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Functional response of the predator *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae) feeding on the aphid *Brachycaudus helichrysi* (Kaltenbach) infesting chrysanthemum in the Laboratory

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Abstract

Functional response of the predatory coccinellid *Hippodamia variegata* (Goeze) to the density of *Brachycaudus helichrysi* (Kaltenbach) aphid infesting chrysanthemum was studied under laboratory conditions at 25 ˚C. A single adult female predator on isolated areas with different prey densities was used. Response pattern of the six-day old predator to the various prey densities was found. Predator exhibited a decelerating curvilinear rise to a plateau (type II) response in which the proportion of prey consumed declines monotonically with the initial number of prey offered. The mortality curve of the prey at different densities due to the predator was also evaluated. The mortality first increases with prey increasing density, and then declines. The predator functional response can be simulated by Holling disc equation and expressed as: (H*a* = 0.97525 H / 1 + 0.0066317 H) and by the reciprocal linear transformation of Holling's equation as: (y = 0.5127 x + 0.0068). The estimated coefficient of attack rate (a) is 1.9505 and the handling time (T*h*) is 0.0034.

الملخص

تمت دراسة الاستجابة الوظيفية للمفترس هيبوداميا فاريجيتا بالنسبة لكثافة من الاقحوان تحت ظروف المختبر على درجة حرارة 25 ْم. و قد وضعت الحشرات الكاملة لانثى المفترس فرادى مع عدة كثافات من الفريسة لهذه الغاية. و قد وجد نمط الاستجابة لاناث المفترس ذات العمر ستة ايام لعدة كثافات من الفريسة حيث اظهر المفترس استجابة من النوع الثاني بزيادة بخط منحني بسرعة متناقصة حتى مرحلة الاستقرار حيث أن نسبة الفريسة المستهلكة تراجعت على نفس الوتيرة بالنسبة للعدد الاولي للفريسة المقدمة. كما و تم تقييم منحنى وفيات الفريسة بكثافاتها المختلفة تحت تأثير حشرات المفترس. في البداية، زادت الوفيات بزيادة كثافة الفريسة و من ثم بدأت الوفيات بالانحدار. و قد أمكن اظهار و التعبير عن الاستجابة الوظيفية للمفترس باستخدام معادلة هولنج القرصية ب (Ha= 0.97525 H/ 1+ 0.0066317 H) و باستخدام التحويل الخطي ذو العلاقة المتبادلة لمعادلة هولنج على النحو التالي: (Y= 0.5127 X + 0.0068) و قد قدر معامل معدل الهجوم ب (1.9505) و قدر زمن المناولة ب (0.0034).

Keywords: *Brachycaudus helichrysi*, functional response, *Hippodamia variegata*, predator-prey interaction .

1. Introduction

The relationship between prey density and a consumption rate is known as the functional response (Abrams and Ginzburg, 2000; Jeschke *et al*., 2002). It is an important phenomenon, it describes the rate at which a predator kills its prey at different prey densities and can thus determine the efficiency of a predator in regulating prey populations (Murdoch and Oaten, 1975). Four fundamental types of functional response curves are described (Holling, 1959, Jervis and Kidd, 1996); linear rise to a plateau (type I), negatively accelerated rise to a plateau (type II), S-shaped rise to a plateau (type III) and dome-shaped type IV. This could further be simplified in terms of density dependence. That is, they result in a constant (type I), decreasing (type II) and increasing (type III) rate of prey killing and yield density-dependent, negatively density dependent and positively density dependent prey mortality, respectively (Pervez and Omkar, 2005). Predators that impose positively density dependence prey mortality (type III) are supposed to potentially manage the prey population and could be considered as efficient biological control agents (Fernandez-Arhex and Corley, 2003). However, certain

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predators exhibiting type II response have been successfully established and managed prey populations (Hughes *et al*., 1992; Fernandez-Arhex and Corley, 2003). Functional response, though an important tool, but cannot only be attributed to reported success and failures in biological control programs. For instance, other factors, such as intrinsic growth rates, host patchiness, predation and competition, host traits, and environmental complexities also have a major influence on the efficiency of the predator (Pervez and Omkar, 2005). The functional response curves can be differentiated by evaluating the functional response parameters, coefficient of attack rate and handling time.

The plum leaf-curl aphid, *Brachycaudus helichrysi* (Kaltenbach) (Hemiptera: Aphididae) is a cosmopolitan insect that known to be the most serious and economic pest of chrysanthemum in glass houses (Wyatt and Brown, 1977). Coccinellids are one of the important groups of predatory insects that have immense biological control potential (Omkar and Pervez, 2003). Many experiments about predaceous insects in agricultural systems have evaluated diverse aspects of the functional response; Veeravel and Baskaran (1997) and Vieira *et al*. (1997) with coccinelids. The originally Palaearctic but now widespread beetle *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae) is an important predator of twelve different aphid species, particularly *B. helichrysi* (Franzmann, 2002). It is native to Europe but introduced to North America.

