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FUNCTIONAL RESPONSE OF *HABROBRACON HEBETOR* SAY (HYM.: BRACONIDAE) TO MEDITERRANEAN FLOUR MOTH (*ANAGASTA KUEHNIELLA* ZELLER), IN RESPONSE TO PESTICIDES

Vahid Mahdavi[1]*, *Moosa Saber*[2]

[1] Young Researchers Club, Parsabad Moghan Branch, Islamic Azad University, Parsabad, 56918-53356, Iran

[2] Department of Plant Protection, College of Agriculture, University of Maragheh, Maragheh, 55181-83111, Iran

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Abstract: The functional response is a behavioral phenomena defined as the relation between the parasitized host per each parasitoid and host density. This phenomenon can be useful in assessing parasitoid efficiency for the biological control of the host. Parasitoid wasps are most important insects and they play a significant role in the natural control of pests via their parasitism activities. In this study, the effects of diazinon and malathion were evaluated on the functional response of *Habrobracon hebetor* Say to different densities of last instar larvae of *Anagasta kuehniella* Zeller. Young adult females (< 24 h old) of the parasitoid were exposed to LC_{30} values of pesticides. Host densities of 2, 4, 8, 16, 32, and 64 were offered, to treated young females for 24 h in 10 cm Petri dishes. At this point, the parasitism data were recorded. The experiments were conducted in eight replications. The functional response was type Ш in the control and insecticide treatments. Searching efficiency in the control, diazinon and malathion-treated wasps were 0.008±0.002, 0.003±0.002, and 0.004±0.002 h^{-1}, handling times were 1.38±0.1, 7.95±0.91, and 6.4±0.81 h, respectively. Diazinon and malathion had the highest and the lowest effect on searching efficiency of *H. hebetor*, respectively. After conducting advanced field studies, it was found that malathion may be used as a compatible chemical material with biological control agent in IPM programs.

Key words: Biological control, chemical control, functional response, IPM, parasitoids

INTRODUCTION

Parasitoid wasps can keep pest species at an acceptable level. These wasps are of great economic importance for agricultural ecosystems. Parasitoid wasps are able to keep down the pest population, and can help prevent a pest outbreak (Hentz *et al*. 1998).

The braconid *Habrobracon hebetor* Say (Hym.: Braconidae) is a gregarious, idiobiont arrhenotokous ectoparasitoid that parasitizes lepidopteran larvae and is an important biological control agent for several stored product moth pests (Heimpel *et al*. 1997; Darwish *et al*. 2003). *Habrobracon hebetor* has been widely used in various studies related to host-parasitoid interactions because of its high reproductive rate, short generation time, and considerable range of host species (Yu *et al*. 2002). In Iran, mass rearing of *H. hebetor* is done on the Mediterranean flour moth, *Anagasta* (*Ephestia*) *kuehniella* Zeller (Mudd and Corbet 1982). The adult wasps are released to parasitize *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) larvae in cotton fields in the Ardabil and Golestan provinces in the northern parts of Iran (Attaran 1996; Navaei *et al*. 2002).

The success of biological control programs is highly dependent on the nature of the host parasitoid interaction. In turn, this has led to many host-parasitoid systems being investigated in great detail (Rolle and Lawrence 1994; Baker and Fabrick 2000; Salvador and Consoli 2008).

One of the important behaviors of a parasitoid is functional response. Functional response refers to the number of hosts attacked successfully per parasitoid as a function of host density (Solomon 1949). Functional response describes the way a natural enemy responds to the changing density of its host, by parasitizing more or fewer individuals, and it is a commonly measured attribute of natural enemies of pests (Hassell 1978; Ives *et al*. 1993). Holling (1959, 1966) considered three types of functional response. Early functional response research conducted by Holling (1959), resulted in the formulation of mathematical models (type I, type II, and type III) to describe parasitism responses that were influenced by changes in parasitoid behavior. Type I responses are mathematically simplest and are exemplified by a parasitoid with a constant search rate over all densities and a random search pattern. The number of host parasitized per parasitoid in a type I system would be directly proportional to host density. Thus, a linear response is yielded until satiation is reached (Hassell 1978). Type II responses incorporate parasitoid handling time, which refers to the act of subduing and parasitizing a host. Cleaning and resting may be involved before moving on to search for more hosts.

*Corresponding address:
vahidmahdavi@live.com

The number of hosts attacked, increases at a constant initial rate under the type II model but then it increases at an ever decreasing rate as satiation is approached. Most arthropod parasitoid possess a type II response (Holling 1961; Royama 1971; Oaten and Murdoch 1975; Hassell 1978; Luck 1985) with some exceptions (Tostowaryk 1972; Hassell *et al*. 1977). The third form of functional response (type III) is sigmoid with a slow increasing attack rate as a parasitoid experiences increased host density. The attack rate then decreases as a parasitoid approaches satiation at higher host densities. The sigmoid shape is thought to be the result of a change in parasitoid search activity with changes in host density (Holling 1959; Hassell 1978).

