experiment (Fig. 1).

Functional response

The mean parasitism rates of second instar nymphs of *P. volucre* during female parasitoid life time are shown in Table 1. The mean number of host parasitized at densities of 4 ($F = 4.437$; d.f. = 7, 96; $P < 0.05$), 8 ($F = 4.590$; d.f. = 7, 99; $P < 0.05$), 32 ($F = 10.669$; d.f. = 7, 89; $P < 0.05$), 64 ($F = 7.088$; d.f. = 7, 95; $P < 0.05$) and 128 ($F = 5.965$; d.f. = 7, 87; $P < 0.05$) were significantly different in the whole parasitoid lifetime, but the lifetime of parasitoid wasp had no significant effect on proportion of host parasitized at densities 2 ($F = 0.608$; d.f. = 7, 105; $P > 0.05$) and 16 ($F = 0.695$; d.f. = 7, 90; $P > 0.05$). The highest mean numbers of host parasitized were observed in the second and third day (Table 1). The mean number of parasitism increased with host density from 2nd to 7th day of parasitoid lifetime.

The results of logistic regression to distinguish between type II and III responses are shown in Table 2. The positive values for the linear coefficients (P_1) indicated a type III functional response for *P. volucre* in first and second days and type II from third day to the end of parasitoid lifetime. The functional response curve of *P. volucre* on different host density for its whole lifetime is illustrated in Fig. 2. The proportion of hosts parasitized by *P. volucre* declined with increasing parasitoid age.

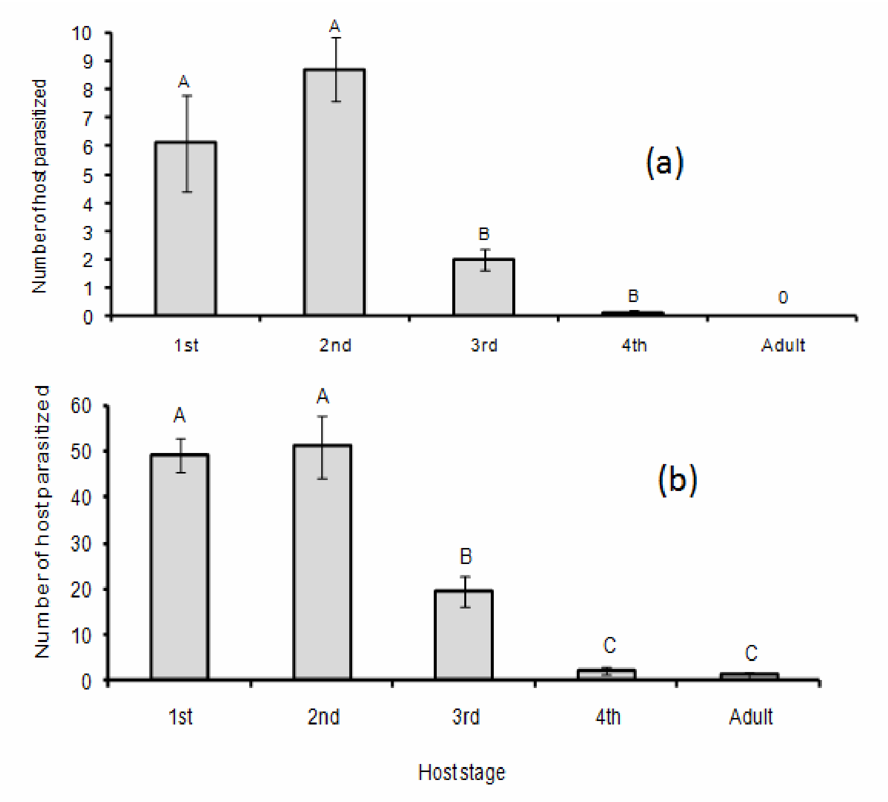

Figure 1 Host-stage preference of *Acyrthosiphon pisum* parasitized by *Praon volucre* in choice (*a*) and no-choice (*b*) tests.

