

## Effect of different foraging periods on the functional response of *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae) at different densities of *Aphis craccivora*

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**Abstract:** Searching efficiency and handling time are two major components of functional response and are usually used to evaluate effectiveness of natural enemies. The effect of different foraging periods on the functional response of larval *Aphidoletes aphidimyza* (Rondani) (Dip.: Cecidomyiidae) feeding on third instar nymphs of *Aphis craccivora* was studied. The experiment was conducted in terms of time-specific (1, 2, 4, 6, 12, 24 h.) functional response to varying densities (5, 10, 20, 40, 60 and 80) of third instar nymphs of *A. craccivora* at  $23 \pm 1$  °C,  $70 \pm 5\%$  of R.H., and a photoperiod of 16:8 h (L: D). Parameter estimates for logistic regressions showed a type II functional response for 4 day-old larvae of the predator at different foraging periods to varying densities of *A. craccivora*. The estimated searching efficiency ( $a'$ ) and handling times ( $T_h$ ), varied with foraging periods. The searching efficiency showed a decreasing trend as the foraging periods increased. The estimated maximum rates of predation ( $T/T_h$ ) for the 4-day old larvae were directly related to the foraging periods increase but handling times ( $T_h$ ), showed a decelerating trend. In conclusion it was found that searching efficiency was a variable parameter in different foraging periods of *A. aphidimyza* and was lowest at the foraging periods of 24 h. It was also suggested that *A. aphidimyza* with type II functional response in all foraging periods, could be considered as a highly effective biological agent in suppressing *A. craccivora* population.

**Keywords:** *Aphidoletes aphidimyza*, *Aphis craccivora*, foraging periods, functional response

### Introduction

The cowpea aphid, *Aphis craccivora* (Koch) (Hemiptera: Aphididae) as a cosmopolitan pest feeds on several host plants especially Fabaceae. It is considered as a major pest of important economic crops such as alfalfa, beans and cowpea, *Vigna unguiculata* (L.) in Africa, Asia and Latin America (Singh and Jackai,

1985; Pettersson *et al.*, 1998). It has been reported that this aphid can transmit some plant pathogenic viruses (Coceano and Peressini, 1989; Chen *et al.*, 1999).

The aphidophagous, *Aphidoletes aphidimyza* (Rondani) (Diptera: Cecidomyiidae) is an effective predator of many aphid species worldwide in glasshouses, on field crops, and fruit trees (Morse, 1981). It shows great promise as a biological control agent because of its high degree of density-dependency (El-Titi, 1973) and its tendency to kill more aphids than it consumes (Uygun, 1971).

The functional response also as a behavioral response is one of the most widely measured

Handling Editor: Dr. Yaghoub Fathipour

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Received: 11 November 2013, Accepted: 15 January 2014  
Published online: 18 January 2014

attributes and the efficiency of predators and parasitoids (Trexler *et al.*, 1988; De Clercq *et al.*, 2000; Lester and Harmsen, 2002; Badii *et al.*, 2004; Reis *et al.*, 2003, 2007; Fathipour *et al.*, 2006; Timms *et al.*, 2008; Casas and Mccauley, 2012). Phenomenalistic descriptions of how predator attack rates differ with prey availability are basic components of consumer resource models. The application of these models typically assumes continuous foraging by individuals, along with stationary in their behavioral and physiological processes (Casas and Mccauley, 2012). However, most species display a diurnal cycle in foraging and resting, and the impact of this foraging pattern on the functional response is unknown (Casas and Mccauley, 2012). The state spaces for parasitoids and predators are the number of mature eggs, the egg load, and the satiation level, respectively (Casas and Mccauley, 2012). The corresponding rates are those of egg maturation and oviposition on one hand, and digestion and prey capture on the other (Casas and Mccauley, 2012).

Attack rate or searching efficiency ( $a'$ ) and handling time ( $T_h$ ) are the two major components of functional response to assess the effectiveness of predators and parasitoids (Hassell and Waage, 1984). The rate of these parameters are affected by different factors such as: age of a predator (Ding-Xu *et al.*, 2007) and a parasitoid (Sahragard, 1989; Asadi *et al.*, 2012), developmental stages of predator (Yaşar and Özger, 2005a; Farhadi *et al.*, 2010), sex of predator (Rocha and Redaelli, 2004; Farhadi *et al.*, 2010), parasitoid density (Tahriri *et al.*, 2007), prey and host developmental stages (De Jong and van Alphen, 1989; Godfray, 1994; Joyce *et al.*, 2001; Gonza'lez-Herna'ndez *et al.*, 2005; Chong and Oetting, 2006 a; Taleb and Sardar, 2007), prey size, availability and density (Laing and Osborn, 1974; Cogni *et al.*, 2002; Pervez and Omkar, 2005; Varone *et al.*, 2007), host age and density (Chen *et al.*, 2006; Chong and Oetting, 2006 b), host plant and plant architecture (De Clercq *et al.*, 2000; Garcia and O'Neil, 2000; Madadi *et al.*, 2007; Timms *et al.*, 2008), and the size of arenas (Yaşar and Özger,

2005b; Sabaghi *et al.*, 2011b). Casas and Mccauley (2012) on the other hand, showed that temporal variation in foraging activity may have high influence on the estimate of interaction rates for predator-prey dynamics. They also stated that the simple approach that is most commonly used implicitly assumes that the functional response is time-invariant, and hence that all underlying behavioral and physiological processes are constant.

