FUNCTIONAL RESPONSE OF *HIPPODAMIA VARIEGATA* (COL.: COCCINELLIDAE) ON *APHIS FABAE* (HOM.: APHIDIDAE) IN LABORATORY CONDITIONS

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Abstract: Functional response is one of the most important behavioral characteristics that reveal different aspects of prey-predator interactions. In this study, functional response of the amber ladybird, *Hippodamia variegata* (Goeze) attacking the black bean aphid, *Aphis fabae* (Scopoli) were investigated. Different level of aphid densities as: 20,40,60,80,100,120,140,160 and 180 were used. Each density was placed in a test cage (6×11×23 cm) and then exposed to a 24h adult. The experiments were carried out at 25±1°C, %60±5 r.h. and 16:8 (L:D) photoperiod. Logistic regression was used to distinguish the shape of the functional response (type п or ш). Nonlinear least-square regression was used to estimate the attack rate (*a*) and handling time (T_h). Nicholson model was used to determine per capita searching efficiency. Logistic regression suggested a type п response on *A. fabae* adults. Searching efficiency, handling time and estimated maximum percent of consume preys were 0.00078, 0.1774 and 135.29 respectively.

Key words: Functional response, *Hippodamia variegata*

INTRODUCTION

The black bean aphid, *Aphis fabae* (S.) is a pest of many plants, occurring in various parts of the world. The aphid causes direct and indirect damage by sucking the sap of plants and transmitting plant viruses (Blackman & Eastop 2000). *Aphis fabae* prefers feeding on younger plant tissues, which makes it an important aphid on beta and bean as it renders the head as tin marketable (Volkl & Stechmann 1998). Control of the aphid is commonly achieved by repeated application of insecticides.

The development of resistance to insecticides and adverse effects on natural enemies highlights the need for less insecticide-dependent methods of pest control. One of the Control measures, which can be used for the beta aphid, is biological control (Hasan & Wapshere 1973, Vandriesche & Bellows 1996). This aphid is attacked by the lady birds.

Hippodamia variegata is the most abundant and important natural enemy of *A. fabae* in Iran and plays a major role in reducing the population density of its prey. In addition to *H. variegata*, there are some other ladybirds in Iran, which are less abundant and less important such as *Coccinella* spp. and *Adalia* spp. from the same family (Coccinellidae) that consumed prey black bean aphid (Rajabi 1998). Among the natural enemies of black bean aphid, *H. variegata* serves as a good candidate for natural support, mass rearing and release for controlling this aphid because of high population densities and high rates of consumed prey (Franzman 2002). In this regard, the study of foraging behavior and demographic parameters of *H. variegata* in a prey-predator system is essential. In this study, different densities of prey and predator were selected according to the reference. The main purpose of the selection of these densities was to identify the role of different densities of the prey and predator on the foraging behavior of the predator and on the prey-predator interactions. The selected densities may not be completely compatible with those of the prey and predator in natural populations.

Before using a predator in a biological control program, it is essential to know about the efficiency of the predator. One of the most important methods to assess the efficacy of natural enemies is the study of behavioral characteristics, including foraging behavioral. Study of predator behavioral is an important key to understanding how the insects live, how they influence the population dynamics of their preys (Dixon 2000). It is thus a necessary prerequisite for the selection of natural enemies for biological control programmers and for the evaluation of their performance after their release (Vandriesche&Bellows 1996).

One of the important behaviors of predator is functional response. Functional response is the number of preys successfully attacked per predator as a function of prey density (Solomon 1949). It describes the way a natural enemy responds to the changing density of its prey, by killing 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. In the type I, there is a linear relation between prey density and the number of preys killed, while in the type п it is curvilinear and saturation level is reached in a gradual way. The type ш is described by a sigmoid relation and considered to be a regulating factor in the population dynamics of the pest and the natural enemy. The functional response of a predator is a crucial factor in the population dynamics of prey-predator systems. This behavior can determine if a predator is able to regulate the density of its prey (Livdahl & Stiven1983). Functional response models help to evaluate two vital parameters, handling time (i.e. the time that it takes a predator to encounter and consume preys a single prey, and attack rate (i.e. the rate at which a predator searches). Several studies (Fan & Zaho. 1988, Ives *et al*. 1993) have been carried out on the functional response of *H.variegata* to different densities of other aphids such as *Aphis gossypii* and *Diuruphis noxia* Mordvi1ko. The type of functional response and the value of its parameters (attack value and handling time) are influenced by different factors such as natural enemy , host species, physical conditions in the laboratory, and the variety of the host plant, etc. (Messina & Hanks 1998).

MATERIAL AND METHOD

Insect cultures

H. variegata used in this study was originally collected from *A. fabae* in an infested beta field at the College of Agriculture of Borojerd University (Lorestan) Iran in May 2007. The *A. fabae* culture was originally started from individuals collected from the above beta field and kept in a growth chamber on beta plants. Both ladybird and aphid individuals were kept in a growth chamber at *25±l*°C 60±5% r.h. and a photoperiod of 16L:8D h.

