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# FUNCTIONAL RESPONSE OF *DINARMUS BASALIS* (ROND.) (HYMENOPTERA: PTEROMALIDAE) PARASITIZING *CALLOSOBRUCHUS MACULATUS* (F.)

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## Abstract

The functional response of the parasitoid *Dinarmus basalis* (Rond.) (Hymenoptera: Pteromalidae) is determined to evaluate its potential as a biological control agent. Four female wasps in the presence of males parasitoids, were allowed to oviposit during their life span or hosts at different densities. The data were fit by Rogers' (1972) parasitoid model. The rate of parasitoid search was $a' = 0.123 \pm 0.005$ life span$^{-1}$, and handling time $T_h = 0.056 \pm 0.002$ life span$^{-1}$. Volume of grain had no significant ($P>0.001$) effect on number of parasitoids emerging.

**Key words**: Functional response, *Dinarmus basalis*, *Callosobruchus maculatus*

## Introduction

The functional response is the number of hosts parasitized as a function of host density. Functional response has traditionally been studied by varying the number of hosts in an arena of constant area (Houck and Strauss 1985). However, it is not clear that host numbers and arena area have exactly reciprocal effects on rate of attack. The question of arena size is particularly important when experimental studies are intended to simulate parasitoid behaviour at low host densities, such as those dedicated by economic injury levels. Arena size can be useful to determine the significance of its effect on parasitism at the spatial scale proposed for a particular experiment (Smith and Press 1992).

*Dinarmus basalis* (Rond.) is a solitary, ectoparasitoid of *Callosobruchus chinensis* L., *C. analis* and *C. maculatus* F. (Islam 1994, 1995). It has a good potential to suppress populations of *Callosobruchus* in stored pulses (Islam and Kabir 1995). The functional response of *D. basalis* as part of the evaluation of its potential as a biological control agent. In addition, information of the functional response is an essential element of population models simulating the parasitoids impacts on the bruchid populations. Much information can be obtained from functional response experiments in which the beheviour of individual parasitoids is recorded e.g. host discrimination, handling times and patch time allocation (van Lenteren and Bakker 1976).

Information on functional response of *D. basalis* on *C. maculatus* is not available. To test the functional response of *D. basalis*, the present experiments were undertaken.

## Materials and Methods

*D. basalis* and its host *C. maculatus* were collected from the stock cultures maintained in the insectary separately in the Institute of Biological Sciences, Rajshahi University, Rajshahi, Bangladesh. Three hundred adult beetles were collected and released for oviposition upto 3 days on 300 gm fresh black gram seeds kept

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in plastic pots. Then the seeds were incubated at 30±0.5$^0$C for 22 days to produce large number of larvae and mixed. One hundred gm infested seeds were combined with uninfested seeds of 3000gm have a total grain mass of 3100 gm. The seeds were then divided into 100, 200, 400, 800 and 1600 gm samples, respectively. These samples were placed in glass jars 200, 420, 825, 1550 and 3500 ml, respectively and covered with markin cloth. Four pairs of *D. basalis* adult of 0 to 24-h-old were placed in each jar and held at 30$^0$C. Four pairs were used to allow intraspecific interactions to occur among foraging females and between sexes, as might occur during inundative releases (Rogers and Hassell 1974, Beddington 1975). All emerged *D. basalis* and *C. maculatus* were counted after the emergence ceased, and the eight initial parasitoids were subtracted. Three replicates of control (no *D. basalis*) and experimental jars were set up for each quantity of grain, and the experiments were preformed three times.