The functional response of *A. aphidimyza* has only been studied at its larval stage to different densities of *Aphis pomi* (Degeer) in 24 h. experiment that was a type II (Morse and Croft, 1987). The larval age-specific searching efficiency of *A. aphidimyza* has also been studied during its larval stage (Madahi, 2012). However, the objectives of this research were to evaluate the effect of different foraging periods on searching efficiency and functional responses of *A. aphidimyza* larvae at different densities of *A. craccivora* as prey.

## Materials and Methods

The nymphs of *A. craccivora* were collected from *Robinia pseudoacacia* L. and reared on black eyed bean, *Vigna unguiculata* (L.). The larvae of *A. aphidimyza* were collected from the colony of *A. craccivora* in an infested black eyed bean field at the College of Agriculture in the University of Guilan (Northern Iran). The predators were reared for two generations on different instars of *A. craccivora* before starting the functional response experiments. All aphids and predator stocks were kept in a growth chamber at  $23 \pm 1$  °C,  $70 \pm 5\%$  relative humidity (R. H.), and a photoperiod of 16:8h (L: D).

## Functional response

In order to evaluate the searching efficiency and handling time of *A. aphidimyza*, the functional response of *A. aphidimyza* was studied at six time periods (1, 2, 4, 6, 12, 24 h) to different densities of third instar nymphs of *A. craccivora* as prey at ( $23 \pm 1$  °C,  $70 \pm 5\%$  relative humidity (R. H.) and a photoperiod of 16:8h (L: D). Since it was very difficult to separate larval instars of the predator,

the experiments were done with 4-day old larvae of *A. aphidimyza*. They were exposed to different densities (5, 10, 20, 40, 60 and 80) of third instar nymphs of *A. craccivora* separately on a black eyed bean leaf in a transparent plastic container (15 × 13 × 3 cm). Aphids were gently transferred with a fine brush from the host plant to the leaves in experimental arenas. After different foraging periods (1, 2, 4, 6, 12, 24 h), the number of aphids eaten by the larvae of *A. aphidimyza* was recorded. Each foraging periods and prey density was replicated 10 times.

### Data analysis

The type of the functional response was determined by logistic regression analysis [SAS/STAT, CATMOD procedure (SAS version 9.1)] of the proportion of prey killed ( $N_a$ ) in relation to initial prey density ( $N_0$ ) (Trexler and Travis, 1993). The data were fitted to the logistic regression which describes the relationship between  $N_a/N_0$  and  $N_0$  (Juliano, 1993):

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

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. If the linear parameter  $P_1$  is negative, a type II functional response is obtained, whereas a positive linear parameter indicates density-dependent predation and thus a type III functional response (Juliano, 1993).

The Rogers' type II random predator model is:

$$N_a = N_0(1 - \exp[-a(T - T_h N_a)])$$

Where  $N_0$  is initial prey density,  $N_a$ , number of prey consumed,  $T$  is the total time (different foraging periods),  $a$  is the attack rate ( $\text{h}^{-1}$ ), and  $T_h$  is handling time in hours.

Statistical analysis of the functional response was performed using the SAS software (SAS Institute, 2001). A nonlinear regression was used (the least square technique with DUD initialization) to estimate parameters. Curves were drawn using the Excel software.

