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EFFECTS OF TEMPERATURE, RELATIVE HUMIDITY AND HOST ON THE BIOLOGY OF *ANISOPTEROMALUS CALANDRAE* (HYMENOPTERA: PTEROMALIDAE)

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Abstract: Developmental period of the pteromalid wasp *Anisopteromalus calandrae,* was observed in the laboratory using two types of hosts at different constant temperature and relative humidity. The developmental period ranged from 28.6 ± 6.6 days at 20°C temperature and 90% R.H. to 10.7 ± 2.1 days at 35°C and 90% R.H. Mating of the adult parasites occurred shortly after emergence at all the temperature regimes and relative humidities under study period. The female started laying eggs within 1 day at 25, 30 and 35°C and in about 1.5 – 2.0 days at 20°C. Relative humidity had no appreciable effect on oviposition. The incubation period was 2.1 ± 0.1 days at 20°C and 50% R.H. The larval period decreased from 9.3 ± 0.1 days at 20°C to 3.2 ± 0.1 days at 35°C. The relative humidity played no pronounced effect on the larval durations. The developmental period from egg to adult with *Rhizopertha dominica* as host was found to be shorter, being approximately one day less than that of *S. oryzae* as host. The duration of developmental period of male was less than that of female irrespective of temperatures and relative humidity conditions. The pupal period in female individuals decreased from 15.5 ± 0.1 days at 20ºC to 5.1 ± 0.1 days at 35ºC. The variations in relative humidity at different constant temperatures lengthened the pupal period to a lesser extent as was revealed form the experiments performed.

Key words: Temperature, relative humidity, progeny production, *Anisopteromalus calandrae*

INTRODUCTION

Studies on the effects of constant temperatures on the development of different hymenopteran parasites were carried out by several workers (Wallace and Sullivan 1963, Sullivan 1965, Pilon *et al.* 1964, Heron 1967, and Philogene and Benjamin 1971). Browning and Oatman (1981) reported that different constant temperatures influenced the developmental time, adult longevity and progeny production in *Hyposoter exiguae* (Viereck) to a greater extent. Temperature also affects the dispersal behaviour of pteromalid parasites as described by Smith *et al.* (1989).

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The effects of temperature and relative humidity on the rate of development and adult longevity of *Anisopteromalus calandrae* and *Apanteles flavipes* (Cam.) have been described by Ghani and Sweetman (1955) and Mohyuddin (1971).

To understand the parasite-host relationship between *Anisopteromalus calandrae* and *Sitophilus oryzae* and also to *Rhizopertha dominica* and the factors affecting their abundance, the combined effects of various constant temperatures and relative humidity conditions on the developmental period, progeny production and adult longevity of the parasite were studied.

MATERIAL AND METHODS

The parasite, *A. calandrae* were reared in rectangular plastic containers (15 cm × 8 cm) covered by muslin using *S. oryzae* larvae as host in the laboratory. The mated female parasites were released into insect cages (25 cm × 22 cm) at an average room temperature of 30°C and 70% R.H. Fifty per cent honey-water solution on cotton was suspended from the top of the cage as food for the parasites.

To determine the effects of temperature and host on the development and progeny production of the parasite, the newly emerged mated female parasites were exposed to the 4^{th} instar larvae or pupae of the host, *S. oryzae,* feeding on wheat kernels. They were then observed under different temperature and humidity conditions. The temperatures used were 20, 25, 30 and 35°C and the relative humidities were maintained at 50, 70, 90% following the procedure of Buxton and Mellanby (1934). All the studies were carried out at 12:12 light: dark photoperiods. To observe the maximal daily progeny production by a newly emerged mated female, 50 preferred host with the food were exposed to parasitization for 24 hours in glass vials covered with fine cloth. The developmental rate and progeny production of the parasite was also observed using *R. dominica* as an alternate host of the parasite to find out any difference in the parasitism. The data were recorded for the incubation period, the duration of various immature stages, the pupal and the prepupal periods, the age of female at oviposition, the post oviposition periods, the date of emergence of adult parasite and the sex of the offsprings. The experiments were repeated ten times.

The effect of temperature on adult longevity was measured by placing the newly emerged adults to the desired temperatures and humidities in plastic vials. The longevity of the mated females also was similarly observed. The records were maintained on the mean longevity of the females in each case. The experiments were replicated 10 times at each of the four temperatures and the three relative humidity conditions. Analyses of variance and Duncan's New Multiple Range Test (Duncan 1955) were utilized for the separation of means.

