

Effects of host's *Helicoverpa armigera* Hubner larval age on the area of discovery of the parasitoid *Campoletis chloridae* Uchida

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Abstract

The area of discovery and killing power (K-value) of the parasitoid *Campoletis chloridae* Uchida with interaction between different larval age of the host *Helicoverpa armigera* (Hübner) were studied at different parasitoid and host densities. The area of discovery of the parasitoid decreases linearly while the killing power (K-value) increases significantly with the increase of parasitoid. However, when the host density increases both the area of discovery and killing power (k-value) increases up to 16 hosts and thereafter they decrease. The area of discovery and killing power (K-value) in maximum in 2nd instar followed by 3rd instar, 1st instar and 4th instar larvae of the host *H. armigera*. As the parasitoid density increases mutual interference increases, which cause a reduction in an individual searching efficiency.

Keywords: area of discovery, killing power, *Helicoverpa armigera*, *Campoletis chloridae*, Mutual interference

Introduction

The gram pod borer *Helicoverpa armigera* (Hübner) is an important pest of chickpea and causes considerable damage to this crop [1,2]. The endolarval parasitoid *Campoletis chloridae* is a potential bio control agent against *H. armigera* and parasitizes the moth's larval stage [3, 4, 5]. The *C. chloridae* helps in suppressing the pest population on chickpea.

The dynamic relationship between parasitoid and their hosts is one of the dominant themes in ecology. Yet the theory of host parasitoid interaction has some notable problems: one of the "paradox of enrichment", where classical model predicts that enriching the system will cause an increase in the equilibrium density of the parasitoid but not in that of the host [6] and will destabilize the commonly equilibrium.

For a successful pest management programme information regarding host finding efficiency, mutual interference and killing power of the parasitoid are necessary [7, 8, 9]. Nicholson [10] and Nicholson & Bailey [11] in their deductive model assumed that parasitoid behavior is unaffected either by host density and distribution or by the density of searching parasitoid and also assumed a random search by the parasitoid density constant searching ability which is the characteristic of the species. The parameter they suggested to describe the searching behavior was parasitoid. "Area of discovery" representing the total area effectively searched by the parasitoid during a period of time or during its life time and can mathematically be derived from the Nicholsonian competition curve by the equation.

$$a = \frac{2.3}{P} \log_{10} \frac{N}{S}$$

Where a= "area of discovery" of the parasitoid; p= density of

parasitoid searching for hosts; N= initial host density; and S= hosts surviving parasitism.

Previously, it was thought that this model was sufficient to describe host parasitoid interactions in some cases [12, 13]. However, soon it was realized that Nicholsonian model was based on inaccurate assumptions and cannot explain all the experimental results. Its main drawback being the prediction of increasing oscillation of host and parasitoid population and the inability to accommodate two or more competing females in the ecosystem. Later, Hassell & Huffaker [14] showed that Nicholsonian "a" is not constant but decreases with increasing parasitoid density. Based on these results and on reanalysis of previous studies Hassell & Varley [15] improved Nicholsonian model by incorporating the effect of density dependent factor i.e. mutual interference [m] (the slope of straight line regression when log a is plotted against log P).

$$\log a = \log Q - m \log P$$

Where Q= Quest constant (the area of discovery of the parasitoid when only one female is searching).

This modification overcame some of the major drawbacks of the original model. It increases the stability of the model and permitted more than one parasitoid to act in the ecosystem [16, 17]. However in spite of criticisms [18, 19, 20], this model is still widely accepted owing to its simplicity [9].

The K value a measure of "Killing power" Ooi, [21] of a particular mortality factor (Parasitism by *C. chloridae* in this case) a logarithmic scale Varley & Gradwell [22] was obtained from the formula:

$$K = \log_{10} \frac{N}{S}$$

In view of the above information in the present work an attempt has been made to investigate the searching efficiency. Mutual interference and killing power of the parasitoid *C. chlorideae* on the different larval ages (1st instars to VIth instar) of the host *H. armigera*.

Materials and Methods

The parasitoid, *C. Chlorideae* and its host *H. armigera* were reared in the laboratory at 22±4°C, 70±10 Rh and 10 h light: 14h dark photoperiod Kumar *et al* [23]. The different larval age (1st Instars to IVth Instar) of the host were drawn from the maintained culture and were utilized as hosts, one day old, satiated Mathavan [24], with 30% honey solution, mated and experienced females T' Hart *et al* [25] were used as parasitoid. To study the area of discovery of the parasitoid, *C. chlorideae*, two sets of experiments were performed.