### Statistical methods

The combined number of *D. basalis* and *C. maculatus* emerged was regressed against number of beetles emerged in controls to determine whether the former was a good estimate of the number of hosts available. Rogers (1972) random parasitoid model was used to fit the functional response data:

$$\mathrm{Na} = \mathrm{N}\left[1-\exp\left(\frac{-\mathrm{a}'\,\mathrm{TP}}{1+\mathrm{a}'/\mathrm{T_h N}}\right)\right]$$

Where Na is the number of host parasitized; N, the number of host available; a', the rate of parasitoid search; P, the number of female parasitoids; T, the duration of the experiment; and $T_h$, the handling time per host. This model assumes random search behaviour, no discrimination of previously parasitized hosts and constant host population during the time interval (Rogers 1972). Adequacy of the model was evaluated by examining residuals plotted against predicted values, number of hosts, date and by comparing the mean squares ratio.

### Results

The mean number of *C. maculatus* emerged from control sample on the 1st (150.66, 312.33, 596.33, 1221.33 and 2405.66), 2nd (135.33, 285.66, 609.33, 1180.33 and 2132.66) and 3rd (172.33, 342.33, 585.66, 1401.33 and 2525.66) experimental dates from the sample size of 100gm, 200gm, 400gm, 800gm and 1600gm respectively were presented in Table 1. Mean number of *D. basalis* emerged from the experiment date 1 (135.33, 280.66, 420.33, 485.33 and 532.66), 2 (120.33, 257.33, 447.33, 480.66, and 501.33) and 3 (147.33, 287.66, 435.33, 490.33 and 497.33) for the above sample size were also presented in Table 1.

Regression of the combined number of emerged *D. basalis* and *C. maculatus* against the number of emerged parasitoids in control indicates a one-to-one correspondence (Y=12.3788+0.9903X, F=15459.7625, df=1, 13, $P>0.0001$, $r^2=0.999$ (Fig. 1).

The random parasitoid model (Rogers 1972) provided an adequate fit to the data ($a'=0.123 \pm 0.005/\mathrm{lifespan}^{-1}$ (unspecified time period), $T_h=0.056 \pm 0.002/\mathrm{lifespan}^{-1}$ (Fig. 2).

**Table 1**. The functional response data of *D. basalis* on *C. maculatus*

| Sample size | No. beetle emergence from control | Experiment | | | The rate of parasitoid search (a') | The handling time ($T_h$) |
|---|---|---|---|---|---|---|
| | | No. of parasitoid | No. of beetles | Total | | |
| | 150.66±5.13[1] | 135.33[1] | 10.66[1] | 145.00±4.53[1] | 0.12[1] | 0.12[1] |
| 100gm | 135.33±3.40[2] | 120.33[2] | 12.66[2] | 132.00±3.23[2] | 0.13[2] | 0.15[2] |
| | 172.33±4.53[3] | 147.33[3] | 22.0[3] | 169.33±5.42[3] | 0.13[3] | 0.12[3] |
| | 312.33±4.1[1] | 280.66[1] | 30.33[1] | 310.99±5.79[1] | 0.13[1] | 0.06[1] |
| 200gm | 285.66±6.52[2] | 257.33[2] | 27.33[2] | 284.66±3.13[2] | 0.12[2] | 0.06[2] |
| | 342.33±5.31[3] | 247.66[3] | 52.67[3] | 340.33±5.12[3] | 0.12[3] | 0.06[3] |
| | 596.33±7.40[1] | 420.33[1] | 175.66[1] | 596.33±7.15[1] | 0.12[1] | 0.04[1] |
| 400gm | 609.33±5.31[2] | 447.33[2] | 152.33[2] | 599.66±5.36[2] | 0.12[2] | 0.04[2] |
| | 585.66±6.22[3] | 435.33[3] | 145.33[3] | 575.66±6.34[3] | 0.12[3] | 0.04[3] |
| | 1221.33±11.32[1] | 485.33[1] | 733.66[1] | 1219.00±9.32[1] | 0.14[1] | 0.04[1] |
| 800gm | 1180.33±8.60[2] | 480.66[2] | 694.33[2] | 1175.00±7.15[2] | 0.14[2] | 0.04[2] |
| | 1401.33±6.92[3] | 490.33[3] | 1009.00[3] | 1499.33±5.15[3] | 0.14[3] | 0.04[3] |
| | 2405.66±10.25[1] | 532.66[1] | 1865.33[1] | 2398.00±8.75[1] | 0.15[1] | 0.03[1] |
| 1600gm | 2132.66±7.11[2] | 501.33[2] | 1630.33[2] | 2131.0±8.67[2] | 0.15[2] | 0.04[2] |
| | 2525.66±8.75[3] | 497.33[3] | 2023.33[3] | 2520.66±7.23[3] | 0.15[3] | 0.04[3] |