Table 1 The mean number of parasitized (± SEM) of second instar nymphs of *Acyrthosiphon pisum by Praon volucre* in the life time (days).

Density	1	2	3	4	5	6	7	8
2	1.40 ± 0.21^{D,a}	1.27 ± 0.15^{D,a}	1.60 ± 0.16^{E,a}	1.33 ± 0.19^{D,a}	1.33 ± 0.16^{D,a}	1.00 ± 0.66^{D,a}	1.31 ± 0.18^{E,a}	1.20 ± 0.25^{D,a}
4	1.27 ± 0.28^{D,c}	2.53 ± 0.27^{D,abc}	3.07 ± 0.25^{E,a}	2.53 ± 0.32^{D,abc}	2.43 ± 0.20^{D,abc}	1.62 ± 0.33^{D,bc}	3.09 ± 0.34^{E,a}	3.00 ± 0.46^{CD,ab}
8	3.00 ± 0.55^{CD,b}	5.07 ± 0.40^{D,a}	5.40 ± 0.42^{DE,a}	4.73 ± 0.47^{D,ab}	4.76 ± 0.45^{D,ab}	4.42 ± 0.50^{CD,ab}	4.17 ± 0.39^{DE,ab}	3.78 ± 0.22^{CD,ab}
16	9.27 ± 0.89^{C,a}	8.60 ± 0.876^{D,a}	10.33 ± 0.96^{D,a}	8.40 ± 0.86^{CD,a}	9.00 ± 1.05^{CD,a}	8.70 ± 0.54^{C,a}	8.56 ± 1.06^{CD,a}	10.83 ± 1.49^{BC,a}
32	20.13 ± 1.64^{B,ab}	22.13 ± 1.35^{C,a}	18.80 ± 1.44^{C,ab}	14.93 ± 1.17^{C,bc}	14.33 ± 0.80^{C,bc}	10.83 ± 0.98^{C,c}	10.80 ± 1.57^{C,c}	8.75 ± 2.32^{BCD,c}
64	33.60 ± 3.16^{A,ab}	37.53 ± 2.52^{B,a}	31.07 ± 1.89^{B,ab}	31.40 ± 2.77^{B,ab}	29.00 ± 2.76^{B,abc}	22.42 ± 1.73^{B,bcd}	17.18 ± 1.87^{B,cd}	16.83 ± 4.64^{AB,d}
128	36.53 ± 1. 51^{A,abc}	50.67 ± 3.42^{A,a}	49.60 ± 3.10^{A,a}	47.73 ± 3.61^{A,ab}	41.85 ± 5.00^{A,ab}	34.60 ± 4.15^{A,abc}	31.86 ± 2.67^{A,bc}	20.40 ± 2.09^{A,c}

Means in a column followed by different capital letters are significantly different (Tukey's test, $P < 0.05$) and means in a row followed by different small letters are significantly different (Tukey's test, $P < 0.05$).

Table 2 Results of logistic regression analysis of the proportion of *Acyrthosiphon pisum* second nymphs parasitized by *Praon volucre* in adult female life time.

Female parasitoid Age (days)	P_0	P_1	P_2	P_3
1	-0.654 ± 0.195	0.074 ± 0.016	-0.0010 ± 0.0003	$6\times10^{-6} \pm 1\times10^{-6}$
2	0.175 ± 0.195	0.032 ± 0.015	-0.0006 ± 0.0003	$3\times10^{-6} \pm 1\times10^{-6}$
3	1.129 ± 0.210	-0.034 ± 0.016	0.0003 ± 0.0003	$-1\times10^{-6} \pm 1\times10^{-6}$
4	0.736 ± 0.197	-0.052 ± 0.015	0.0009 ± 0.0003	$-5\times10^{-6} \pm 1\times10^{-6}$
5	0.786 ± 0.206	-0.053 ± 0.016	0.0008 ± 0.0003	$-4\times10^{-6} \pm 1\times10^{-6}$
6	0.362 ± 0.209	-0.046 ± 0.017	0.0007 ± 0.0003	$-3\times10^{-6} \pm 2\times10^{-6}$
7	0.984 ± 0.230	-0.079 ± 0.018	0.0010 ± 0.0003	$-4\times10^{-6} \pm 2\times10^{-6}$
8	0.982 ± 0.281	-0.075 ± 0.025	0.0010 ± 0.0005	$-4\times10^{-6} \pm 2\times10^{-6}$

