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Development and Thermal Requirements of *Abaris basistriata* (Coleoptera: Carabidae) Under Laboratory Conditions

Desarrollo y exigencias térmicas de *Abaris basistriata* (Coleoptera: Carabidae) bajo condiciones de laboratorio

MARIA JOSÉ ARAÚJO WANDERLEY[1*] FRANCISCO JORGE CIVIDANES[2] NIVÂNIA PEREIRA DA COSTA-MENEZES[1] SIDNÉIA TEREZINHA SOARES DE MATOS[3] RENER LUCIANO DE SOUZA FERRAZ[4]

[1] Universidade Federal da Paraíba, Bananeiras, PB., Brasil. mjwander@gmail.com, costanp@yahoo.com.br
[2] Instituto Biológico, Laboratório de Parasitologia Vegetal de Ribeirão Preto, SP. Brasil. fjcivida@gmail.com
[3] Universidade Estadual Paulista "Júlio de Mesquita Filho", Jaboticabal, SP, Brasil. sidimatos@yahoo.com.br
[4] Universidade Estadual da Paraíba, Campina Grande, PB., Brasil. rener.ferraz@servidor.uepb.edu.br

*** Corresponding author**
Maria José Araújo Wanderley. Universidade Federal da Paraíba. Centro de Ciências Humanas, Sociais e Agrárias, Departamento de Agricultura. Campus III - Baneiras, CEP: 58.220-000, Baneiras - PB., Brasil.

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Abstract: The carabid beetle *Abaris basistriata* (Coleoptera: Carabidae) is noteworthy for its predatory capabilities and its generalist function in the habitat. This study aimed to assess the influence of different temperatures on the development of *A. basistriata* and determine its thermal requirements. The insect was fed with larvae of *Tenebrio molitor* (Coleoptera: Tenebrionidae) and maintained at 18, 22, 25, and 28 ± 1 °C, 70 ± 10 % relative humidity, and 14-hour photoperiod. There were significant differences in the development time of stages and instars of *A. basistriata* as a function of temperature. Threshold temperatures for egg, larva, pupa, and preimaginal development were 10.68, 11.32, 12.67, and 11.73 °C, respectively. The thermal constants were 82.41, 264.83, 84.57, and 664.89 degree-days, respectively. The highest number of *A. basistriata* individuals reached the adult stage in the shortest time of development at 28 °C, where 70 % of survival was recorded. This finding suggests that 28 °C is the most favorable temperature for rearing this carabid species under laboratory conditions.

Keywords: Biological control, biology, ground beetle, predator, temperature, *Tenebrio molitor*.

Resumen: El carábido *Abaris basistriata* (Coleoptera: Carabidae) se destaca por su potencial depredador y por ser generalista en relación con el hábitat. Este estudio tuvo como objetivo evaluar la influencia de diferentes temperaturas en el desarrollo de *A. basistriata* y determinar sus exigencias térmicas. El insecto fue alimentado con larvas de *Tenebrio molitor* (Coleoptera: Tenebrionidae) y mantenido a temperaturas de 18 °C, 22 °C, 25 °C y 28 ± 1 °C; 70 ± 10 % de humedad relativa y fotoperíodo de 14 horas. Hubo diferencias significativas en el tiempo de desarrollo de las etapas e instares de *A. basistriata* en función de la temperatura. Los límites para las etapas de huevo, larva, pupa y desarrollo pre-imaginal fueron 10,68 °C; 11,32 °C; 12,67 °C y 11,73 °C, y las constantes térmicas fueron 82,41; 264,83; 84,57 y 664,89, grados día, respectivamente. El mayor número de individuos de *A. basistriata* llegó a la fase adulta en el menor tiempo de desarrollo a los 28 °C, cuando se obtuvo 70 % de supervivencia, indicando que esta es la temperatura más favorable para la cría de este carábido en condiciones de laboratorio.

Palabras clave: biología, control biológico, depredador, escarabajos del suelo, temperatura, *Tenebrio molitor*.

Introduction

Carabids (Coleoptera: Carabidae) include numerous species that are predators of insect pests. They occur in different components of the agroecosystems (Sunderland, 2002), such as cotton, *Gossypium hirsutum* crops (Barros et al., 2006), areas with grasses (Semere & Slater, 2007), vegetables and aromatic plants (Resende et al., 2012), mango, *Mangifera indica* (Oliveira et al., 2013), apple, *Malus domestica* (Hedde et al., 2015), soybean, *Glycine max* and maize, *Zea mays* crops (Martins et al., 2016), and areas with weeds (Cividanes et al., 2018).