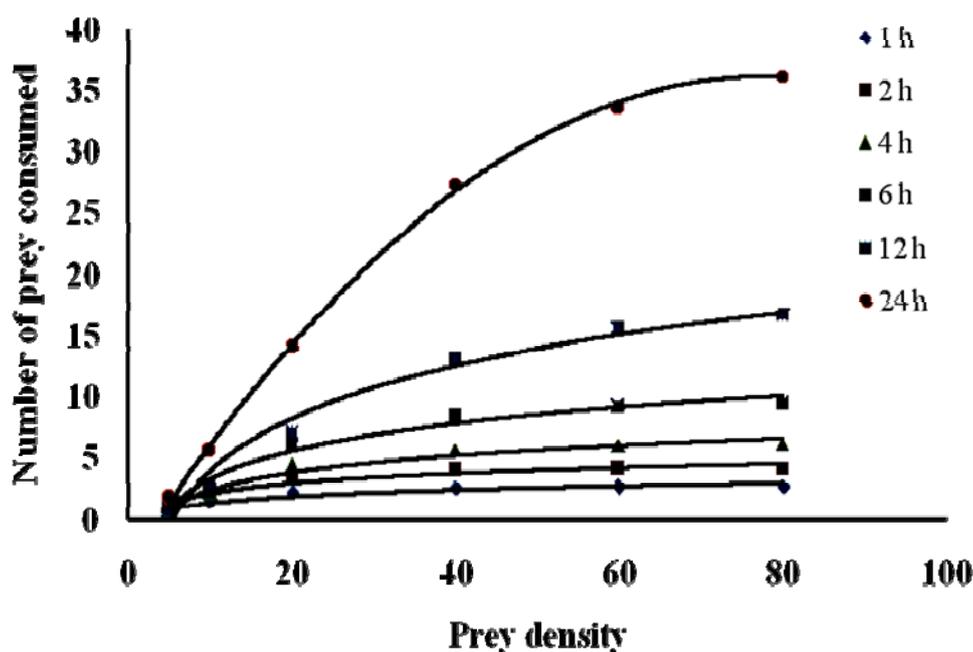
### Results

The prey consumption rate of 4-day-old larvae of *A. aphidimyza* at different prey densities and different foraging periods were all significantly different (1 hour:  $F_{2,60} = 221.30$ ,  $p < 0.0001$ ; 2 hours:  $F_{2,60} = 266.20$ ,  $p < 0.0001$ ; 4 hours:  $F_{2,60} = 237.19$ ,  $p < 0.0001$ ; 6 hours:  $F_{2,60} = 582.88$ ,  $p < 0.0001$ ; 12 hours:  $F_{2,60} = 640.37$ ,  $p < 0.0001$ ; 24 hour:  $F_{2,60} = 774.59$ ,  $p < 0.0001$ ).

Parameter estimates for logistic regressions of proportion of prey killed ( $N_a/N_0$ ) against number of prey offered ( $N_0$ ) showed that the linear parameter  $P_1$  was negative, resulting in a type II functional response (Table 1). Therefore, the 4-day-old larvae of *A. aphidimyza* showed a type II functional response at all different foraging periods to varying densities of *A. craccivora* (Fig. 1)

**Table 1** Maximum likelihood estimate from logistic regression of proportion of third instar *Aphis craccivora* eaten as a function of initial prey densities by *Aphidoletes aphidimyza* 4-day-old larvae at different foraging periods.

Time interval (h)	Parameters	Estimate	SE	p
1	Constant	-1.3244	0.2970	< 0.0001
	Linear	-0.0504	0.0161	0.0017
	Quadratic	0.00034	0.00017	0.0512
2	Constant	-0.6254	0.2485	0.0119
	Linear	-0.0655	0.0134	< 0.0001
	Quadratic	0.0005	0.00014	0.0004
4	Constant	-0.2302	0.2273	0.3113
	Linear	-0.0718	0.0120	< 0.0001
	Quadratic	0.0006	0.0001	< 0.0001
6	Constant	-0.2022	0.2097	0.3352
	Linear	-0.0407	0.0104	< 0.0001
	Quadratic	0.0002	0.0001	0.0253
12	Constant	0.1419	0.1972	0.4719
	Linear	-0.0362	0.0093	0.0001
	Quadratic	0.00025	0.00009	0.0101
24	Constant	1.2269	0.2145	< 0.0001
	Linear	-0.0160	0.00936	0.0868
	Quadratic	-0.00001	0.00009	0.8885



**Figure 1** Type II functional response of *Aphidoletes aphidimyza* 4-day-old larvae to varying densities of third instar *Aphis craccivora* at different foraging periods (hours).

The searching efficiency ( $a'$ ) and handling time ( $T_h$ ) (estimated by Rogers' random attack equation) for *A. aphidimyza* 4-day-old larvae feeding on different densities of third instar *A. craccivora* nymphs at different foraging periods are presented in Table 2. The searching efficiency decreased as the foraging periods increased (Fig. 2). However, the handling time had a decelerating trend as the foraging periods increased (Fig. 3). The estimated maximum attack rates of predation ( $T/T_h$ ) was directly related to foraging periods (Fig. 4).

## Discussion

Many studies have been devoted to the functional response of insect predators (Sarmiento *et al.*, 2007; Sekoand Miura, 2008; Xiao and Fadamiro, 2010; Sabaghi *et al.*, 2011a; Heidarian *et al.*, 2012) in foraging periods of 24 h., but the time specific functional response has received little attention. This is the first study on the functional response of *A.*

*aphidimyza* to varying densities of third instar nymphs of *A. craccivora* at different foraging periods. According to Morozov (2010) individual predators often forage over landscapes or in environments where there is significant spatial variation in quantities of prey, and recent work has shown how this spatial variability alters the functional response and hence the interaction rates between predators and prey in space. Dunlap *et al.* (2009) state that although spatial variation has received much attention, there is surprisingly little research on the effects of temporal changes in prey density on the functional response. This temporal variation can arise in a variety of ways. Indeed, many predators possess diurnal foraging patterns, and several other chronobiological rhythms which are of great importance in the life of many organisms.