Experiment-1

In the first set of experiment 4 troughs (Ca 20 cm diameter x 10 cm height) were arranged and numbered as 1 to 4. 50 first instars larvae were placed separately on four moistened filter paper and were transferred individually in the marked troughs. Troughs were covered with glass plates. In the 1st trough one, in 2nd two, in the 3rd four and in the 4th troughs eight parasitoid were introduced and were allowed to attack host for 3 hrs. The same experiments were performed on the 2nd instars, 3rd instars and 4th instars larvae of the host *H. armigera*.

Experiment-2

In the second set of experiment varied host density viz. 1, 2, 4, 8, 16, 32 and 64 hosts were placed in seven moistened filter paper. These filter papers having the hosts were transferred individually in 7 differently marked troughs as in the first set. Troughs were covered with glass plates. One parasitoid was introduced each petri dish and was allowed to attack for 3 hrs. The same experiments were performed on the 2nd instars, 3rd instars and 4th Instars larvae of the host *H. armigera*.

Both the experiments were replicated five times with new experienced female parasitoid and fresh hosts. After parasitisation, the larvae in both the experiments were transferred in to the glass tubes having fresh foliage of gram (*Cicer aritenum*) plants Kumar *et al* [23] (to provide moisture to the developing egg) until emergence. The glass vials were kept plugged with absorbent cotton. Emergent were counted and the data was statistically analyzed.

Results

Figs-1 and Figs-2 explain the area of discovery (a) Calculated by Nicholson's [10] Model, while Figs-3 and Figs-4 are from Hassell & Varley's [15] model. In all the four host larval age the numerical value of area of discovery, M value and Q value in increasing parasitoid density are shown in Table-1 while the value of area of discovery in increasing host density is given Table-2.

Increase in the parasitoid density has a two-fold effect: (i) The area of discovery decreases linearly with a significant negative correlation. This decrease being Minimum in 2nd larval age ($y = -0.189 - 0.605x$, $r = -0.976$, $p < 0.001$, mean value = 0.382±0.184)

followed by 3rd larval age ($y = -0.246 - 0.576x$, $r = -0.977$, $p < 0.001$, mean value = 0.342±0.159), 1st larval age ($y = -0.269 - 0.594x$, $r = -0.972$, $p < 0.001$, mean value = 0.321±0.151) and 4th larval age ($y = -0.528 - 0.710x$, $r = -0.999$, $p < 0.001$, mean value = 0.164±0.101) of the host (Table-1, Fig -1) and (ii) K-value increases linearly (Table-3, Fig-3), This increase being maximum in 2nd larval age ($y = -0.279 - 0.366x$, $r = -0.977$, $p < 0.001$, mean value = 0.445±0.145) followed by 3rd larval age ($y = -0.242 - 0.360 \log x$, $r = -0.988$, $p < 0.001$, mean value = 0.405±0.141), 1st larval age ($y = -0.233 - 0.315 \log x$, $r = -0.975$, $p < 0.001$, mean value = 0.376±0.126) and 4th larval age ($y = -0.126 - 0.119 \log x$, $r = -0.993$, $p < 0.001$, mean value = 0.179±0.046) of the host. The mutual interference constant [m] and quest constant (Q) (Table-1) is maximum in 2nd larval age (m = -0.605, Q = 0.579) followed by 3rd larval age (m = -0.576, Q = 0.510), 1st larval age (m = -0.594, Q = 0.477) and 4th larval age (m = -0.710, Q = 0.300) of the host (Table-3, Fig -3). Interestingly, when the host identity increases both the area of discovery and K-value increases up to 16 hosts and thereafter they decrease. The area of discovery is high in 2nd instars (mean value = 0.715±0.157) followed by 3rd instars (mean value = 0.572±0.196), 1st instars (mean value = 0.504±0.187) and 4th instars (mean value = 0.414±0.121) of the host (Table-2, Fig-2). The killing power (K-value) is maximum in 2nd instars (mean value = 0.311±0.068) followed by 3rd instars (mean value = 0.249±0.085), 1st instars (mean value = 0.219±0.081) and 4th instars (mean value = 0.180±0.053) of the host (Table-4, Fig-4).