RESULTS AND DISCUSSION

Developmental period: The relationship between the temperature and developmental time of *A. calandrae* varied inversely and generally developmental time did not increase with the increase of relative humidity (R.H.) (Table 1). Developmental time from egg to adult ranged from 28.6 ± 6.6 days at 20°C and 90% R.H. to 10.7 ± 2.1 days at 35°C and 90% R.H. The developmental durations of various immature stages on exposed hosts were found to be similar compared to those developing inside the kernels. Mating of the adult parasites occurred shortly after emergence at the temperatures and relative humidities under study period. The female started laying eggs within a day at 25°C, 30°C and 35°C and in about 1.5 to 2 days at 20°C. Relative humidity had no appreciable effect on oviposition.

The incubation period of the eggs occupied 2.1 ± 0.1 days at 20°C and 50% R.H. The larval period decreased from 9.3 ± 0.1 days at 20°C to 3.2 ± 0.1 days at 35°C. The relative humidity played no pronounced effect on the larval durations (Table 1).

Pupal development also was depended upon the temperature and relative humidity to a great extent and the prepupal period occupied 1 day at all the temperatures and relative humidities. The developmental period from egg to adult with *R. dominica* as host was found to be shorter, being approximately one day less than that of *S. oryzae* as host. The pupal period in female individuals decreased from 15.5 ± 0.1 days at 35ºC to 5.1 ± 0.1 days at 20ºC. The variations in relative humidity at different constant temperatures lengthened the pupal period to a lesser extent as was revealed form the experiments performed.

From the present observations it is evident that lowest threshold in larval development of *A. calandrae* was 35°C and 90% R.H. and the highest was 20ºC and 70% R.H. and the optimal constant temperature and relative humidity was 35ºC and 70% R.H. (Table 1). These results comply with the view of Puttler (1961) who reported a decreased developmental period for *H. exiguae* on a lepidopteran host, *Peridromia saucia* (Hubner) at increased temperatures. The developmental durations of *A. calandrae* decreased with increase of temperature (Ghani and Sweeman 1955). The lowest threshold of larval development in *Spodoptera littoralis* (Lepidoptera : Noctuidae) was recorded at the temperature of 15ºC (Sidibe and Lauge 1977). *Microplitis rufiventris* Kokujev (Hymenoptera: Braconidae), a parasite of beet armyworm, *Spodoptera exigua (*Hubner*)* (Lepidoptera: Noctuidae) successfully attacked and parasitized 2nd instar host

Table 1. The mean duration of different life cycle stages of *Anisopteromalus calandrae* at different constant temperature and relative humidity reared on *Rhizopertha dominica* as host

Temp. (°C)	Relative humidity (%)	Incubation period (days) (Mean ± Sd.)	Duration of immature stages (days)						Total developmental period (days)	
			Male			Female			Male	Female
			Larval (Mean ± Sd.)	Prepupal (Mean ± Sd.)	Pupal (Mean ± Sd.)	Larval (Mean ± Sd.)	Prepupal (Mean ± Sd.)	Pupal (Mean ± Sd.)		
20	50	2.1 ± 0.1a**	9.3 ± 0.1a	1.2 ±0.07a	14.2± 0.1a	9.5±0.1a	1.1±0.07a	15.5±0.1a	26.8±6.1a	28.2a
	70	2.0 ± 0.1a	9.3 ± 0.1a	1.3 ±0.08a	14.5±0.1a	9.6±0.1a	1.2±0.09a	15.6±0.1a	27.1±6.2a	28.4a
	90	2.0 ± 0.1 a	9.3 ± 0.1a	1.3 ±0.07a	14.6±0.1a	9.6±0.1a	1.2±0.1a	15.8±0.1a	27.2±6.3a	28.6a
25	50	1.1 ± 0.07a	4.2 ±0.1a	1.0 ±0.08a	7.5±0.1a	4.6±0.1a	1.1±0.07a	8.40.1a	13.8±3.0a	15.2a
	70	1.0 ± 0.05a	4.5 ± 0.1a	1.0 ±0.08a	7.4±0.1a	5.5±0.1a	1.1±0.08a	8.6±0.1a	13.9±3.0a	16.2a
	90	1.0 ± 0.06a	4.3 ± 0.2a	1.0 ±0.08a	7.5±0.3a	5.3±0.1a	1.2±0.1a	8.7±0.1a	13.8±3.1a	16.2a
30	50	0.9 ± 0.1a	3.5 ± 0.1a	0.9 ± 0.1a	4.5±0.2a	4.1±0.1a	1.0±0.1a	4.9±0.1a	9.8±1.8a	10.9a
	70	0.8 ± 0.1a	3.4 ± 0.1a	0.9 ±0.08a	4.3±0.1a	3.2±0.2a	0.9±0.07a	4.8±0.1a	9.4±1.7a	9.7b
	90	0.9 ± 0.1a	3.2 ± 0.1a	1.0 ±0.09a	4.4±0.1a	4.1±0.1a	4.1±0.1b	5.2±0.1b	9.5±1.7a	11.2b
35	50	0.8 ± 0.1a	3.2 ± 0.1a	0.9 ±0.06a	4.0±0.2a	4.0±0.2a	1.0±0.1a	4.7±0.1a	8.9±1.6a	10.5a
	70	0.9 ± 0.1a	3.4 ± 0.1a	0.8 ±0.1a	4.0±0.1a	4.1±0.2a	0.9±0.08a	4.6±0.1a	9.1±1.6a	10.5a
	90	0.8 ± 0.1a	3.2 ± 0.1a	0.9 ±0.1a	4.3±0.1a	3.9±0.1a	0.9±0.1a	5.1±0.1a	9.2±1.6a	10.7a