This study showed that the time-specific functional response of 4-day old larvae of *A. aphidimyza* was a type II response at all foraging periods. It seems that the functional response studies at different foraging periods

provide us better insights into the behavior of an insect's natural enemy. Predators which exhibit the type II functional response are commonly regarded as efficient biological control agents (Fernández-Arhexand Corley, 2003; Pervez and Omkar, 2005). The type II functional response has also been found on other insect natural enemies (Ryoo, 1986; De Clercq *et al.*, 2000; Reis *et al.*, 2003; Badii *et al.*, 2004; Timms *et al.*, 2008). Therefore, 4-day-old larvae of *A. aphidimyza* showing type II response to varying densities of *A. craccivora* at different foraging periods can be considered as an effective biocontrol agent in suppressing aphid populations especially

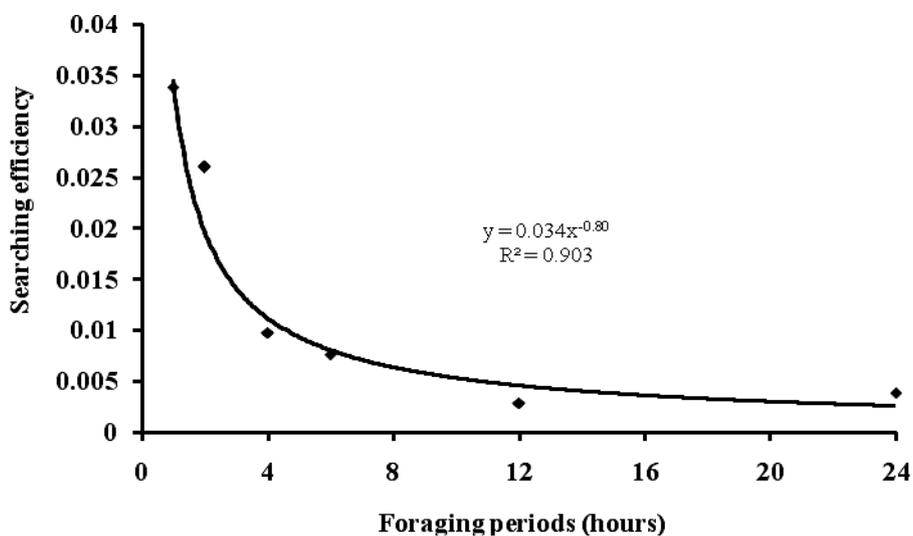
*A. craccivora*. The searching efficiency showed a decreasing trend as the foraging periods increased. However, in contrast, the handling time had a decelerating trend as the foraging periods increased.

Casas and McCauley (2012) showed that the length of the foraging period altered both the shape of the functional response and the magnitude of attack rates, compared to a daily functional response proportional to the time spent foraging. However, it was concluded here that although the values of functional response parameters of *A. aphidimyza* changed at different foraging periods, the type of functional response did not vary.

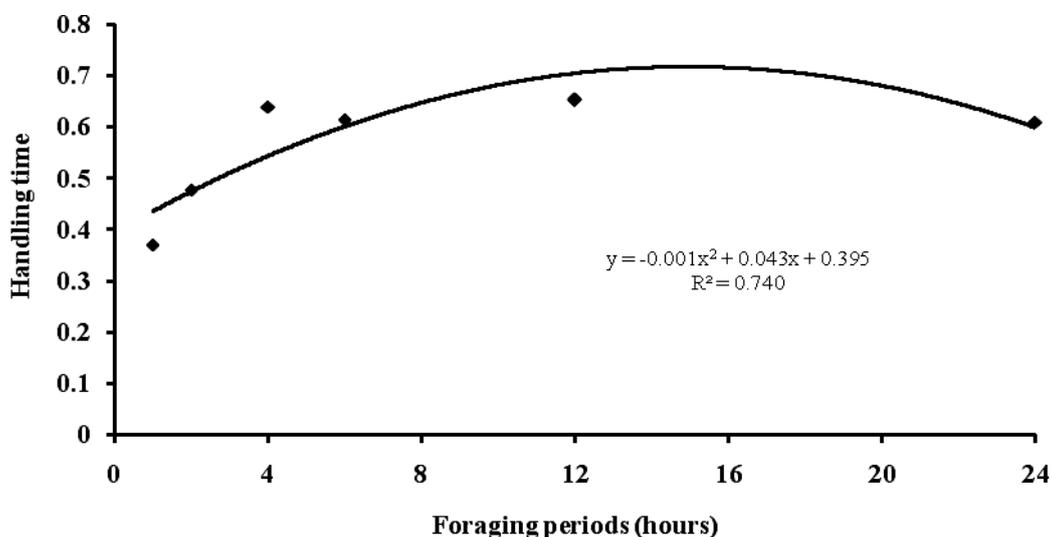
**Table 2** Coefficient of searching efficiency ( $a'$ ) and handling time ( $T_h$ ) (estimated by Rogers random attack equation) of *Aphidoletes aphidimyza* 4-day-old larvae fed on third instar *Aphis craccivora* at different foraging periods.