Temperature holds significance as a crucial environmental factor, influencing the speed of insect development. It accelerates at high temperatures and decelerates at low temperatures (Castro et al., 2011). In this context, the presence of carabid species in habitats may be subjected to environmental conditions (Moraes et al., 2013), with population density increasing when temperatures increase (Martins et al., 2009). For example, the most significant population peaks of *Abaris basistriata* Chaudoir, 1873 (Coleoptera: Carabidae) in soybean crops were documented at maximum temperatures between 32.9 °C and 33.8 °C (Martins et al., 2016).

According to Barbosa-Andrade et al. (2018), there is little information in Brazil concerning the biology and rearing techniques of Carabidae. *Abaris basistriata* is characterized by its substantial predatory potential and its generalist behavior regarding habitat preference (Cividanes & Santos-Cividanes, 2008; Cividanes et al., 2014; Martins et al., 2009). However, there is currently a lack of information on the effects of temperature on its development, necessary for determining its thermal requirements.

The successful adaptation of a predatory insect to laboratory conditions and its rapid population production within a short timeframe are factors that render the species promising for integrated pest management programs (Lemos et al., 2005). It has been established that continuous rearing of *A. basistriata* in the laboratory is feasible, suggesting its potential use in inoculative releases within biological pest control programs (Barbosa et al., 2018). Furthermore, this species proved to be easy to rear and understanding the influence of temperature on its development is crucial. Such knowledge holds significant potential to improve the rearing conditions of the predator.

The present study aimed to assess the influence of different temperatures on the development of *A. basistriata* and determine the thermal requirements of different stages of development, instars, and preimaginal development (egg to adult) under laboratory conditions.

Material and Methods

The laboratory experiments involved using climatic chambers adjusted at 18 °C, 22 °C, 25 °C, and 28 °C ± 1 °C, 70 % ± 10 % relative humidity, and a 14-hour photoperiod. The evaluated specimens were obtained from laboratory-reared insects, sourced from *A. basistriata* adults collected in a maize field and a guava, *Psidium guajava* orchard.

Paired *A. basistriata* were reared in acrylic boxes kept in a climatized room at 24 °C ± 1 °C. A distilled water-moistened cotton wad was placed in these boxes, enclosed in small plastic containers serving as a site for egg laying. Pieces of black ethylene vinyl acetate (EVA) sheets were placed at the center of the acrylic boxes, serving as a shelter for beetles. Carabids were fed larvae of *Tenebrio molitor* L., 1758 (Coleoptera: Tenebrionidae), daily and "*ad libitum*". The size of the prey provided was proportional to the size of the evaluated carabid larva.

The moistened cotton wads with *A. basistriata* eggs were removed from acrylic boxes every 24 hours and placed in 100-ml plastic containers lined with filter paper. The containers were sealed with perforated plastic lids. Then, the containers, considering 100 eggs for each temperature, were subjected to temperatures of 18 °C, 22 °C, 25 °C, and 28 °C, respectively. To study the duration of the egg stage, 20 fertile eggs were selected from which 20 new larvae hatched. Larvae were individualized and constantly evaluated until the emergence of adults. The larvae and, subsequently, the pupae were housed individually in plastic containers similar to those described above. These containers were filled with 30 g of soil and monitored until the emergence of adults. The soil, characterized by a clayey texture, underwent chemical composition analysis at the Laboratory of Soil and Plant Analysis of the Department of Soils and Fertilizers (Table 1). Subsequently, it was autoclaved at 120 °C for 60 minutes. After cooling, the soil was distributed in plastic pots and moistened with distilled water.

Table 1. Chemical analysis of the soil used in the study of *Abaris basistriata* at different temperatures.

pH	OM	P resin	K	Ca	Mg	H+Al	SB	T	V
$CaCl_2$	g/dm^{3*}	mg/dm^{3**}	----------	----------	----------	$mmol_c/dm^{3***}$	----------	----------	----------
5.4	18	30	3.5	33	11	28	47.5	75.5	63

g/dm^{3*} = % x 10; mg/dm^{3**} = ug/cm^3; $mmol_c/dm^{3***}$ = $meq/100\ cm^3$ x 10

Eggs and larvae of *A. basistriata* underwent inspection every 24 hours to assess their development time and survival rates. This process involved inspecting the soil moisture for insect rearing and replacing food as needed. Pupae were also observed to record their survival and later adult emergence rates.

The experimental design used a completely randomized design with 20 replications. The duration of each development stage and pre-imaginal period of *A. basistriata* underwent analysis of variance. The means were compared by Tukey test at 5 % probability. Lower temperature thresholds and thermal constants were determined for different instars, developmental stages, and the pre-imaginal period (egg to adult) using the Hyperbole Method (Haddad et al., 1999).