*Data based on 10 observations.
**Average within the column followed by a common letter are not significantly different at the 5% level of DNMRT.

larvae regardless of rearing temperature and usually emerge from 4th instar larvae (Hutchison *et al.* 1986). Developmental times for the egg/larval stage (both sexes) decreased with increasing temperature up to 32°C. It was found that there exists a relationship between the rate of development of *A. calandrae* larvae and age of host parasitized and early instars developed more rapidly in older hosts, whereas the last parasite instar developed more slowly in older hosts. A similar result was described by Jowyk and Smiliwitz (1978) in *H. exiguae* reared on *Trichoplusia ni* (Lepidoptera: Noctuidae) as host:

The incubation and prepupal periods of *A. calandrae* always decreased with increase of temperature in both the sexes but the effect of different percentage of relative humidity seemed to be less prominent. Increasing the rearing temperature to 27°C, decreased the average incubation period of *Spalangia nigra* Latreille (Hymenoptera: Pteromalidae) (Hall and Fischer 1988). The average postovipostion period of the parasite decreased with an increase of temperature at all the relative humidity concerned was observed by Ghani and Sweetman (1955) on *A. calandrae*. At 28.5 ± 2°C the life cycle of braconid parasite, *Apanteles flavipes* of the graminaceous borers was completed in 16.5 days, the larval period being 11 days on an average and the prepupal and pupal periods were 5.5 days (Gifford and Mann 1967).

Pupal period was largely depended upon the prevailing temperature and the female pupal period was always longer than that of male pupa in the present observation (Table 1). Temperature regulated the pupal development also in *H. exiguae* reared on *P. saucia* (Puttler 1961). The developmental period from egg to adult of *A. calandrae* on *R. dominica* was found to be nearly 1 day less than *S. oryzae* as host under similar experimental conditions and this may be due to smaller host size of the former host. This finding is in accordance with the view of Chatterji (1955). According to Ghani and Sweetman (1955), the influence of temperature and moisture on reproduction of *Aplastomorpha calandrae* (*Anisopteromalus calandrae*) was well marked. The parasites developed and emerged in 10 to 12 days at 30°C but development was prolonged to 28 to 30 days at 22°C. The female larvae spent about 3.5 to 4 days in the larval stage, less than a day in the prepupal stage and about 6 days as pupa at 30°C.

The progeny production of *A. calandrae* was extremely low at lower temperatures than at higher ones and peak progeny production was achieved in optimum temperature of 30°C and 70% R.H (Table 2). The maximum number of daily progeny production occurred on the 3rd day at 30°C on *S. oryzae* as host (Fig. 1). The highest daily progeny production in the ichneumonid parasite, *H. exiguae* on day 5 at 21°C with *T. ni* as host was recorded (Browning and Oatman 1981). Elevated temperature of 35°C decreased the total progeny production and increased the pupal mortality as in low temperature of 20°C. A similar result was also reported earlier by Puttler (1961) in the same insect (*H. exiguae*). Smith and Rutz (1985) reported that pteromalid wasp, *Urolepis rufipes* completes its development within 10 days at 30°C and develops faster than all the other known housefly pupal parasites except *N. vitripennis.* Pteromalid parasites *e.g. M. raptor* and *Spalangia endius* Walker take 15 and 18 days respectively to develop at 28°C (Whiting 1967).