Foraging periods (hour)	Parameters	Estimate	SE	95% CI <sup>1</sup>	
				Lower	Upper
1	$a'$	0.0339	0.0106	0.0127	0.0551
	$T_h$	0.3699	0.0212	0.3275	0.4123
2	$a'$	0.0261	0.0076	0.0110	0.0412
	$T_h$	0.4781	0.0250	0.4280	0.5283
4	$a'$	0.0098	0.0029	0.00412	0.0155
	$T_h$	0.6401	0.0376	0.5648	0.7154
6	$a'$	0.0077	0.00142	0.00484	0.0105
	$T_h$	0.6153	0.0241	0.5672	0.6635
12	$a'$	0.0029	0.0005	0.00192	0.00389
	$T_h$	0.6539	0.0307	0.5924	0.7155
24	$a'$	0.0039	0.00074	0.00243	0.00539
	$T_h$	0.601	0.0279	0.5539	0.6658

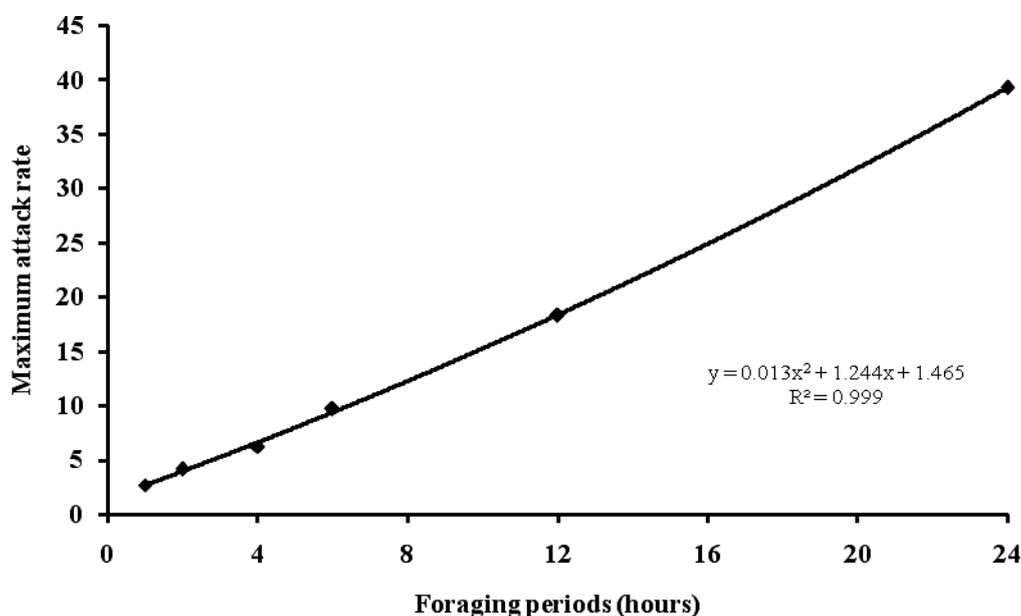
<sup>1</sup>CI indicates confidence intervals.



**Figure 2** Searching efficiency (a') of *Aphidoletes aphidimyza* 4-day-old larvae feeding on third instar *Aphis craccivora* at different foraging periods.



**Figure 3** Handling times of *Aphidoletes aphidimyza* 4-day-old larvae feeding on third instar *Aphis craccivora* at different foraging periods.



**Figure 4** Maximum attack rate of *Aphidoletes aphidimyza* 4-day-old larvae feeding on third instar *Aphis craccivora* at different foraging periods.

### Acknowledgments

We thank the authorities of the Faculty of Agricultural Sciences, University of Guilan for providing us research facilities and for their financial support.

### References

- Asadi, R. Talebi, A. A., Khalghani, J. Fathipour, Y., Moharrampour, S. and Askari Siahooei, M. 2012. Age-specific functional response of *Psyllaephagus zdeneki* (Hymenoptera: Encyrtidae), parasitoid of *Euphyllura pakistanica* (Hemiptera: Psyllidae). *Journal of Crop Protection*, 1: 1-15.
- Badii, M. H., Hernandez-ortiz, E., Flores, A. and Landeros, J. N. 2004. Prey stage preference and functional response of *Euseius hibisci* to *Tetranychus urticae* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, 34: 263-273.
- Casas, J. and McCauley, E. 2012. Daily foraging cycles create overlapping time-scales in functional responses. *Oikos*, 121: 1966-1976.
- Chen, K. R., Xu, Z. Y., Zhang, Z. Y., Fang, X. P. and Yan, L. Y. 1999. Biological characters and sequence analysis of coat protein gene of Chinese strains of peanut stripe virus (PStV). *Chinese Journal of Oil Crop Sciences*, 21: 55-59.
- Chen, W. L., Leopold, R. A. and Harris, M. O. 2006. Parasitism of the glassy-winged sharpshooter, *Homalodisca coagulata* (Homoptera: Cicadellidae): Functional response and superparasitism by *Gonatocerus ashmeadi* (Hymenoptera: Mymaridae). *Biological Control*, 37: 119-129.
- Chong, J. H. and Oetting, R. D. 2006 a. Functional response and progeny production of the Madeira mealybug parasitoid, *Anagyrus* sp. nov. nr. *sinope*: The effect of host stage preference. *Biological Control*, 41: 78-85.
- Chong, J. H. and Oetting, R. D. 2006b. Host stage selection of the mealybug parasitoid *Anagyrus* sp. nov. nr. *sinope*. *Entomologia Experimentalis et Applicata*, 121: 39-50.
- Coccano, P. G. and Peressini, S. 1989. Colonisation of maize by aphid vectors of barley yellow dwarf virus. *Annals of Applied Biology*, 114: 443-447.