Results

Significant differences emerged among the evaluated temperatures at each developmental stage and the pre-imaginal period. The average development time for the egg, larva, and pupae stages and the duration of the pre-imaginal period increased with decreasing temperatures from 28 °C to 18 °C. In other words, the duration of each stage showed an inversely proportional relation to temperature (Table 2).

Concerning the survival of *A. basistriata*, there were no significant differences observed for the larval, pupal, and pre-imaginal stages among the evaluated temperatures (Table 2).

The mean developmental time of *A. basistriata* instars was influenced significantly by temperature (Table 3). The duration of all instars increased with decreasing temperature, mirroring that observed for the development of egg, larva, and pupa stages, and the pre-imaginal period.

The lower temperature threshold and the thermal constants of *A. basistriata* showed different values for instars and stages of development (Table 4). Notably, in the first instar, the lower temperature threshold was higher, and the thermal constant was lower compared to the other instars. The third instar showed the lowest threshold and the highest thermal constant among instars. Among developmental stages, the larval period showed the highest thermal constant (264.83 degree days). The threshold for pre-imaginal development was 11.73 °C, and the thermal constant was 664.89 degree days.

Table 2. Developmental time and survival of stages and the pre-imaginal period of *Abaris basistriata* fed on larvae of *Tenebrio molitor* and subjected to different temperatures, relative humidity of 70 % ± 10 %, and photophase of 14 hours.

Temperature (°C)					Development time (days ± SE)			
	Egg	**n**	**Larva**	**n**	**Pupa**	**n**	**Pre-imaginal period**	**n**
18	11.8 ± 0.12[a]	20	40.0 ± 0.85[a]	09	15.9 ± 0.27[a]	09	67.0 ± 1.90[a]	09
22	7.0 ± 0.11[b]	20	23.7 ± 0.77[b]	15	9.0 ± 0.25[b]	13	39.3 ± 1.61[b]	13
25	5.7 ± 0.11[c]	20	21.1 ± 1.14[b]	15	6.9 ± 0.08[c]	12	31.6 ± 2.12[c]	12
28	4.9 ± 0.08[d]	20	15.4 ± 0.57[c]	15	5.5 ± 0.14[d]	14	25.3 ± 0.94[d]	14
CV (%)	6.52		13.77		7.57		8.06	
F	854.63*		113.37*		492.06*		357.07*	
Survival (% ± SE)								
18	100.0 ± 0.0[a]	20	66.7 ± 4.7[a]	09	45.0 ± 15.0[a]	09	45.0 ± 15.0[a]	09
22	100.0 ± 0.0[a]	20	90.0 ± 4.3[a]	15	65.0 ± 12.6[a]	13	65.0 ± 12.6[a]	13
25	100.0 ± 0.0[a]	20	80.0 ± 8.2[a]	15	60.0 ± 16.3[a]	12	60.0 ± 16.3[a]	12
28	100.0 ± 0.0[a]	20	85.0 ± 5.7[a]	15	70.0 ± 5.8[a]	14	70.0 ± 5.8[a]	14
CV (%)	3.1		13.5		13.5			
F	3.41ns		1.01ns		1.01ns			

SE = Standard error; CV = Coefficient of variation; n = number of evaluated individuals; ns = not significant; *significant at $p < 0.05$.

Table 3. Mean development time (days) ± SE of *A. basistriata* instars fed on larvae of *Tenebrio molitor* and subjected to different temperatures, relative humidity of 70 % ± 10 %, and photophase of 14 hours.

Temperature (°C)					Instar	
	1	**n**	**2**	**n**	**3**	**n**
18	9.7 ± 0.25a	16	9.3 ± 0.30a	15	20.7 ± 0.80a	9
22	5.4 ± 0.41b	20	5.2 ± 0.14b	19	12.7 ± 0.56b	15
25	4.4 ± 0.26b	17	4.4 ± 0.15b	16	12.2 ± 0.84b	15
28	3.1 ± 0.06c	18	3.4 ± 0.15c	18	8.8 ± 0.52c	15
CV (%)	21.77		15.24		20.76	
F	93.73*		152.68*		37.81*	

SE = Standard error; CV = Coefficient of variation; n = number of individuals evaluated; significant differences ($p < 0.05$).

Table 4. Threshold, thermal constant, and coefficient of determination (R^2) of different stages and instars and the pre-imaginal period (egg to adult) of *Abaris basistriata* fed on larvae of *Tenebrio molitor* kept under different temperatures, relative humidity of 70 % ± 10 %, and photophase of 14 hours.

Stage/Instar	Lower temperature Threshold (°C)	Thermal Constant (degree-days)	R^2
Egg	10.68	82.41	0.99
1	13.46	46.49	0.98
2	11.71	56.53	0.99
3	9.91	165.40	0.94
Larva	11.32	264.83	0.97
Pupa	12.67	84.57	0.99
Pre-imaginal period	11.73	664.89	0.99

R2 = coefficient of determination.