For the success of the IPM (Integrated Pest Management), it is recommended that biological control agents and chemical compounds be used at the same time (Hull and Beers 1985). Furthermore, given that chemical compounds may affect the behavioral responses of natural enemies, the effect of pesticides is estimated on the functional response of the natural enemies. Faal-Mohammad Ali *et al*. (2010) evaluated the sublethal effects of chlorpyrifos and fenpropathrin on the functional response of *H. hebetor.* They showed that the functional response was type III in the control and the treatments.

The aim of this study was to evaluate the effects of the diazinon and malathion pesticides on the functional response of *H. hebetor*.

MATERIALS AND METHODS

Insects

The *H. hebetor* colony was obtained from an insectarium maintained by the Plant Protection Bureau of Kaleibar, Iran. The colony was maintained in the laboratory at 26±1°C, 60±5% relative humidity (RH) and a photoperiod of 16:8 (L:D) on larval *A. kuehniella*, that was reared on flour in a growth chamber at the above mentioned environmental conditions. Parasitoid wasps were reared on 5th instar larvae of *A. kuehniella* for five generations and used for all the experiments. Honey was provided as food for the adult parasitoids on 5 × 30 mm strips of paper (Sarmadi 2008).

Chemical compounds

The pesticides used in the assays were diazinon (60EC, AriaShimi Co., Iran), malathion (57EC, GazalShimi Co., Iran).

Experimental procedures

Exposure cages were used to expose the adults to the residue of the pesticides (Saber *et al*. 2005). The glass plates of the exposure cages were sprayed with aqueous pesticide solutions of LC_{30}. The values of LC_{30} were 6.99 and 9.24 ppm for diazinon and malathion, respectively. The control was treated with distilled water plus Tween 80. As a spreader, Tween 80 (Merck, Darmstadt, Germany) was used at a concentration of 200 ppm in all dilutions (Rosenheim and Hoy 1988). Before completely assembling the cages, 50 young female adults (< 24 h) were anesthetized with CO_2 and placed in each exposure cage. After 24 h, six randomly selected, mated females were transferred individually to 10 cm Petri dishes with the densities 2, 4, 8, 16, 32, and 64 of *A. kuehniella* last instars. Petri dishes were transferred to the growth chamber in which the chamber had the mentioned conditions, for 24 h. Honey was supplied as food for the adult parasitoids on 5 × 30 mm strips of paper. The number of parasitized larvae was registered after 24 h. The experiments were done in eight replications. Logistic regression and nonlinear regression of SAS software (SAS Institute 2002) were used to determine the type of functional response and to estimate the parameters of attack rate and handling time, respectively.

RESULTS

The positive values for the linear parameters obtained in the present study confirmed a type III response for the all treatments used (Table 1). The results of the polynomial regression and parasitism percentage graphs introduced a type III functional response for all treatments (Fig. 1).

The handling times and searching efficiency values are shown in table 2. This study showed that the control and diazinon had the lowest (1.38±0.1 h) and highest values (7.95±0.91 h) of handling time, respectively. The highest and lowest value of Searching efficiency was observed in the control (0.008±0.002 h^{-1}) and diazinon (0.003±0.002 h^{-1}), respectively.

Table 1. Results of the logistic regression analysis of the proportion of *A. kuehniella* larvae parasitized by *H. hebetor*, against the initial density

Treatments	Parameters	Estimate ±SE	p – value
Control	constant	–0.59±0.46	0.2
	linear	0.37±0.08	< 0.0001
Malathion	constant	–1.36±0.49	0.0060
	linear	0.06±0.07	0.3900
Diazinon	constant	–1.37±0.51	0.0080
	linear	0.02±0.08	0.7700