The present study was carried out to determine how *H. variegata* will respond to changing prey density under simplified experimental conditions

2. Materials and Methods

2.1. Insect's culture & maintenance and experimental design:

B. helichrysi aphid was obtained from infested chrysanthemum plants grown in the plastic houses of Al-Balqa' Applied University/ in Al-Salt City and cultured inside cages (2x2x2 m) on chrysanthemum seedlings maintained at 25 ± 2˚C, 65% RH and in 16: 8 light: dark. Adults of the predator *H. variegata* were collected from the same location as the prey and brought to the laboratory in Al-Balqa' Applied University and reared inside chambers. Coccinellids were kept in pairs inside cages (2x2x2 m) containing chrysanthemum seedlings infested with aphids for oviposition. Seedlings held at the previously mentioned environmental conditions. Leaves with eggs were isolated individually in Petri dishes (9 cm in diameter) to obtain six-day old virgin adult females to be used in experiments. Tests were undertaken on chrysanthemum leaves cut so that they retained two cm of petiole length covered with wet cotton wool and placed upside down in Petri dishes. Females of the predator were kept without food for 12 hrs to standardize their hunger before use. Thereafter, they were kept separately at different densities 10, 20, 40, 60, 70, 100, 120 and 140 of the aphid after it settled down, in 15 replicates. After 12 hrs, the females removed and the number of aphids left was recorded but consumed prey were not replaced during the experiment. Then, we calculated the number of aphids preyed in each dish.

2.2. Data Analysis:

A logistic regression model was used to determine the shape of the functional response by taking into consideration the proportion of the prey eaten (H*a*/ H) as a function of prey offered (H) (Juliano, 2001). The data were fitted to a polynomial function that describes the relationship between H*a*/H and H:

$$\frac{Ha}{H} = \frac{\exp\left(L_o + L_1 H + L_2 H^2 + L_3 H^3\right)}{1 + \exp\left(L_0 + L_1 H + L_2 H^2 + L_3 H^3\right)}$$

With L0, L1, L2 and L3 being the intercept, linear, quadratic and cubic coefficients, respectively, estimated using the method of maximum likelihood. If L1 < zero, describing a type II functional response (Juliano, 2001). After the determination of the functional response type, the handling time (T*h*) and the attack constant (a) were estimated using Holling's disc equation modified by reciprocal linear transformation (Livdahl and Stiven, 1983). The modified equation is as follows:

$$\frac{1}{Ha} = \frac{1}{a} \cdot \frac{1}{H.T} + \frac{Th}{T}$$

where $\frac{1}{Ha}$ represents y, $\frac{1}{a}$ represents α, $\frac{1}{H.T}$ represents x and $\frac{Th}{T}$ represents ß. The linear regression form becomes y = α x + ß. The maximum number of consumed prey per predator (asymptote), Ha_{max} = T/T*h* was found.

3. Results

Predation potential of *H. variegata* was evaluated across eight prey densities of *B. helichrysi* to asses the form of its functional response. Figure 1 shows the graph of the predator functional response that corresponds to Holling disc equation. The functional response curve obtained is belonging to Holling's type II. Most of the values of L1 were negative; confirming the functional response to be of type II (Table 1). The number of prey killed approaches the asymptote hyperbolically as prey density increases. This corresponds to an asymptotically declining proportion of prey killed (Figure 2). The highest percentage of death was recorded at the aphid density of 20 and then the curve goes down with increasing prey density.

The linear regression of the predator as shown in Figure 3 can be represented by the equation: y = 0.5127 x + 0.0068. From the coefficients of the linear regression, the instantaneous search rate (a) was estimated to be 1.9505 and the handling time (T*h*) was 0.0034. The calculated maximum number of consumed prey per predator was 147.06.

Table 1: The experimental data for the functional response parameters of the predator *Hippodamia variegata* feeding on the *Brachycaudus helichrysi* aphid infesting chrysanthemum plants

Prey density (H)	Total prey killed for the 15 repl.	% Prey killed	Average no. prey killed (Ha)	1/Ha	1/(H.T)	Death (d) = Ha/H	Linear coefficient (L1)
10	133	88.7	8.867	0.113	0.20	0.887	- 0.90334
20	288	96.0	19.20	0.052	0.10	0.960	Reference value
40	540	90.0	36.0	0.0278	0.05	0.900	0.44794
60	660	73.3	44.0	0.0227	0.033	0.733	- 0.03419
70	705	67.1	47.0	0.0213	0.029	0.671	- 0.35861
100	785	52.3	52.33	0.0191	0.02	0.523	- 0.80835
120	825	45.8	55.0	0.0182	0.017	0.458	0.22760
140	870	41.4	58.0	0.0172	0.014	0.414	- 0.28905

*The duration of the experiment (T) = 12 hrs

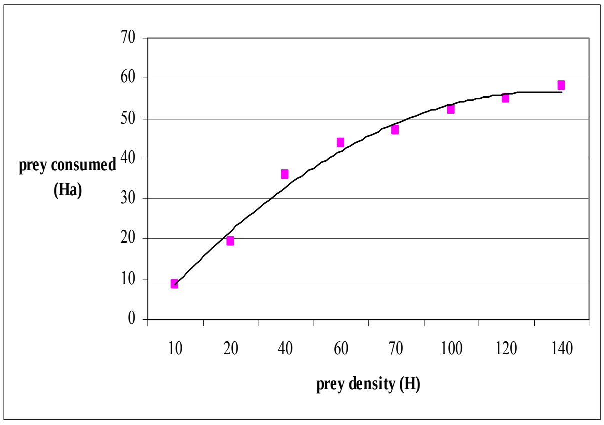

Figure 1: Type II functional response of the predatory coccinellid *Hippodamia variegata* feeding on different densities of the aphid *Brachycaudus helichrysi*.