[1]Date 1, [2]Date 2, [3]Date 3

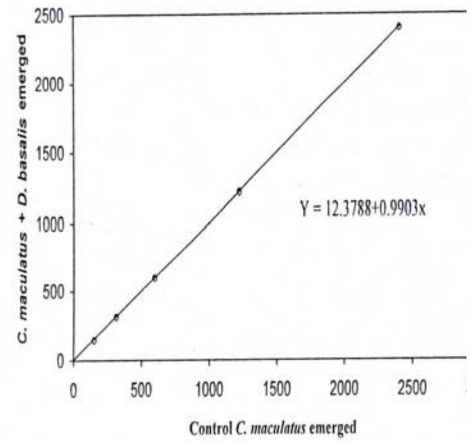

**Fig.1.** Regression of combined number of *C. maculatus and D. basalis* emerged in experimental samples on number of *C. maculatus* emerged in control samples.

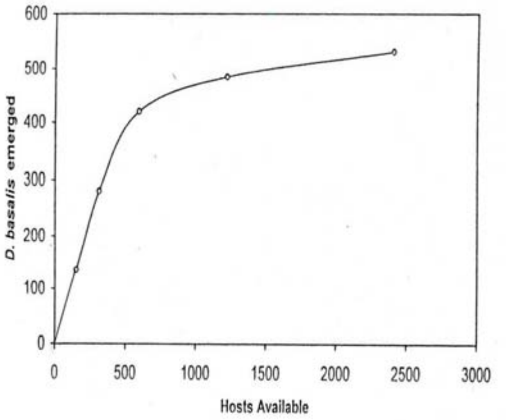

**Fig. 2.** Functional responses of *D. basalis* on *C. maculatus* in black gram by Rogers (1972) random parasitoid model.

Grain volume had also significant effect on number of parasitoids emerged when regression after blocking for experimental dates (host numbers differed between dates but were constant within dates): date 1, Y=2.353 + 0.97X, F= 263643.294 df=1, 3, $r^2$=1.00, P>0.001; date 2, Y= 22.42 + 0.97X, F=923.36, df=1, 3, $r^2$=0.997, P>0.001; date 3, Y=6.57 + 0.96X, F=13674.56, df=1,3, $r^2$=1.00, P>0.001 whereas X is the volume of grain in liters. Although each of the three regression equation had a positive slope, none of them were significantly different from zero. This indicates that grain volume had no significant effect on the number of hosts parasitized.

## Discussion

Functional response has received considerable attention in the ecological literature. This interest arises from questions such as whether density dependent parasitism occurs, which would stabilize host-parasitoid interactions and which is thought to be an important criterion for the selection of parasitoids in biological control (van Lenteren and Bakker 1976). Furthermore, scientists have been working on simulation models for parasitism and resource competition of parameters for their models, and on the effect of those parameters on stability.

Experimental setups differ widely among different authors. For example, the size and “artificialness” of the experimental arena, the actual densities tested (in relation to naturally occurring densities), the time duration of experiments, the distribution of hosts, the possibility of searching parasitoids to leave the experimental unit, and the number of parasitoids searching together (interference) vary among authors. It is often extremely difficult to replace parasitized hosts during the experiment without disturbing the searching female. Nevertheless, all these variables have their effect on the out come of the experiments, and some variable put strong limitations on the type of models which are appropriate, and on the kind of statistical analysis which can be employed. Houck and Strauss (1985) discuss appropriate experimental designs. The selection of appropriate model (Type II or Type III functional response) requires logistic regression of the proportion of host parasitized versus the number of hosts present (Trexler *et al*. 1988, Juliano 1993). Estimation and comparison of parameters are best done through non linear least squares regression techniques (Williams and Juliano 1985, Juliano and Williams 1987). Juliano (1993) described appropriate non-linear curb fitting procedures for functional response experiments.