Rogers' type III equation was fitted for first and second days and type II was fitted from third to eighth days of parasitoid female lifetime. The estimated values of searching efficiency and handling time of *P. volucre* are shown in Table 3. The searching efficiency (a) varied in response to parasitoid lifetime and was highest at 3rd day and lowest at the end of lifetime (6th, 7th and 8th day). The handling time was also different in parasitoid life time. The lowest and highest handling times were observed at 4th day (T_h = 0.19 ± 0.04) and 8th day (T_h = 0.94 ± 0.15), respectively. The maximum attack rate ranged from 126.31 nymphs/24 hon fourth day to 25.53 nymphs/24 h on 8th day. The maximum value of a/T_h (0.22) was observed on 3rd day. Parasitism rate of second instar nymphs of *A. pisum* by *P. volucre* at different ages are shown in Fig. 3.

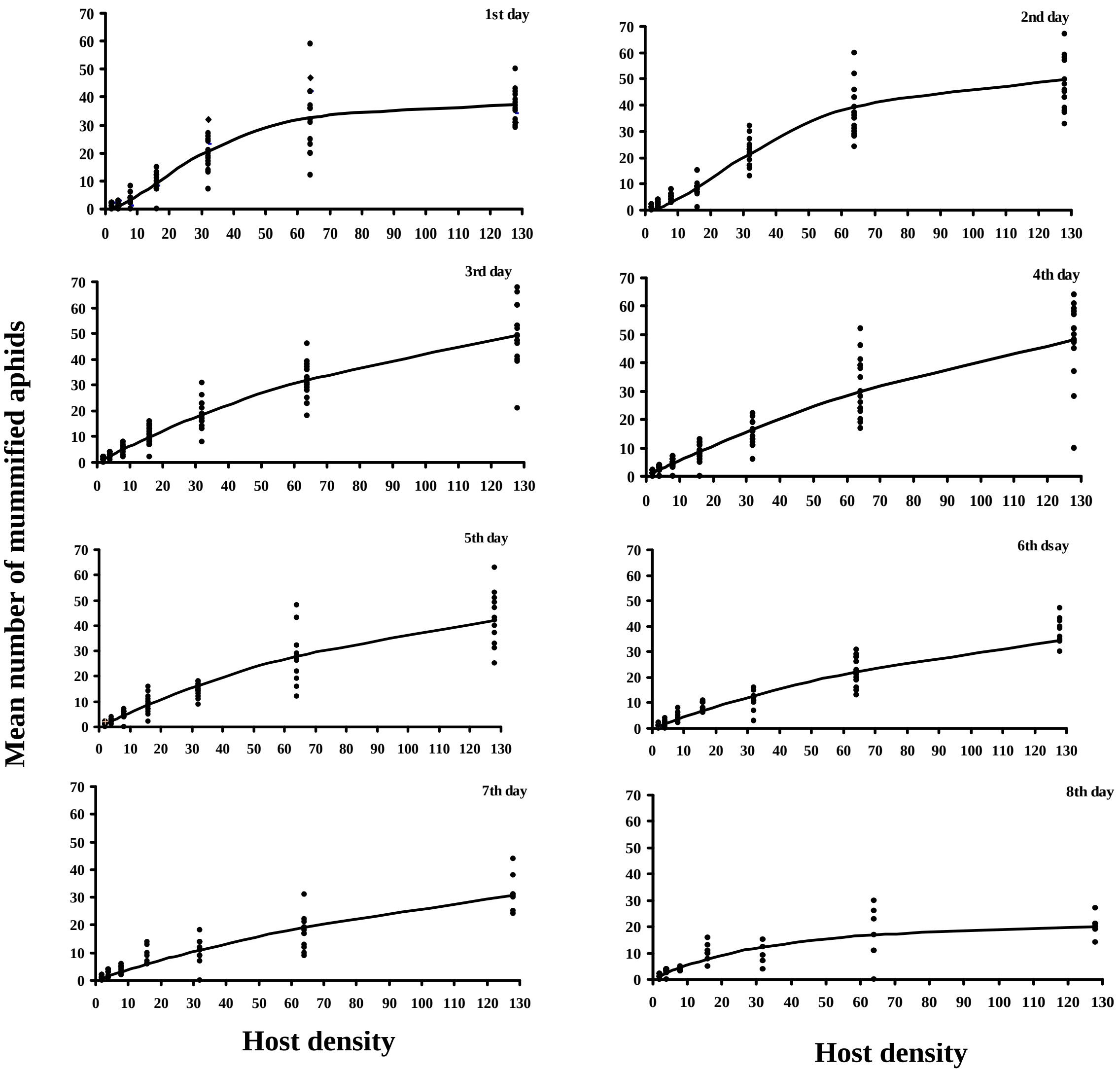

Figure 2 Age specific functional response of *Praon volucre* on different densities of second instar nymphs of *Acyrthosiphon pisum* using the Rogers type III and II model.

Table 3 Estimated values for searching efficiency (a) and handling time (T_h) from Rogers' type II and III equations for *Praon volucre* females of different ages.

Female parasitoid age (days)	Searching efficiency (a) (h^{-1})	Handling time (T_h) (h)	Maximum attack rate (T/T_h)	a/T_h
1	0.004 ± 0.0011*	0.51 ± 0.02	47.06	-
2	0.003 ± 0.0008*	0.35 ± 0.02	68.57	-
3	0.048 ± 0.007	0.22 ± 0.03	109. 09	0.22
4	0.038 ± 0.006	0.19 ± 0.04	126.31	0.20
5	0.039 ± 0.008	0.27 ± 0.06	88.88	0.14
6	0.020 ± 0.002	0.34 ± 0.05	70. 58	0.06
7	0.021 ± 0.003	0.32 ± 0.08	75.00	0.06
8	0.020 ± 0.021	0.94 ± 0.15	25. 53	0.02