- Cogni, R., Freitas, A. V. L. and Amaral, Filho, B. F. 2002. Influence of prey size on predation success by *Zelus longipes* L. (Het.: Reduviidae). *Journal of Applied Entomology*, 126: 74-78.
- De Clercq, P., Mohaghegh J. and Tirry, L. 2000. Effect of host plant on the functional response of the predator *Podisus nigrispinus* (Heteroptera: Pentatomidae). *Biological Control*, 18: 65-70.
- De Jong, P. W. and van Alphen, J. J. M. 1989. Host size selection and sex allocation in *Leptomastix dactylopii*, a parasitoid of *Planococcus citri*. *Entomologia Experimentalis et Applicata*, 50: 161-169.
- Ding-Xu, L., Juan, T. and Zuo-Rui, Sh. 2007. Functional response of the predator *Scolothrips takahashii* to hawthorn spider mite, *Tetranychus viennensis*: effect of age and temperature. *BioControl*, 52: 41-61.
- Dunlap, J. C., Loros, J. J. and DeCoursey, P. J. 2009. *Chronobiology: Biological timekeeping*, first edition. Sinauer Associates, p. 382.
- E1-Titi, A. 1973. Einflüsse von Beutedichte und Morphologie der Wirtspflanze auf die Eiablage von *Aphidoletes aphidomyza* Rondani (Dip., Itonididae). *Zeitschrift für Angewandte Entomology*, 72, 400-415.
- 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). *Environmental Entomology*, 39: 1586-1592.
- Fathipour, Y., Hosseini, A., Talebi, A. A. and Moharrampour, S. 2006. Functional response and mutual interference of *Diaeretiella rapae* (Hymenoptera: Aphidiidae) on *Brevicoryne brassicae* (Homoptera: Aphididae). *Entomologica Fennica*, 17: 90-97.
- Fernández-Arhex, V. and Corley, J. C. 2003. The functional response of parasitoids and its implications for biological control. *Biocontrol Science and Technology*, 13: 403-413.
- Garcia, J. F. and O'Neil, R. J. 2000. Effect of *Coleus* size and variegation on attack rates, searching strategy, and selected life history characteristics of *Cryptolaemus montrouzieri* (Coleoptera: Coccinellidae). *Biological Control*, 18: 225-234.
- Godfray, H. C. J. 1994. *Parasitoids: Behavior and Evolutionary Ecology*. Princeton University Press, Princeton, MA, USA, p. 473.
- González-Hernández, H., Pandey, R. R. and Johnson, M. W. 2005. Biological characteristics of adult *Anagyrus ananatis* Gahan (Hymenoptera: Encyrtidae), a parasitoid of *Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae). *Biological Control*, 35: 93-103.
- Hassell, M. P. and J. K. Waage. 1984. Host-parasitoid population interactions. *Annual Review of Entomology*, 29: 89-114.
- Heidarian, M., Fathipour, Y. and Kamali, K. 2012. Functional response, switching, and prey- stage preference of *Scolothrips longicornis* (Thysanoptera: Thripidae) on *Schizotetranychus smirnovi* (Acari: Tetranychidae). *Journal of Asia-Pacific Entomology*, 15: 89-93.
- Joyce, A. L., Hoddle, M. S., Bellows, T. S. and Gonzalez, D. 2001. Oviposition behavior of *Coccidoxenoides peregrinus*, a parasitoid of *Planococcus ficus*. *Entomologia Experimentalis et Applicata*, 98: 49-57.
- Juliano S. A. 1993. Nonlinear curve fitting: predation and functional response curves. In: Scheiner, S. M., and Gurevitch, J. (Eds.), *Design and Analysis of Ecological Experiments* (Chapman and Hall, New York, pp. 159-182.
- Laing, J. E. and Osborn, J. A. L. 1974. The effect of prey density on functional and numerical response of three species of predatory mites. *Entomophaga*, 19: 267-277.
- Lester, P. J. and Harnsen, R. 2002. Functional and numerical responses do not always indicate the most effective predator for biological control: an analysis of two predators in a two-prey system. *Journal of Applied Ecology*, 39: 455-468.
- Madadi, H., Enkegaard, A., Brodsgaard, H.F., Kharrazi-Pakdel, A., Mohaghegh, J. and Ashouri, A. 2007. Host plant effects on the