Table 1: Area of discovery of *Camponotus chlorideae* at its four densities. Each test utilized 50 hosts (*Helicoverpa armigera*) on the different host's larval age

Initial parasitoid density	Area of discovery of the parasitoid			
	1 st Instar	2 nd Instar	3 rd Instars	4 th Instars
1	0.477	0.579	0.510	0.300
2	0.410	0.483	0.433	0.178
4	0.255	0.300	0.269	0.111
8	0.142	0.168	0.158	0.068
Meanvalue	0.321±0.151	0.382±0.184	0.342±0.159	0.164±0.101
M value	-0.594	-0.605	-0.576	-0.710
Q value	0.477	0.579	0.510	0.300
Regression: $y = a + bx$				
A	-0.269	-0.189	-0.246	-0.528
B	-0.594	-0.605	-0.576	-0.710
R	-0.972	-0.976	-0.977	-0.999
P	-0.001	-0.001	-0.001	-0.001

Table 2: Area of discovery of *Camponotus chlorideae* at seven level of host densities (*Helicoverpa armigera*) with one searching female parasitoid on the different hosts larval age

Initial host density	Area of discovery of the parasitoid			
	1 st Instars	2 nd Instars	3 rd Instars	4 th Instars
1	0.223	0.510	0.223	0.223
2	0.356	0.692	0.510	0.356
4	0.510	0.798	0.597	0.430
8	0.596	0.855	0.692	0.510
16	0.770	0.884	0.826	0.597
32	0.655	0.770	0.692	0.439
64	0.421	0.499	0.464	0.343
Mean Value	0.504±0.187	0.715±0.157	0.572±0.196	0.514±0.121

Table 3: K-Value (killing power) of *Camponotus chlorideae* at its four densities. Each test utilised 50 hosts (*Helicoverpa armigera*) on the different hosts larval age

Initial parasitoid density	K- value of the parasitoid			
	1 st Instar	2 nd Instar	3 rd Instars	4 th Instars
1	0.208	0.252	0.222	0.131
2	0.356	0.420	0.377	0.155
4	0.444	0.523	0.468	0.194
8	0.495	0.585	0.553	0.237
Mean Value	0.376±0.126	0.445±0.145	0.405±0.141	0.179±0.046
Regression: $y = a + b \log x$				
A	0.233	0.279	0.242	0.126
B	0.315	0.366	0.360	0.119
R	0.975	0.977	0.988	0.993
P	0.001	0.001	0.001	0.001

Table 4: K- Value (Killing power) of *Camponotus chlorideae* at seven level of host densities (*Helicoverpa armigera*) with one searching female parasitoid on the different hosts larval age

Intitial host density	K-Value of the parasitoid			
	1 st Instars	2 nd Instars	3 rd Instars	4 th Instars
1	0.097	0.222	0.097	0.097
2	0.155	0.301	0.222	0.155
4	0.222	0.347	0.259	0.187
8	0.259	0.372	0.301	0.222
16	0.335	0.385	0.359	0.259
32	0.285	0.335	0.301	0.191
64	0.183	0.217	0.202	0.149
Mean Value	0.248±0.081	0.425±0.068	0.333±0.085	0.138±0.053

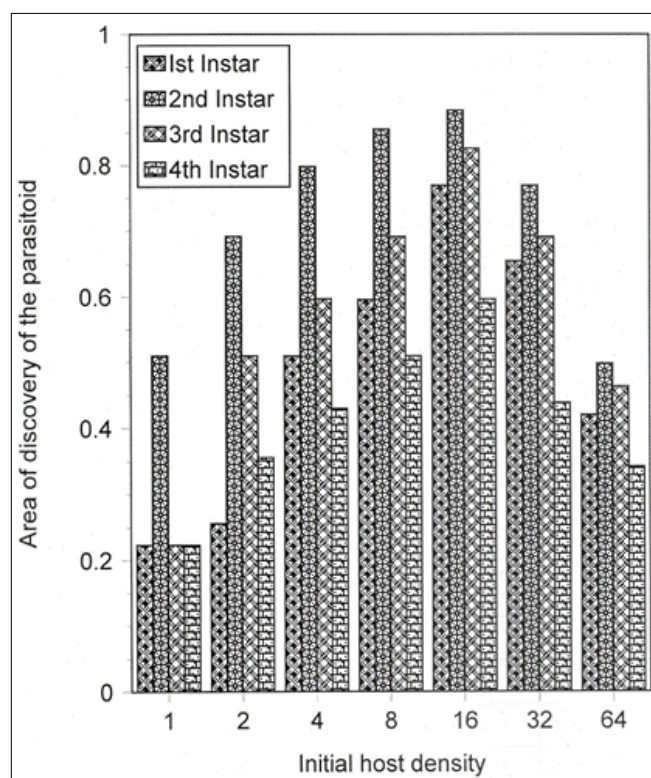
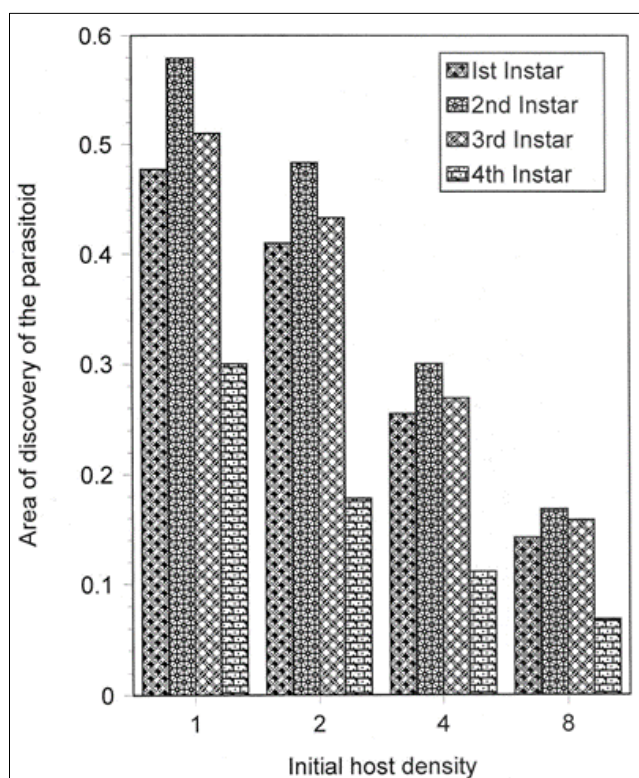