* = b and $a = bN_0$

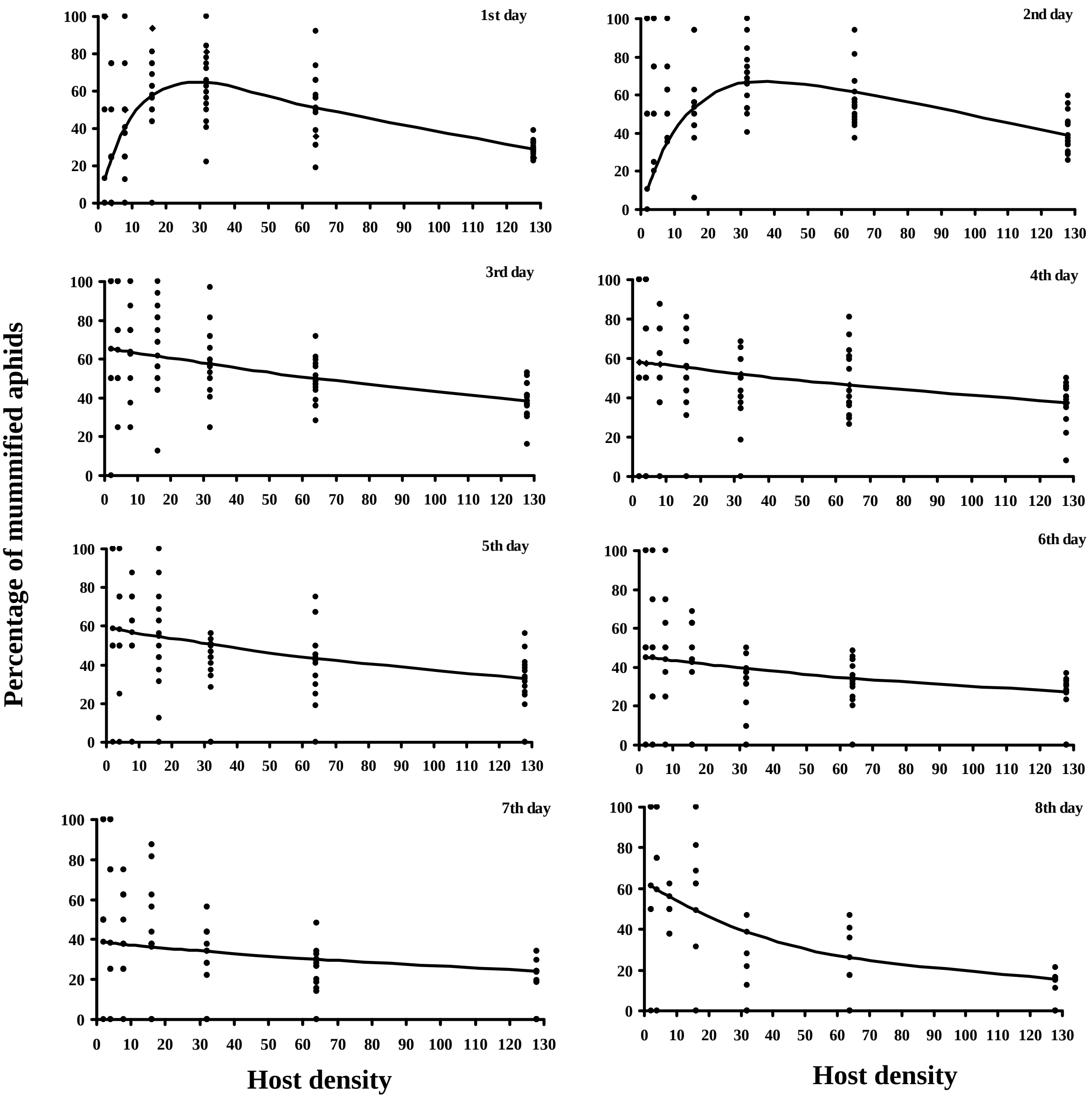

Figure 3 Percentage of parasitism on second instar nymphs of *Acyrthosiphon pisum* by *Praon volucre on* different days of life time.

Discussion

Praon volucre oviposited in all instar nymphs of the pea aphid in choice preference test and parasitized all instar nymphs and adults of *A. pisum* in no-choice preference test. Our findings revealed that *P. volucre* preferred to oviposit into first and second instar nymphs of *A. pisum.* Previous studies showed that *P. volucre* preferred second instar nymphs of *Sitobion avenae* (Fabricius) for oviposition (Farhad *et al*., 2011). In agreement with our findings, *Monoctonus paulensis* (Ashmead) preferred first and second instar nymphs of *A. pisum* for oviposition (Chau and Mackauer, 2000) While *Diaeretiella rapae* (Mclntosh) preferred to oviposit into third and fourth instar nymphs of *Diuraphis noxia* (Mordvilko) (Tazerouni *et al*., 2011). In this research, female parasitoid wasps were able to parasitize all stages of aphids but they preferred to oviposit into first and second instar nymphs. This result may be related to defensive behavior of the third and fourth instar nymphs and may result in increasing the handling time of female parasitoids (Liu *et al.*, 1984; Kant *et al.*, 2008). In addition Mackauer and Kambhampati (1988) suggested that more adult parasitoids emerged from early instar nymphs in comparison to adult aphids. It is believed that host stage preference is affected by different factors such as experimental condition, host densities and host defensive behavior (Stary, 1988; Wyckhuys *et al.*, 2008). Choosing the age specific of the host by parasitoid can affect the population growth of parasitoid and host. Also it is an important to determine parasitoid ability to control the pest population (Hagvar and Hofsvang, 1991).