Preliminary curve fitting in this study was done with functions derived from Goudriaan (1979). Earlier experiments had shown good fits with this approach. Lower the densities, the curves predict lower parasitisation rates than actually observed. The data also suggest that the plateau level may be higher and/ or may be attained at higher densities than the curves indicate.

Hassell *et al*. (1985) observed that 5.8% of *C. maculatus* in black-eyed beans produced neither an adult host nor parasitoid when exposed to parasitoid, *Anisopteromalus calandrae*, so the host number (3.24) was low in this estimation. The precision of data would not permit detection of host mortality less than 6.4%.

Islam (1995) observed female of *D. basalis* producing an average of 177 progeny on the pulse beetle at 30$^0$C and 70% RH. In this experiments, 150.25 progeny per female over her life, which is more or less similar to that of by Islam (1995).

A decrease in number of suitable hosts, due to parasitism, during the experiment would violate the assumption of constant host population made in Rogers (1972) random parasitoid model. This would cause us to underestimate a', the attack rate but it would not undermine conclusions regarding the effect of grain volume and host number because all treatments would be affected similarly. However, the host involved were distributed over a wide range of age and size classes. Small hosts, which are unsuitable for parasitism (Islam 1994), would grow and become suitable during the course of the experiment. This tends to replace hosts that have become unsuitable by being parasitized or maturing into unsuitable stages. During the 14d periods (Islam 1995) most of the parasitism occurred and the population of suitable hosts probably did not differ greatly.

The proportion of pulse beetle that escaped parasitism ranged from ≤7.5% at ≤150 hosts to ≤80% at ≤2405 hosts per container. The low proportion of hosts parasitized in the present experiment could be due to interference between the four adult females and males, which is known to reduce the rate of parasite search (Rogers and Hassell 1974, Beddington 1975, Abidi *et al*. 1989). It could also be due to some of the hosts being outside the suitable size range for parasitism (Islam 1994, 1995).

Smith and Press (1992) reported that mean number of *Sitophilus oryzae* emerged per control sample on the three experimental dates were: 571.8 (15.4), 222.5 (4.7), and 397.7 (14.1). Combined number of *A. calandrae* and *S. oryzae* emerged per experimental sample was 566.0 (9.3), 205.5 (5.3) and 388.9 (8.1), respectively which were related to the present observations.

Handling time ($T_h$) and the rate of parasitoid search (a') were estimated, $T_h$ =0.056 ± 0.0021 lifespan and a' = 0.123 ± 0.005/lifespan interprets the observation of Smith and Press (1992), who reported that the handling time ($T_h$) and the rate of search (a') of *A. calandrae* on *S. oryzae* were ($T_h$) = 0.0027 lifespan, and (a') = 0.32 lifespan$^{-1}$.

This study indicates that the number of hosts parasitized by *D. basalis* is dependent upon the number of hosts available, rather than their density (hosts per volume or surface area), at this spatial scale. This suggests that functional response data collected from different-sized arenas will produce comparable model parameter estimates, provided that the arena is not larger than the area that can be searched in the time available. Whether such conclusions would hold for patchily distributed host in a much larger environment may depend on the efficiency of the parasitoid to locate the host patches, relative to finding hosts within a patch. Such behaviour is likely to involve on different mode of searching. Although the larger spatial scale presents a serious challenge to experimentation, such knowledge is crucial for applying quantitative laboratory results to the development of effective biological control strategies.

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