Fig 1: Area of discovery of *Camponotus chlorideae* at its four density on the different larval age of the host *Helicoverpa armigera*

Fig 2: Area of discovery of *Camponotus chlorideae* at seven host density level in different larval age of the host *Helicoverpa armigera*

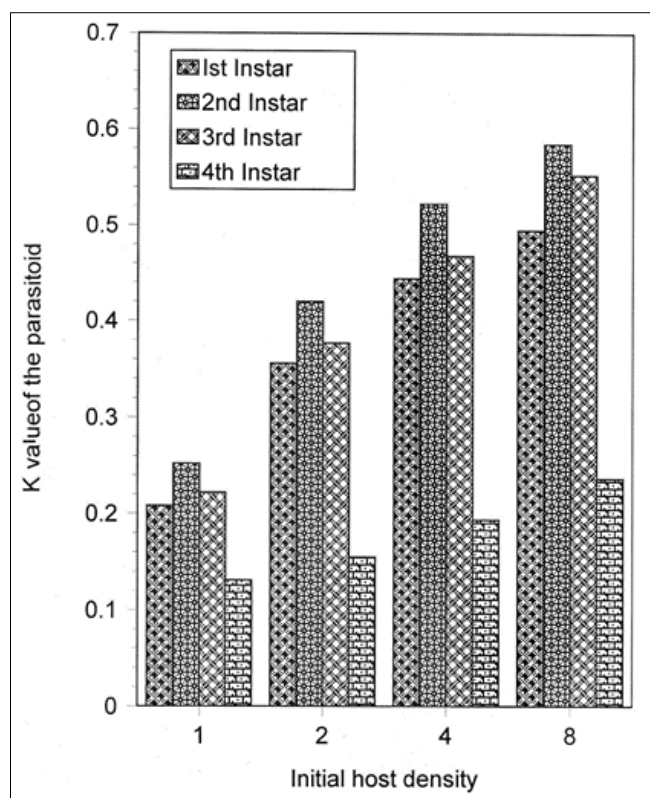


Fig 3: Killing power (K-value) of *Campoletis chlorideae* at four instars on the different larval age of the host *Helicoverpa armigera*

