

**TEMPERATURE AND HOST DEPENDENT FUNCTIONAL RESPONSE  
OF *ANISOPTEROMALUS CALANDRAE* (HOW.) AND *CHOETOSPILA  
ELEGANS* (WESTW.) PARASITODS IN PARASITIZING WHEAT  
INFESTING *RHYZOPERTHA DOMINICA* (F.)  
(COLEOPTERA: BOSTRICHIDAE)**

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**Abstract:** *Rhizopertha dominica* (F.) (Coleoptera: Bostrichidae) is an internal feeder of whole wheat seed, flour, etc. *R. dominica* is parasitized by two pteromalid ectoparasitoids, *Anisoptromalus calandrae* (How.) and *Choetospila elegans* (Westw.) in the larval and pupal stages. The effects of host density and temperature on the functional response of the parasitoids in parasitizing the larval and pupal stages of the hosts were examined. Four temperatures and five host densities were used. A functional response equation was used in which a quadratic component that included temperature was substituted for handling time. Functional response of parasitization by *A. calandrae* and *C. elegans* fit a formula of Hassell *et al.* (1977) type III model. The maximum rate of parasitization of *A. calandrae* was 8.6 larvae/24 hrs and 7.2 larvae/24 hrs of *C. elegans* at 30°C, respectively. Handling time and instantaneous search rate varied with temperatures. The ability of *A. calandrae* and *C. elegans* to find and parasitize *R. dominica* over a broad range of temperatures demonstrate it as a good candidate for natural control of the pest.

**Key words:** *Anisoptromalus calandrae*, *Choetospila elegans*, functional response, lesser grain borer, *Rhizopertha dominica*

## INTRODUCTION

The lesser grain borer, *Rhizopertha dominica* (F.) an internal feeder is one of the most abundant pests of wheat, stored cereals and grains (Potter 1935, Alam 1971). The species virtually feeds on all kinds of stored grain and milled cereals causing severe damage of the stored commodities throughout the world (Chittenden 1911, Edde 2012), and especially in the tropical and subtropical countries (Dhaliwal 1976) including Bangladesh (Alam 1971, Hossain *et al.* 1986). The damage is caused by larval and adult stages (Cotton 1963, Cambell and Sinha 1976). This pest is with high fecundity, polyphagous in nature, and also shows quick resistance against insecticides so consequently the control of this pest for a long time is quite difficult. *Anisoptromalus calandrae* (How.) and *Choetospila elegans* (Westw.) are the larval and pupal ectoparasitoids of *R. dominica* belonging to the family Pteromalidae (Islam 1993, Biswas *et al.* 2004). These parasitoids are present in the natural conditions and at certain time of the year they considerably check the population in the granaries or

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stores infested by *R. dominica*. The mated female of *A. calandrae* and *C. elegans* deposited their eggs on the external surface of the host body by inserting the ovipositor through the outer seed-coat of the infested grains separately. The newly hatched larvae suck the body fluids of the host continuously for development, pass through different life-stages and ultimately emerge as adults by causing death of the host insects. The parasitoid takes 10 - 12 days to complete their entire life cycle from egg to adult emergence in case of *A. calandrae* but 16 - 18 days in case of *C. elegans* (Islam 1993, Biswas *et al.* 2004). Host-feeding is generally regarded as a normal process in Ptreomalidae (Clausen 1962). Both the parasitoids forms feeding tube extending from the surface of the body of the host insect to outside the seed and feeds on the host's fluid that oozes through the feeding tube.

The rate at which parasitoids attack hosts is dependent on host density. This relationship has been described as a functional response to host density (Solomon 1949). Temperature also affects functional response and general models have been developed (Flinn 1991). Parasitoid life-history characteristics change as a function of temperature (Smith 1994). Searching and attack rates are also expected to be affected by temperature (Flinn 1991), and it is possible that handling time is also affected. A good number of reports are available on the effects of temperature on functional response (Messenger 1968, Flinn 1991) and only Mack *et al.* (1981) proposed a general eight-parameter equation. However, the shape and height of the curve vary among species and foraging conditions. Thus, to build a predictive model, a study on the particular parasitoid, host, and environment of interest must be conducted. In the present study a temperature-mediated functional response equation that uses a quadratic function for handling time. This model is used to predict attack rate as a function of host density and temperature.

## MATERIAL AND METHODS

Adult *Rhizopertha dominica* and its parasitoids, *Anisopteromalus calandrae* and *Choetospila elegans* used in this research were obtained from cultures maintained in control temperature (CT) room ( $30 \pm 0.5^\circ\text{C}$  and 70% RH) at Entomology and Insect Biotechnology Laboratory, Institute of Biological Sciences, University of Rajshahi since last ten years. One to two day-old eggs of *R. dominica* were obtained by allowing adults to oviposit in wheat and then the beetles were separated from the wheat to recover the eggs. The wheat kernels were infested with *R. dominica* larvae by using a needle to make a small hole in the kernel and placing one *R. dominica* egg on it. The kernels were placed into the individual vials and held at CT room for 21 days to allow them to develop into the 4<sup>th</sup> instar larvae. The wheat kernels were infested with *R. dominica* larvae. Different infested kernels 2, 4, 8, 16 and 32 were mixed into 300 gm

wheat (12% moisture content, wet weight) and kept in glass jars (7 cm diam, 13.5 cm length).