Discussion

The presence of insects has been confirmed under different conditions, ranging from the Arctic to the Equator. It is widely acknowledged that temperature plays a pivotal role in regulating insect activities. The optimal temperature range and activities is between 15 °C and 38 °C. In this study, temperatures ranging from 18 °C to 28 °C proved conducive to the development of *A. basistriata*, as the species completed its pre-imaginal development at all evaluated temperatures (Table 2). This finding aligns with Tielle (1977), who reported that numerous species of Carabidae are eurythermic, allowing them to withstand significant thermal variations. Insects exposed to a temperature of 28 °C required the shortest time to complete pre-imaginal development and reached the highest survival rate. This highlights that 28 °C is the most favorable for rearing *A. basistriata* under laboratory conditions.

The rise in temperature led to a decrease in the development time of instars, stages (egg, larva, and pupa), and the pre-imaginal period (egg-adult) (Tables 2 and 3). The duration for pre-imaginal development was 2.6 times shorter when individuals were kept at 28 °C compared to 18 °C. Studies conducted by Barbosa-Andrade et al. (2018) on *A. basistriata* kept at 26 °C reported values for egg, larva, and pupa stages, and the pre-imaginal period similar to those obtained in this study at 25 °C.

The duration of the larva and pupal stages, as well as the pre-imaginal development of *A. basistriata* at temperatures of 18 °C and 22 °C (Table 2), were longer than those reported for the carabid *Amara communis* (Panz, 1797) (Coleoptera: Carabidae) (Lopatina et al., 2012a). The authors reported that the duration of the larval and pupal stages and the pre-imaginal development of *A. communis* was 30.3 ± 0.43, 10.4 ± 0.41, and 50.1 ± 0.67 days, respectively, when kept at 18 °C and 20.1 ± 0.21, 7.5 ± 0.10, and 34.7 ± 0.33 days at 22 °C, respectively (Lopatina et al., 2012a). In another study, Lopatina et al. (2012b) identified significant differences in the egg development times of five species of carabids, with variations ranging from 7.3 to 16.1 days (18 °C) and from 5.2 to 9.8 days (22 °C).

In this study, the lower temperature threshold varied for stages and instars and the pre-imaginal period of the predator *A. basistriata.* Notably, to complete the pupal stage, the species required the highest threshold in relation to other stages and pre-imaginal development (Table 4). This implies that below 10.68 °C, *A. basistriata* rearing is not viable, as the development is unsatisfactory. Growth and energy accumulation in insects typically initiate from the lower threshold of development (Haddad et al., 1999). The lower temperature threshold data obtained in this study are higher than those reported by Saska and Honěk (2003) for the carabid beetles *Amara familiaris* (Duftsshmid, 1812) and *A. similata* (Gyllenhal, 1810) (Coleoptera: Carabidae) when exposed to temperatures of 17 °C and 28 °C.

The lower temperature threshold values for egg, larva, and pupa and the pre-imaginal development of *Abaris basistriata* were also higher than the values reported by Lopatina et al. (2012a) for *A. communis*. In other studies, Lopatina et al. (2012b) identified a significant difference in the development duration of eggs of five carabid species, with lower threshold temperature values ranging from 6.2 °C to 10 °C. These values are also lower than those obtained for *A. basistriata* in the present study. The geographic location of insects can influence their development depending on various climatic factors (Honék, 1996; Nava et al., 2005).

Despite the significant importance attributed to Carabidae as predatory insects (Holland & Luff, 2000; Pfiffner & Luka, 2000), there is little information in Brazil on the development of these beetles at different temperatures, in addition to their thermal requirements. Typically, studies on these topics focus on species from temperate regions of the northern hemisphere (Lopatina et al., 2012a*,* b; Saska & Honěk, 2003). Understanding the thermal requirements of an insect species is fundamental for its rearing under laboratory conditions, enabling conducting basic studies during periods that, under natural conditions, might be unfeasible (Parra, 2001).

Conclusions

Temperature exerts a significant impact on the development times of egg, larval, and pupal stages and on the instars of *A. basistriata.* Rearing is deemed nonviable below 10.68 °C. The highest number of individuals of *A. basistriata* reached adulthood faster at 28 °C, with a 70 % survival rate, suggesting that this temperature is the most favorable for rearing this carabid in the laboratory.

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Author Contribution

The first author designed and developed the research, as well as writing the manuscript.

The second author assisted in preparing the research and supervised the work.

The third author contributed to writing and formatting the manuscript.

The fourth author contributed to data collection.

The fifth author contributed with the research design and statistical analysis.

Conflict of Interest

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