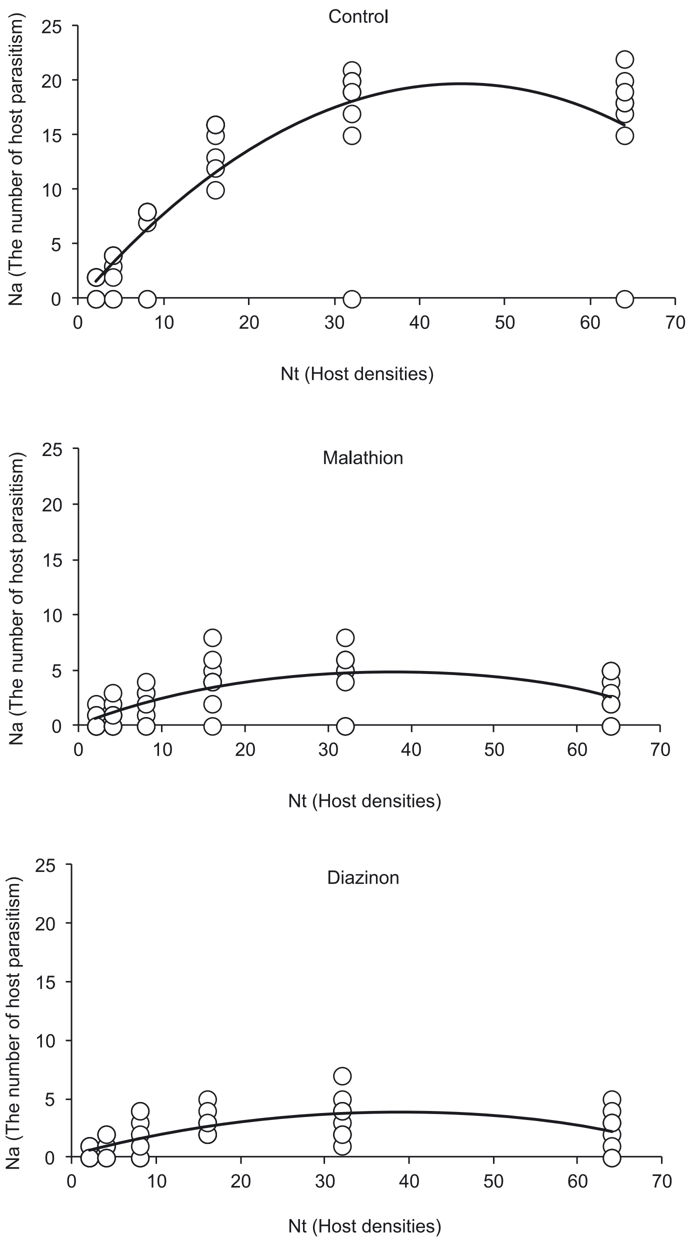

Fig. 1. Funcional response of the ectoparasitoid *H. hebetor*, exposed to different pesticides, and in the control

Table 2. Estimated functional response parameters of *H. hebetor* exposed to pesticides, and in the control

Treatments	Functional response type	a(h^{-1})±SE (lower upper)	T_h(h)±SE (lower upper)	T/T_h
Control	III	0.008±0.002	1.38±0.1	17.4
Malathion	III	0.004±0.002	6.4±0.81	3.75
Diazinon	III	0.003±0.002	7.95±0.91	3.02

a – Search efficacy; T_h – Handling time

DISCUSSION

The functional response of a parasitoid is a key factor regulating the population dynamics of parasitoid-host systems (Pervez and Omkar 2005). The number of hosts attacked per parasitoid is used as the experimental measure of the functional response (Mills and Getz 1996). The assumptions made, are that the parasitoid search is random and the host population is distributed at random and is homogenous. The functional response can determine the efficiency of a parasitoid in regulating host populations (Murdoch and Oaten 1975). Given the importance of determining the type of functional response in the regulation of pest populations and the impact of pesticides on natural enemies of behavior, our study evaluated the effects of common pesticides in the cotton fields on *H. hebetor* behavioral responses (functional response).

In functional response, whenever changes in parasitism are density dependent, parasitoid can control the population of the host (Hassell 1978). Also, among the functional response types, type II and III have received the most attention, because most natural enemies show these types (Rafiee-Dastjerdi *et al*. 2009). A sigmoid functional response type III was observed in *H. hebetor* to its host *A. kuehniella.* The type of functional response in all the experimental treatments has been reported to be type III and the proportion of hosts being attacked is dependent on the host density, so it may be concluded that pesticide treatments did not change the type of parasitoid functional response. Abedi *et al*. (2012) conciliated the effects of azadirachtin, cypermethrin, methoxyfenozide, and pyridalil on the functional response of *Habrobracon hebetor* Say (Hym.: Braconidae), and reported a type II functional response for all treatments and the control. Their results are inconsistent with the present study.

Searching efficiency and handling time are important parameters in the evaluation of the functional response to a parasitoid (Juliano 1993). The maximum value of handling time has been observed in the diazinon-treated (7.95 h), and the minimum value is related to the control treatment (1.38 h). The minimum and maximum values of searching efficiency have been observed in the control (17.4 h^{-1}) and diazinon (3.02 h^{-1}), respectively (Table 2). Our results are consistent with the results of Rafiee-Dastjerdi *et al.* 2009. They reported that pesticide treatment handling times decreased compared to the control. Also, our results are inconsistent with the results by Alikhani *et al*. (2010) who found that functional response at 25°C was type III. Among all natural enemies, only species with a type III functional response are able to regulate their host populations (Hassell 1978). A parasitoid with a type III functional response is density dependent and increases its searching efficiency on higher densities of the host. The essential premise of the type III response is that the parasitoid is able to discern host density and adjust its searching efficiency (O'Neil 1990). Rafiee-Dastjerdi (2008) reported that pesticides had adverse effects on *H. hebetor* functional response parameters. Saber *et al*. (2002), evaluated the sublethal effects of fenitrothin and deltamethrin insecticides on *Trissolcus semistriatus* and reported the functional response to be type III in the control and insecticide treatments. Faal-Mohammad Ali *et al*. (2010) evaluated sublethal effects of chlorpyrifos and fenpropathrin on the functional response of immature *H. hebetor*. They showed that the functional response was type III in the control and the treatments.

The results showed that malathion rather than diazinon had the lowest adverse effects on the functional response of *H. hebetor.* After conducting advanced field studies, it was found that malathion may be used as a compatible chemical material with biological control in IPM programs.

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