After mating, the mated females of *A. calandrae* and *C. elegans* were released in to the jars separately. After emergence, the number of adult parasitoids was recorded. The experiment was carried out at four different temperatures viz., 20, 25, 30 and 35°C and 70 ± 0.5% RH. Each treatment was replicated five times.

The type III response is the most common for insect predators and parasitoids. Here type I and type II models of Holling's (1959a,b) and type III model of Hassell *et al.* (1977) are used following the formula given below:

$$\begin{array}{ll} \text{Type I: } N_A = aTN & 1 \\ \text{Type II: } N_A = aTN/(1 + aT_hN) & 2 \\ \text{Type III: } N_A = N [1 - \exp\{-a(T - T_hN_a)\}] & 3 \end{array}$$

In these models,  $N_A$  is the number of host parasitized,  $N$  is the initial density of parasitoids,  $T$  is the time available for searching during the experiment,  $a$  is the instantaneous rate of discovery and  $T_h$  is the amount of handling time per host. The coefficient of determination ( $r^2$  values) were calculated by SAS PROCNLIN (SAS Institute 1996). Parameters  $a$  and  $T_h$  from the functional response models were estimated using SAS PROCNLIN methods (SAS Institute 1996) also. All analyses of density effects on predations and comparisons of predation relating to male and female were completed using SAS PROC MIXED method (SAS Institute 1996).

## RESULTS AND DISCUSSION

The different temperatures were fit separately in equation III model (Table 1). In *A. calandrae*, the parasitization rate increased with host density at all temperatures tested. Handling time was highest at 20°C but lowest at 30°C, respectively. Instantaneous search rates were 0.015 ± 0.008, 0.061 ± 0.16, 0.112 ± 0.045 and 0.451 ± 0.110 at 20, 25, 30 and 35°C, respectively. The coefficients of determination ( $r^2$  values) were 0.9890, 0.9959, 0.9936 and 0.9636 on the above mentioned temperatures. The instantaneous search rates were highest at 35°C and lowest at 20°C. The maximum parasitization rates were 1.80, 4.40, 8.60 and 7.90 at 20, 25, 30 and 35°C, respectively. It was highest (8.6) at 30°C but lowest (1.8) at 20°C. Analysis of variance shows that production of  $F_1$  progeny of *A. calandrae* on *R. dominica* was significantly ( $p > 0.01$ ) different in different parasitoid densities and temperatures.

In case of *C. elegans*, handling times were 20 ± 3.10, 5.68 ± 0.62, 3.37 ± 0.18 and 4.90 ± 0.37 at 20, 25, 30 and 35°C, respectively (Table 2). Instantaneous search rates

were  $0.020 \pm 0.006$ ,  $0.056 \pm 0.021$ ,  $0.125 \pm 0.035$  and  $0.501 \pm 0.120$  on the same temperatures but highest at 35°C and lowest at 20°C. The coefficients of the determination ( $r^2$  values) were 0.3124, 0.9974, 0.9783 and 0.9978 and the maximum number of parasitized were 0.8, 4.4, 7.2 and 4.8 at 20, 25, 30 and 35°C, respectively. The maximum parasitized was highest at 30°C and lowest at 20°C. Analysis of variance shows that production of  $F_1$  progeny of *C. elegans* on *R. dominica* was significantly ( $p > 0.01$ ) different in different parasitoids densities and temperatures.

**Table 1. Estimates of handling time ( $T_h$ ), instantaneous search rate ( $a$ ), coefficient of determination ( $r^2$  values) and maximum number of parasitized by *A. calandreae* on *R. dominica***

Temperature (°C)	Handling time ( $T_h$ ) $\pm$ SE(h)	Instantaneous search rate ( $a$ ) $\pm$ SE	$r^2$ values for type-III	Max. no. parasitized
20	16.15 $\pm$ 3.35	0.015 $\pm$ 0.008	0.9890	1.8
25	6.25 $\pm$ 0.73	0.061 $\pm$ 0.016	0.9959	4.4
30	2.85 $\pm$ 0.21	0.112 $\pm$ 0.045	0.9936	8.6
35	3.16 $\pm$ 0.26	0.451 $\pm$ 0.110	0.9636	7.8

**Table 2. Estimates of handling time ( $T_h$ ), instantaneous search rate ( $a$ ), coefficient of determination ( $r^2$  values) and maximum number of parasitized by *C. elegans* on *R. dominica***