- functional response of *Neoseiulus cucumeris* to onion thrips larvae. *Journal of Applied Entomology*, 131: 728-733.
- Madahi, Kh. 2012. Predatory behavior and life table parameters of *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae) on *Aphis gossypii* Goeze and *Aphis craccivora* Koch (Hemiptera: Aphididae). Msc., Thesis, Faculty of Agricultural Sciences, University of Guilan, Iran, 148 p.
- Morozov, A. Y. 2010. Emergence of Holling type III zooplankton functional response: bringing together field evidence and mathematical modeling. *Journal of Theoretical Biology*, 265: 45-54.
- Morse, J. G. 1981. Biological studies on *Aphidoletes aphidimyza* Rondani (Dip.: Cecidomyiidae) and its use in the biological control of the apple aphid *Aphis pomi* DeGeer (Hom.: Aphididae). Ph.D. Thesis. Michigan State University. E. Lansing, Michigan.
- Morse, J. G. and Croft, B. A. 1987. Biological control of *Aphis pomi* (Hom.: Aphididae) by *Aphidoletes aphidimyza* (Dip.: Cecidomyiidae); A predator-prey model. *Entomophaga*, 32: 339-356.
- Pervez, A. and Omkar, G. A. K. 2005. Functional responses of coccinellid predators: an illustration of a logistic approach. *Journal of Insect Science*, 5: 1-6.
- Pettersson, J., Karunaratne, S., Ahmed, E. and Kumar, V. 1998. The cowpea aphid, *Aphis craccivora*, host plant odours and pheromones. *Entomologia Experimentalis et Applicata*, 88: 177-184.
- Reis, P. R., Sousa, E. O., Teodoro, A. V. and Neto, M. P. 2003. Effect of prey densities on the functional and numerical response of two species of predaceous mites (Acari: Phytoseiidae). *Neotropical Entomology*, 32: 461-467.
- Reis, P. R., Teodor, A. V., Neto, M. P. and Silva, E. A. 2007. Life history of *Amblyseius herbicolus* (Acari: Phytoseiidae) on coffee plant. *Neotropical Entomology* 36: 282-287.
- Rocha, L. da. and Redaelli, L. R. 2004. Functional response of *Cosmoclopius nigroannulatus* (Hem.: Reduviidae) to different densities of *Spartocera dentiventris* (Hem.: Coreidae) nymphs. *Brazilian Journal of Biology*, 64: 309-316.
- Ryoo, M. 1986. Studies on the basic component of the predation of *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Researches on Population Ecology*, 28: 17-26.
- Sabaghi, R., Sahragard, A. and Hosseini, R. 2011a. Functional and numerical response of *Scymnus syriacus* Marseul (Coleoptera: Coccinellidae) to the black bean aphid, *Aphis fabae* Scopoli (Hemiptera: Aphididae) under laboratory conditions. *Journal of Plant Protection Research*, 51: 423-428.
- Sabaghi, R., Sahragard, A. and Hosseini, R. 2011b. Area dependent searching efficiency of *Scymnus syriacus* (Col.: Coccinellidae) feeding on *Aphis craccivora* (Hem.: Aphididae). *Journal of Entomological Society of Iran*, 31 (1): 1-16.
- Sahragard, A. 1989. Biological studies on *Dicondylus indianus* Olmi (Hym.: Dryinidae) with particular reference to foraging behavior. Ph.D. Thesis, University of Wales. College of Cardiff, Wales, UK. 297 p.
- Sarmiento, R. A., Pallini, R., Venzon, M., Fonseca de Souza, O. F., Molina-Rugama, A. J. and Lima de Oliveira, C. 2007. Functional response of the predator *Eriopis connexa* (Coleoptera: Coccinellidae) to different prey types. *Brazilian Archives of Biology and Technology*, 50: 121-126.
- SAS Institute. 2001. SAS/STAT User's Guide. SAS Institute Inc., Cary, NC. Inc.
- Seko, T. and Miura, K. 2008. Functional response of the lady beetle, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) on the aphid *Myzus persicae* Sulzer (Homoptera: Aphididae). *Applied Entomology and Zoology*, 43: 341-345.
- Singh, S. R. and Jackai, L. E. N. 1985. Insect pests of cowpeas in Africa: their life cycle, economic importance, and potential for control. In: Singh S. R. and Rachie, K. O. (Eds.), *Cowpea Research, Production and Utilization*. Wiley, Chichester, pp. 217-231.