The results of this study showed that the age of adult parasitoid, *P. volucre* affects the searching efficiency and the type of functional response. The functional response studies at different ages of parasitoid provide better insights into the behavior of an insect natural enemy. Significant positive linear coefficient of the logistic regression model indicated a type III functional response in first and second dayof parasitoid lifetime. The functional response on the third day to the last day of life time (eighth day) was type II. The Type II functional response has been reported for other parasitoid such as *D. rapae* on *D. noxia* (Lester and Holtzer, 2002; Tazerouni *et al.*, 2012) and on *Brevicoryne brassicae* (Linnaeus) (Fathipour *et al.*, 2006), *Aphidius uzbekistanicus* (Luzhetzki) on *Metopolophium dirhodum* (Walker) (Dransfield, 1979), *Aphidius ervi* Haliday on *A. pisum* (Ives *et al.*, 1999), *Aphidius matricariae* (Haliday) on *Aphis fabae* Scopoli (Tahriri *et al.*, 2007) and *A. matricariae* on *A. gossypii* (Zamani *et al.*, 2006).

Van Alphen and Jervis (1996) stated that the type II functional response in insects is more frequent than type III, but in determining the efficiency of parasitoid, type III functional response is more beneficial than type II (Fathipour *et al.*, 2003). The Type III functional response has been reported for several parasitoids such as *P. volucre* on *S. avenae* (Stilmant, 1996), *Aphidius colemani* (Viereck) on *Aphis gossypii* (Glover) (Van steenis and El-khawass, 1995), *D. rapae* on *Lipaphis erysimi* (Koltenbach) (Pandey *et al.*, 1984; Abidi *et al.*, 1987), *A. colemani* and *Lysiphlebus testaceipes* Cresson on *Schizaphis graminum* (Rondani) (Jones *et al.*, 2003), *Trioxys palidus* (Halliday) on *Chromoaphis juglandicola* (Kaltenbach) (Rakhshani *et al.*, 2004) and *Trioxys indicus* Subba Rao and Sharma on *Aphis craccivora* Koch (Singh and Sinha, 1983).

The functional response can also be affected by various factors including plant cultivar, parasitoid strain, host species, temperature, time of exposure and age of parasitoid. Thus in different experimental conditions, the type of functional response may change among parasitoid wasps (Hassell *et al.*, 1977; Messina and Hanks, 1998; Fathipour *et al.*, 2001; Lester and Holtzer, 2002).

The maximum estimated searching efficiency for *P. volucre* on *A. pisum* was on third day of adult life (0.045 day^{-1}). According to Farhad *et al.* (2011), searching efficiency of *P. volucre* on *S. avenae* was highest on first day of adult life (0.03 day^{-1}). Also it was (0.062 h^{-1}) for *D. rapae* on *D. noxia* (Tazerouni *et al.*, 2012). Searching efficiency in a 24 hours period of time for *A. colemani* and *A. matricariae* on *A. gossypii* was reported 0.869 day^{-1} and 0.687 day^{-1}, respectively (Zamani *et al.*, 2006). In parasitoids, handling time is defined as the time interval between two ovipositions and lower handling time means the parasitoid can parasitiz more number of hosts in a given time interval (Rogers, 1972; Hassell, 1978). The lowest handling time of *P. volucre* on *A. pisum* was observed on fourth day of its life time (0.19 h). In this study, handling time was also (1.02 h) lower than that reported by Farhad *et al.* (2011) for *P. volucre* on *S. avenae*.