Temperature (°C)	Handling time ( $T_h$ ) $\pm$ SE (h)	Instantaneous search rate ( $a$ ) $\pm$ SE	$r^2$ values for type-III	Max. No. parasitized
20	20 $\pm$ 3.10	0.020 $\pm$ 0.006	0.3124	0.8
25	5.68 $\pm$ 0.62	0.056 $\pm$ 0.021	0.9974	4.4
30	3.37 $\pm$ 0.18	0.125 $\pm$ 0.035	0.9783	7.2
35	4.90 $\pm$ 0.37	0.501 $\pm$ 0.120	0.9978	4.8

The efficacy of both the parasitoids were found to increase with increasing temperatures. A short handling time increases the time available for searching and hence the likelihood of finding additional hosts. The estimated handling time was lowest at 30°C but highest at 20°C in the present findings. Table 3 shows the equation fitted *A. calandreae* and *C. elegans* on *R. dominica* to each temperature. The rate of parasitization was more variable at 30 and 35°C than at 20 and 25°C. Thirty degree centigrade is the suitable temperature for parasitization than others one. In every case, *A. calnadrae* is better than *C. elegans* for parasitization.

In the present result handling time and search rate varied in response to temperature. Both handling time and instantaneous search rate were correlated over the range of temperatures examined. Thus, by making handling time a function of temperature, instantaneous search rate was also adjusted. In control, instantaneous search rate primarily affects the shape of the functional response at low to intermediate host densities.

Mack *et al.* (1981) developed a temperature-mediated functional response and found that the relationship between handling time and temperature should be U-shaped because there should exist an optimum and two temperature extremes at which handling time is infinite. The present results are similar to that of Mack *et al.* (1981).

**Table 3. Functional response of *A. calandrae* and *C. elegans* parasitizing *R. dominica* at different temperatures**

Den- sity	<i>A. calandrae</i> (°C)				<i>C. elegans</i> (°C)			
	20	25	30	35	20	25	30	35
2	0.2 ±0.20	0.40 ±0.24	0.60 ±0.24	0.60 ±0.24	0	0.60 ± 0.24	0.80 ± 0.37	0.60 ± 0.24
4	0.60 ±0.24	1.00 ±0.31	1.60 ±0.40	1.00 ±0.31	0	0.80 ± 0.37	1.20 ± 0.37	1.20 ± 0.37
8	1.05 ±0.31	2.20 ±0.37	3.80 ±0.37	3.40 ±0.51	0.4 ± 0.24	1.60 ± 0.51	3.20 ± 0.37	1.60 ± 0.51
16	1.40 ±0.51	2.60 ±0.51	4.80 ±0.08	4.80 ±0.37	0.6 ± 0.24	2.80 ± 0.48	4.80 ± 0.37	2.80 ± 0.37
32	1.80 ±0.37	4.40 ±0.51	8.60 ±0.67	7.80 ±0.60	0.8 ± 0.37	4.40 ± 0.40	6.80 ± 0.58	4.80 ± 0.37

Present results suggest that both *A. calandrae* and *C. elegans* could be effective in reducing populations of *R. dominica* in stored wheat. They are able to attack up to 8.6 larvae and 7.2 larvae per 12 hrs. This is relatively high rate of attack compared with other stored-grain parasitoids. The above mentioned parasitoids have been found throughout the stored wheat grain mass in stores. Thus, parasitoids should be able to parasitize hosts that are located in any region of the wheat grain mass. The parasitoids also attacked *R. dominica* over more or less all full range of temperatures that are optimal for its growth.

Host feeding is an important mortality factor that would need to be included in a model for *R. dominica*. Host feeding is a desirable character for biological control agents because it does not only depress host density but also has a stabilizing effect on the system (Yamamura and Yano 1988). Hosts that are parasitized but are not killed by host feeding may provide additional stability to the system. In the present study parasitized hosts larvae do not progress to the next developmental stage ultimately the hosts die due to host feeding.

*A. calandrae* and *C. elegans* are the best candidates for biological control of the lesser grain borer. The changes of parasitoid for finding suitable host may be much greater than for other developing inside the grain kernel. Both the parasitoids increases host mortality by parasitizing and feeding on 2nd to all life stages of *R. dominica*. The generation times are half than that of their host and

they are very host-specific. Searching efficiency is usually higher in host-specific parasitoids (Hassell 1978) and can lead to a greater depression of host equilibrium.

The ability of *A. calandae* and *C. elegans* to find and parasitize *R. dominica* over a broad range of temperatures make them good candidates for natural control of stored grain pests where temperature fluctuations are frequent. Expert systems already exist for pest management in stored grain (Flinn and Hagstrum 1990). *A. calandae* and *C. elegans* are two efficient parasitoids of *R. dominica* in stores that could be used for biological control agents. The experiments conducted in this study have demonstrated that the effectiveness of the parasitoids depend on the prevailing temperatures in different storages.

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