In the present study, it was obvious that at 20°C with higher relative humidity of 90% larger numbers of *A. calandrae* females were produced resulting in 75.2% females and the female: male sex ratio being 3.04 : 1. These results differ from those of Ghani and Sweetman (1955), who mentioned that temperature and moisture did not seem to have any effect on the proportion of sexes. Hoebeke and Rutz (1988) mass reared a colony of pteromalid parasite, *Trichomalopsis dubius* (Ashmead) at 23-26°C and 45-60% R.H. on fresh pupae of *Musca domestica* L. The parasite emergence usually occurs 12-15 days after oviposition and an average of 12.6 adults emerged per fly puparium. The average sex ratio of females/males per puparium was 1.4:1. Hall and Fischer (1988) recorded the sex ratio of *S. nigra* to be 1.4 females per male at 27°C temperature. The progeny production of *A. calandrae* on *R. dominica* was found to be lower than that of *S. oryzae* as host may be due to lesser host suitability and comparatively compact seed coat of wheat kernels containing larvae and pupae.

Adult longevity of both the sexes of *A. calandrae* was significantly higher at low temperatures and high humidity conditions (Table 2). Adult longevity of *M. rufiventris* declined as a function of temperature and the response was similar for males and females, the parasite lived longer at lower temperatures than at higher ones. Keeping freshly formed cocoons of braconid parasites, *A. flavipes* and *A. sesamiae* that for *A. flavipes* since the survival of the latter was higher, on the other hand, survival of both species was the same at high humidity (Mohyuddin 1971).

The average longevity of both males and females of *A. calandrae* decreased with increase in temperature at any percentage of relative humidity. The adult males and females fed with 50% honey-water showed an increased longevity, compared to those receiving no food or water. During the present observation it was noted that a mated female lived a maximum period of 41 days, whereas a starved female had a maximum life span of 12 days. These results supported the view of Ghani and Sweetman (1955) who found higher longevity in *A. calandrae* when the female received nutrition. It was also noted in the present study that survival of female was higher in higher humidity conditions than lower humidity.

Table 2. The mean duration of different life cycle stages of *Anisopteromalus calandrae* at different constant temperature and relative humidity reared on *Sitophilus oryzae* as host

Temp. (°C)	Relative humidity (%)	Progeny produced per female during life time*				Mean oviposition period (in days)	Mean post oviposition period (in days)	Mean adult longevity of egglaying female (in days)	Maximum longevity of male (starved) (in days)
		Female (Mean ± Sd.)	Male (Mean ± Sd.)	Total (Mean ± Sd.)	Sex-ratio (Mean ± Sd.)				
	50	5.1 ±2.4a**	2.2 ±1.1a	7.3 ±2.3a	2.31:1a	18.1a	5.3±1.2a	23.3a	8.5a
20	70	13.7 ±2.3b	7.0 ±1.9b	20.7 ±3.0b	1.95: 1b	24.2b	6.1±1.1a	30.2b	8.2a
	90	7.0 ±2.0a	2.3 ±1.1a	9.3 ±2.8a	3.04: 1a	20.4a	6.0±0.8a	26.6a	9.7b
	50	4.4 ±2.5a	1.8 ±0.7a	6.2 ±3.0a	2.44: 1a	12.8a	5.0±1.5a	18.0a	8.6a
25	70	14.4 ±7.8c	8.7 ±1.7b	22.7 ±9.3c	1.60: 1a	13.6a	4.8±0.5a	18.4a	8.4a
	90	11.6 ±6.5b	6.0 ±2.4b	17.6 ± 8.8b	1.93: 1a	14.6a	5.5±1.2a	20.4b	9.5b
	50	20.5 ±7.0a	10.5 ±3.3a	31.4 ±8.6a	1.95: 1a	8.2a	1.0±0.2a	9.0a	5.8a
30	70	30.9 ±16.2b	39.3±25.7b	70.3±20.5b	0.78: 1b	13.6b	2.8±2.1b	15.7c	6.1a
	90	23.3 ±13.2a	11.4 ±4.4a	34.7±12.5a	2.04: 1a	11.0a	1.8±0.8a	12.8b	6.4a
	50	8.1 ±6.1a	5.7 ±4.1b	13.8±10.1a	1.32: 1a	3.1a	0.8±0.2a	4.1a	3.1a
35	70	8.0 ±7.9a	3.0 ±1.1a	11.0 ±8.6a	2.66: 1b	5.6b	1.5±0.5a	7.2b	4.2a
	90	14.4 ±8.2b	7.1 ±5.6b	21.5±13.8b	2.02: 1b	5.0b	1.4±0.5a	6.3a	5.3b

*Data based on 10 observations.
**Average within the column followed by a common letter are not significantly different at the 5% level of DNMRT.