In current study, the maximum attack rate of *P. volucre* increased with age of adult parasitoid, reached to the highest level on fourth day and declined as the parasitoid approached the end of its reproductive life This result shows that the parasitoid on the fourth day (mid-life) has more ability to parasitize its host. The maximum attack rate for *P. volucre* on *S. avenae* was 23.52 nymphs/24h by Farhad *et al*. (2011) which is lower than that obtained in this study This may be due to the origin of the populations, different experimental conditions and host species.

Our laboratory results revealed that *P. volucre* can be useful as biological control agent against *A. pisum*. Host stage preference and functional response are important factors in determining the potential of parasitoid before using of the parasitoid in the management programs. However, other factors such as environmental conditions, host plant, and parasitoid longevity may affect the efficiency of natural enemies (Montoya *et al*., 2000). Therefore, for accurate interpretation of the efficacy of *P. volucre* against *A. pisum,* more studies are recommended.

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ترجیح مرحله میزبانی و واکنش تابعی وابسته به سن زنبور *Praon volucre* (Hymenoptera: Braconidae: Aphidiinae) پارازیتویید شته *Acyrthosiphon pisum* (Hemiptera:Aphididae)

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چکیده: شته نخود، *Acyrthosiphon pisum* (Harris) یکی از آفات مهم نخود در ایران و جهان است. ترجیح مرحله سنی میزبان به دو صورت انتخابی و غیرانتخابی و واکنش تابعی وابسته به سن زنبور پارازیتویید *Praon volucre* (Haliday) روی شته نخود *A. pisum* در اتاقک رشد با دمای ۱ ± ۲۵ درجه سلسیوس، رطوبت نسبی ۵ ± ۶۰٪ و دوره نوری ۱۴ : ۱۰ ساعت (روشنایی: تاریکی) مورد بررسی قرار گرفت. واکنش تابعی در روزهای مختلف عمر زنبورهای ماده بالغ *P. volucre* در ۷ تراکم مختلف (۲، ۴، ۸، ۱۶، ۳۲، ۶۴ و ۱۲۸) پوره سن دوم (به‌عنوان سن مرجح) میزبان مورد بررسی قرار گرفت. در هر دو روش انتخابی و غیرانتخابی، زنبور پارازیتویید *P. volucre* پوره‌های سنین اول و دوم میزبان را برای تخم‌گذاری ترجیح داد. نتایج حاصل از رگرسیون لجستیک نشان داد واکنش تابعی زنبور پارازیتویید *P. volucre* در روزهای اول و دوم عمر زنبور از نوع سوم و از روز سوم تا روز آخر عمر از نوع دوم بود. مدت زمان دستیابی (T_h) و قدرت جستجوگری (a یا b) با استفاده از مدل Rogers برآورد شد. کم‌ترین و بیش‌ترین مدت زمان دستیابی به میزبان به‌ترتیب در روز چهارم (۰/۰۴ ± ۰/۱۹) و هشتم (۰/۱۵ ± ۰/۹۴) عمر زنبور پارازیتویید مشاهده شد. حداکثر مقدار قدرت جستجوگری در روز سوم (۰/۰۰۵ ± ۰/۰۴۸ بر ساعت) و حداقل آن در روزهای پایانی عمر زنبور (روزهای ششم تا هشتم) مشاهده شد. مقدار حداکثر نرخ پارازیتیسم زنبور پارازیتویید طی ۲۴ ساعت از ۱۲۶/۳۱ پوره در روز چهارم تا ۲۵/۵۳ پوره در روز هشتم عمر زنبور پارازیتویید متغیر بود. نتایج حاصل از این تحقیق نشان داد زنبور پارازیتویید *P. volucre* یکی از عوامل بیوکنترل مؤثر علیه شته *A. pisum* است.

واژگان کلیدی: ویژگی‌های رفتاری، شته نخود، زنبور پارازیتویید، کنترل بیولوژیک