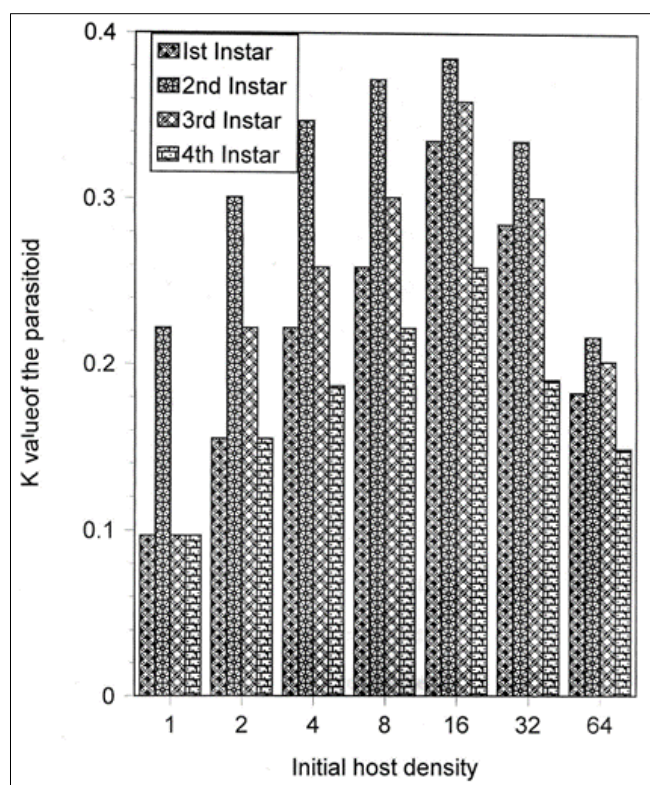


Fig 4: Killing power (K-value) of *Campoletis chlorideae* at seven host density level in different larval age of the host *Helicoverpa armigera*

Discussion

The assumption that host searching behavior of a female parasitoid is constant irrespective of host and parasitoid density, Nicholson [10]; Nicholson & Baily [11] has already been refuted by Hassan [26] and Latheef *et al* [7]. Now it is known to

be regulated by a number of factors viz. parasitoid's age Hollings [27], confusion, area of searching environment Wiedenman & O'Neil [28], host defense, host dispersion, learning Taylor [29], availability of alternative host stages, climatic conditions of host and parasitoid Kumar & Tripathi [30], host distribution Hassell, *et al.* [31] and nutrition of the parasitoid during its larval development [32], physical state of the parasitoid and the co-presence of males with the females [33]. These study the representative of the full range of response by a parasitoid to host density.

The inverse relationship between the parasitoid density and the area of discovery was the most significant trend exhibited during this study (Fig-2). This reflects the existence of intraspecific competition amongst the parasitoid [34, 35]. The results obtained that as the parasitoid density increases, mutual interference increases which cause a reduction in an individual's searching efficiency [36]. The effect of this interference on the stability of host parasitoid interactions has been explored theoretically by Hassell & May [16]. They demonstrated that the greater the value of mutual interference constant amongst the parasitoid of the different host ages helps in their dispersal which favor's the area of interaction [33]. Therefore, interference is considered as a common behavioral phenomenon in the host parasitoid systems. It has also been observed that parasitoid accumulate in the area of higher host densities [37] and stays there for a longer period which adversely affects its searching efficiency [38].

The strong mutual interference constant amongst the parasitoids in different larval instars helps in their dispersal which favors' the area of interaction. The K- value of the parasitoid (Table-3, Fig-3) increases significantly with the increase of their own number resulting in the parasitisation of more hosts [21].

Both the area of discovery and K-value of the parasitoid *C. chlorideae* are maximum in the 2nd larval age followed by 3rd larval age, 1st larval age and 4th larval age. Due to the parasitoid *C. chlorideae* preferred 2nd instar larvae of the host *H. armigera* [39] because this stage in addition to having more food than first instars and quality of food resources emanates more host seeking stimulant. The large size of the host, hardness of the cuticle and defense mechanism of 3rd & 4th instar's of the host was play an important role in the host stage preference by the parasitoid [40]. The host age significantly affects the area of discovery and K-value of the parasitoid at varied parasitoid and host density.

The attraction of the female parasitoid to the host is mainly due to odour of the host [41, 42]. The chemical Stimuli (kairomones) stimulate the host seeking response of the parasitoid, thus play a significant role in host location and has acceptance by the parasitoid [43, 44]. Kairomones affect the behavior of the parasitoid in at least three different ways: (1) by the activation of searching for hosts (2) through retention of the parasitoid in the target area and (3) by improving the egg distribution of the parasitoid [45].

As the host density increases both the area of discovery (Table-2, Fig-2) and K- value (Table-4, Fig-4) increases up to 16 hosts, over that limit they decrease. This decrease is slow up to 32 hosts there after it gains a momentum. This may be due to increase in the behavioral interactions caused by the increased host density [46], the effect of increase in the handling time [15], less egg supply [47] and/ or fatigue of the parasitoid [48]. Further

any parasitoid that parasitizes more hosts for a given host density must produce a higher value of area of discovery as illustrated by the rising curve in Fig-2. The subsequent decline in the curve is possibly due to over time spent by the parasitoid in the area of higher host density.

The result discussed so far reveal that *C. chloridae* is a promising bio-control agent and it can effectively be used against *H. armigera* by its release as it has a high searching efficiency. The searching efficiency and killing power was maximum in 2nd instars than other instars. Therefore, it is recommended that lesser number of parasitoids may be released for young hosts is better than old hosts at any recommended site for control purposes.

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