Functional response

The experimental arena consisted of a Plexiglas cage (6×11×23 cm) with a micromesh screen on the lid for ventilation. Adults of A. *fabae* were randomly placed on the beta leaves inside the cages at densities of 20, 40, 60, 80, 100, 120, 140, 160 and 180 per cage. A single female predator (maximum 24 hours old) was introduced into each cage. Each prey density was replicated 10 times. After 24 hours, the ladybirds were removed and the number of consumed preys was counted. The experiment was conducted at 25±1°C, 60+5% r.h. and a photoperiod of 16L: 8D h.

Two principal steps underlie the statistical analysis of the functional response: first model selection, and second hypothesis testing (Juliano 1993). In the first step, a logistic regression analysis was made of the proportion of preys predatised as a function of initial density. The proportion of preys consumed declines monotonically with prey density in the type п response, but is positively density-dependent over some region of prey density in the type п response (Trexler *et al.* 1988). The sign of the linear coefficient estimated by the logistic regression (negative or positive) can be used to distinguish the shape of the functional response curve (type п or type ш, respectively) (Juliano 1993, Messina & Hanks 1998). In the second step, both the disc equation (Holling 1959, 1966) (Eq.1) and the random predator equation (Royama 1971, Rogers 1972) (Eq.2) were used to obtain estimates for handling time (T_h) and searching efficiency or attack rate (a).

For the type п response, the equations are as follows:

$$N_a = aTN_t / 1 + aT_h N_t \quad (1)$$

$$N_a = N_t \left[1 - \exp(a(T_H N_t - T))\right] \quad (2)$$

where N_a is the number of consumed preys, N_t: the number of preys offered ,T: the total time available for the predator, a: the attack rate (searching efficiency), and T_h: the handling time.

Statistical analysis was performed using the SAS package (SAS Institute 1989). In order to estimate the handling time and searching efficiency, nonlinear regression, using the least square method with DUD initialization, was used**.**

RESULTS

Functional response and percentage of consumed prey's curves are depicted in Fig. 1. The logistic regression analysis (Table 1) indicated a type п functional response. The estimate of the linear coefficient was significantly different from 0 (p<O.Ol) and its value was —0.3637 S.E.

Attack rate and handling time for the disc equation were 0.00078±0.0000111 h^{-1} and 0.1774±0.0004 h, respectively, and for the random predator equation they were 0.00093±0.000201 h^{-1} and 0.1999±0.0094 h, respectively (Table 2).

The lower coefficient of determination [R^2 =1-(residual sum of squares / corrected total sum of squares)] for the disc equation and the random predator equation were thus 0.62 and 0.61, respectively. The estimated maximum rate of consumed prey (T / T_h) for the disc equation and the random predator equation were determined as 135.29 and 120.07, respectively.

The rates and standard errors of the estimated parameters indicated that both equations (disc equation and random predator equation) adequately describe the functional response of *H. variegata.*

Discussion

The type п functional response displayed by *H. variegata* to different densities of *A. fabae* adults is characteristic of many aphid predators, though the type ш responses have also been reported (Lanzoni *et al*. 2004). In most related literature, the functional response of *H. variegata* to different densities of Aphids (Dixon 2000, Kontadimas & Statha 2005), *Brevicoryne brassica* (Elhagh & Zaiton 1996) and *A. goosypii* (Fan & Zaho 1988) has been determined to be of the type п. However, in the studies reported by Lanzoni *et al*. (2000), *H.variegata* displayed a type ш functional response to *A. goosypii*.

The rates of searching efficiency (a) and handling time (T_h) were reported to be 0.09624 h^{-1} and 0.852 h, respectively (Kontadimas & Statha 2005) and 0.12421 h^{-1} and 0.421 h, respectively (Fan & Zhao 1988). The cited rates of a are greater and T_h are smaller than those obtained in our study. However, the differences among the experimental conditions such as prey species and physical conditions between different studies were substantial.

For the type п response, consumed preys are not density dependent: that is, the intensity of consume preys does not increase with prey density (Hassell 1978). Several authors (sources) have tried to explain why the type ш response is less common than the type п.

They agree that in laboratory tests, predator is forced to remain in the patch, whereas under natural field conditions they probably leave the patch because of the very low prey density or because most preys are already consumed. (Ives *et al.*1993, Oneil 1990).

Fan & Zhao (1988) pointed out that the relation between functional responses observed in the laboratory and field performance of natural enemies is not clear, but some studies showed a significant difference between the responses observed in laboratory and field environments. It is recognized that functional response derived from laboratory studies may bear little resemblance to those that could be measured in the field (Wang *et al*. 2004).

Fan and Zhao (1988) pointed out, however, that studies of functional response in laboratory could be used to infer basic mechanisms underlying natural enemy-prey interactions. Such studies provide valuable information for biological control programs. Elhag & Zaiton.(1996) expressed that during biological control evaluation processes, comparisons of parameter values of two or more predators may be more meaningful and convenient than similar comparisons involving functional response curves.

In most available literature, the functional response of *H. variegata* to different densities of aphids has been determined as the type п.

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