- Tahriri, S., Talebi, A. A., Fathipour, Y. and Zamani, A. A. 2007. Host stage preference, functional response and mutual interference of *Aphidius matricariae* (Hym.: Braconidae: Aphidiinae) on *Aphis fabae* (Hom.: Aphididae). *Entomological Science*, 10: 323-331.
- Taleb, M. A. and Sardar, M. A. 2007. Predation efficiency of insect predators in suppressing red Mite, *Tetranychus bioculatus* attacking marigold. *Journal of Agriculture and Rural Development*, 5: 98-104.
- Timms, J. E., Oliver, T. H., Straw, N. A. and Leather, S. R. 2008. The effects of host plant on the coccinellid functional response: Is the conifer specialist *Aphidecta obliterate* (L.) (Coleoptera: Coccinellidae) better adapted to spruce than the generalist *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae)? *Biological Control*, 47: 273-281.
- Trexler, J. C. and Travis, J. 1993. Nontraditional regression analysis. *Ecology*, 74: 1629-1637.
- Trexler, J. C. McCulloch, C. E. and Travis, J. 1988. How can the functional response best be determined? *Oecology*, 76: 206-214.
- Uygun, N. 1971. Der Einfluss der Nahrungsmenge auf Fruchtbarkeit und Lebensdauer von *Aphidoletes aphidimyza* Rond. (Diptera: Itonididae). *Zeitschrift für Angewandte Entomologie*, 69: 234-258.
- Varone, L., O. Bruzzone and G. A. Logarzo. 2007. Egg limitation and the functional response of the parasitoid *Campoletis grioti* (Hym: Ichneumonidae). *Biocontrol Science and Technology*, 17: 945-955.
- Xiao, Y. and Fadamiro, H. Y. 2010. Functional responses and prey-stage preferences of three species of predacious mites (Acari: Phytoseiidae) on citrus red mite, *Panonychus citri* (Acari: Tetranychidae). *Biological Control*, 53: 345-352.
- Yaşar, B. and Özger, S. 2005a. Development, feeding and reproduction responses of *Adalia fasciatopunctata revelierei* (Mulsant) (Coleoptera: Coccinellidae) to *Hyalopterus pruni* (Geoffroy) (Homoptera: Aphididae). *Journal of Pest Science*, 78: 199-203.
- Yaşar, B. and Özger, S. 2005b. Functional response of *Oenopia conglobata* L. (Coleoptera: Coccinellidae) on *Hyalopterus pruni* Geoffroy (Homoptera: Aphididae) in three different size arenas. *Türkiye Entomoloji Derneğive Dergisinin*, 29: 91-99.

## تأثیر دوره‌های زمانی مختلف جستجوگری روی واکنش تابعی *Aphidoletes aphidimyza* در تراکم‌های مختلف شته افاقیا *Aphis craccivora*

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دریافت: ۲۰ آبان ۱۳۹۲؛ پذیرش: ۲۵ دی ۱۳۹۲

**چکیده:** قدرت جستجو ( $a'$ ) و زمان دستیابی دو جزء مهم واکنش تابعی دشمنان طبیعی هستند و به‌طور معمول برای ارزیابی کارایی آن‌ها استفاده می‌شوند. تأثیر دوره‌های زمانی مختلف جستجوگری روی واکنش تابعی لارو *Aphidoletes aphidimyza* با تغذیه از پوره‌های سن سوم شته افاقیا *Aphis craccivora* مورد مطالعه قرار گرفت. آزمایش براساس واکنش تابعی وابسته به زمان در دوره‌های (۱)، ۲، ۴، ۶، ۱۲ و ۲۴ ساعت به تراکم‌های مختلف (۵، ۱۰، ۲۰، ۴۰، ۶۰ و ۸۰) پوره‌های سن سوم شته افاقیا *A. craccivora* در شرایط کنترل شده (در شرایط  $1 \pm 23$  درجه سلسیوس،  $5 \pm 70$  درصد رطوبت نسبی و دوره نوری-تاریکی ۱۶:۸ ساعت) انجام شد. برآورد پارامترها با استفاده از رگرسیون لوجستیک، واکنش تابعی نوع دوم را برای لارو چهار روزه شکارگر در دوره‌های زمانی مختلف را در تراکم‌های مختلف شته افاقیا *A. craccivora* نشان داد. قدرت جستجو ( $a'$ ) و زمان دستیابی ( $T_h$ ) با زمان‌های مختلف تغییر کرد. قدرت جستجو روند کاهشی با دوره‌های زمانی نشان داد. برآورد حداکثر نرخ شکارگری ( $T/T_h$ ) برای لارو چهار روزه به‌طور مستقیم با افزایش دوره‌های زمانی رابطه داشت اما زمان دستیابی ( $T_h$ ) روند کم شونده ای را نشان داد. در نتیجه مشخص شد که قدرت جستجو پارامتر متغیر دوره‌های زمانی مختلف جستجوگری *A. aphidimyza* است. همچنین پیشنهاد شد که *A. aphidimyza* با دارا بودن واکنش تابعی نوع دوم در دوره‌های زمانی مختلف می‌تواند به‌عنوان عامل کنترل بیولوژیک بسیار مؤثر در کاهش جمعیت *A. craccivora* در نظر گرفته شود.

**واژگان کلیدی:** واکنش تابعی، دوره‌های جستجوگری، *Aphidoletes aphidimyza*، *Aphis craccivora*