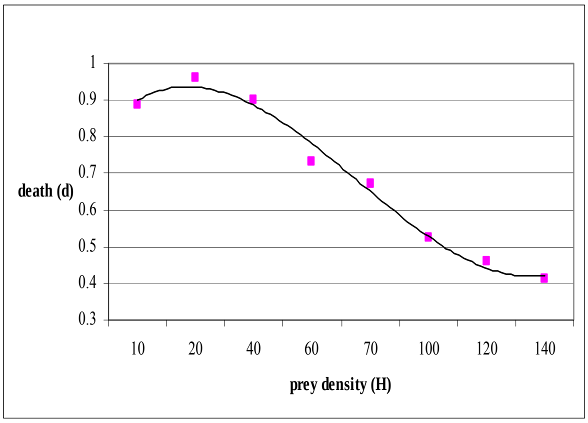

Figure 2: Prey mortality curve of the chrysanthemum aphid *Brachycaudus helichrysi* due to the predator *Hippodamia variegata.*

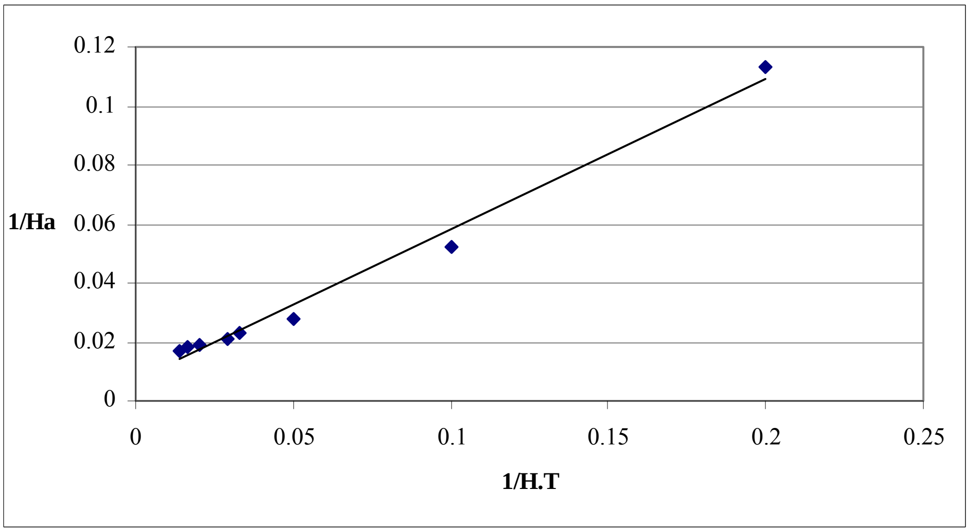

Figure 3: The linear regression for parameters estimation of *Hippodamia variegata* feeding on *Brachycaudus helichrysi* aphid (y = 0.5127 x + 0.0068.

4. Discussion

In this study, the type II functional response model obtained gave a satisfactory fit to the data of *H. variegata* preying on *B. helichrysi*; which being the most frequently observed type for a wide variety of predators including insects (Aukema and Raffa, 2004; Begon *et al*., 1996). A logistic regression model of proportions of prey killed (H*a*/H) versus (H) was also used to confirm the correctness of the functional_response type obtained (Figure 2), because it provides a more powerful and accurate means of distinguishing between type II and type III (Trexler *et al*., 1988). Moreover, the resulted negative values for the linear coefficient in Table 1 (L1 < zero) were also confirmed the obtained type. The predator shows a negative density dependence of the proportion of the prey killed (H*a*/H) as the density increases (Table 1). The predator shows a decreasing consumption rate with increasing prey density. Our finding coincides with the results found by Pervez and Omkar (2003) who mentioned that a high rate of prey consumption at higher densities is not a feature of aphidophagous coccinellid predators.

The obtained functional response parameters (a) and (T*h*) can be used to determine the simulated prey consumed (H*a*) at any wanted prey density (H) using the obtained equation: H*a* = 0.97525 H / (1 + 0.0066317 H). This will lead to minimizing the future efforts needed to generate voluminous empirical data at different aphid densities in the laboratory.

Our data provide information and idea as to how this predator responds to a change in prey density on single and isolated patches under laboratory conditions. These patches are small leaves, confining the predator and the prey movement to a few square centimeters. For conclusive estimation of its control potential, field data are essential to complete the laboratory results, since in natural conditions other variables can interfere in predator behavior; introducing modifications in functional response components.

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