This view agrees with the observations of Mohyuddin (1971), who stated that high humidity increased the survival of *Apanteles flavipes* (Cam.) and *A. sesamiae* Cam.

Table 3. Mean duration of oviposition by mated females of *Anisopteromalus calandrae* at different temperature and relativ humidity (%) in the laboratory

Temp. (°C)	Relative humidity (%)							
	50	70	90	Average	50	70	90	Average
	Maximum in 24 hours				Maximum in life time			
20	1	2	1	1.3a	11	23	13	15.6a
25	3	6	5	4.6ab	12	38	33	27.6a
30	7	13	10	10.0c	39	106	60	68.3b
35	6	6	8	6.6b	33	28	51	37.3ab

*Data based on 10 observations. **Averages within the column followed by a common letter are not significantly different at the 5% level of DNMRT.

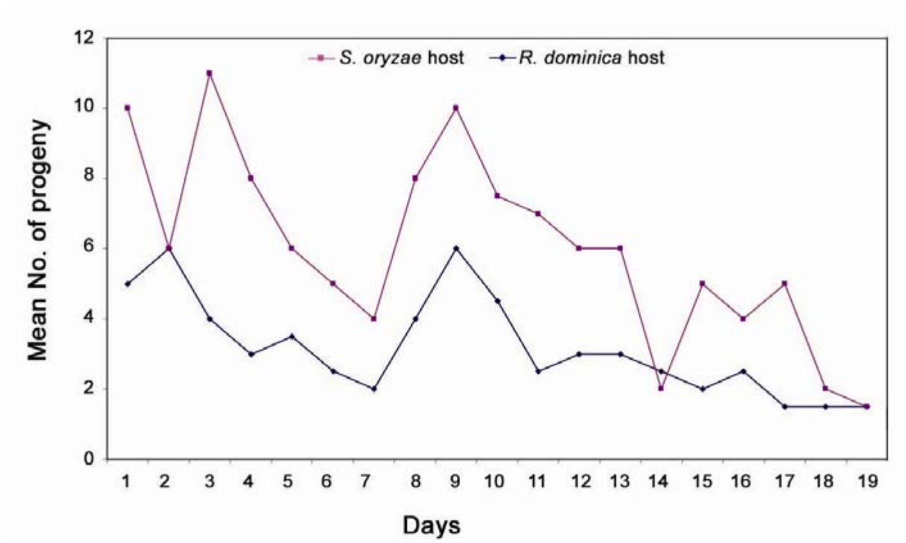

Fig.1. Effect of temperature and relative humidity on mean daily progeny production by a mated *Anisopteromalus calandrae* at 30 ± 1° C and 70 ± 5% R.H. on different hosts

At 35°C, the ovipositing adult parasite lived a mean period of 7.2 days (Table 2) at 70% R.H. and all the newly emerged females died within 3 days and males died within 1 or 2 days at this temperature. Thus, 35°C seemed to be the upper limit of development of *A. calandrae* females and the adults were very restless and always tried to get rid of this unavoidable circumstance.

It is evident from the experiment that the flight activity of *A. calandrae* increased with the increasing temperatures from 20 to 35°C. The rate of parasitism of the parasites increased at 30°C compared to the temperature of 20°C. Smith *et al.* (1988) recorded that parasitism *M. raptor* and *U. rufipes* remained high when the average air temperature ranged from 8.9 to 20.3°C. The range of flight activity for *M. raptor* and *U. rufipes* is similar to that of other pteromalid parasites which fly at constant temperatures>15°C, with activity increasing at higher temperatures. Flight activity was positively correlated to mean air temperature between 12 and 25°C. *N. vitripennis* was the only parasite species observed to actively parasitize during cold winter months when the temperature ranged from 12 to 16°C (Rutz and Scoles 1989).

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