http://dx.doi.org/10.1590/1519-6984.08715 Original Article

Effect of energetic cost to maintain the trap for *Myrmeleon brasiliensis* (Neuroptera, Myrmeleontidae) in its development and adult size

T. N. Lima[a*] *and D. C. R. Silva*[b]

[a]Universidade Federal de Mato Grosso do Sul – UFMS, Campus Universitário de Aquidauana – CPAQ, Rua Oscar Trindade de Barros, 740, Bairro da Serraria, Unidade II, CEP 79200-000, Aquidauana, MS, Brazil

[b]Programa de Pós-graduação em Biologia Animal, Universidade Federal de Mato Grosso do Sul – UFMS, Cidade Universitária, s/n, CEP 79070-900, Campo Grande, MS, Brazil

*e-mail: tatianenlima@gmail.com

Received: June 2, 2015 – Accepted: October 20, 2015 – Distributed: February 28, 2017
(With 2 figures)

Abstract

Antlion larvae *Myrmeleon brasiliensis* Návas, 1914 (Neuroptera, Myrmeleontidae) are sit-and-wait predators who build traps to catch their prey. The aim of this study was to observe under laboratory conditions, how the energy cost spent on maintenance of their traps affects: the larval developmental time, time spent as a pupa, mortality rate of larvae and adult size. *M. brasiliensis* larvae were collected in the municipality of Aquidauana, Mato Grosso do Sul, Brazil and were individually maintained in plastic containers and subjected to two treatments. In the control treatment larvae did not have their traps disturbed while in the manipulated treatment, larvae had their traps disturbed three times a week. The experiments were followed until adult emergence. When the adults emerged, their body size (head-abdomen), anterior and posterior wing span and width were measured. Furthermore, the number of larvae that died during the experiment was recorded. The results showed that the larvae whose traps were manipulated had longer larval development time, smaller pupal development time and were smaller adults. It can be concluded that the energy expenditure spent on maintenance of the trap constructed by *M. brasiliensis* larvae can affect the development of negative ways, represented by a longer larval development and reduced adult size.

Keywords: ant-lion larvae, body size, sit-and-wait predators.

Efeito do custo energético com a manutenção da armadilha de *Myrmeleon brasiliensis* (Neuroptera, Myrmeleontidae) no seu desenvolvimento e no tamanho dos adultos

Resumo

Efeito do custo energético com a manutenção da armadilha de *Myrmeleon brasiliensis* no seu desenvolvimento e no tamanho dos adultos. Larvas de formiga-leão *Myrmeleon brasiliensis* são predadores senta-espera que constroem armadilhas para a captura de suas presas. O objetivo deste trabalho foi observar em laboratório, como o gasto energético despendido com a manutenção dessas armadilhas afeta: o tempo de desenvolvimento larval, o tempo de pupa, a taxa de mortalidade das larvas e o tamanho dos adultos. *M. brasilienses* foram coletadas no município de Aquidauana, Mato Grosso do Sul, então foram individualizadas em potes plásticos e submetidas a dois tratamentos. No tratamento controle, as larvas não tiveram suas armadilhas perturbadas e no tratamento manipulado, as larvas tiveram as suas armadilhas perturbadas três vezes por semana. Os experimentos foram acompanhados até a emergência dos adultos. Quando esses emergiam, era medido o seu tamanho corporal (cabeça-abdômen), envergadura da asa anterior e posterior e largura da asa anterior e posterior. Além disso, foi contabilizado o número de larvas mortas no decorrer dos experimentos. Como resultado foi observado que as larvas manipuladas apresentaram o tempo de desenvolvimento larval maior, o tempo de pupa menor e o tamanho dos adultos foi menor. Pode-se concluir que o gasto energético despendido com a manutenção da armadilha construída pelas larvas *M. brasiliensis* pode afetar o seu desenvolvimento de maneiras negativas, representados pelo maior tempo de desenvolvimento larval e menor tamanho do adulto.

Palavras-chave: larva de formiga-leão, tamanho corpóreo, predador senta-e-espera.

1. Introduction

Antlion larvae (Neuroptera, Myrmeleontidae) are sit-and-wait predators that build funnel-shaped traps in sandy soil to catch their prey (Farji-Brener, 2003). This foraging strategy implies that the larvae need to invest time and energy in building their traps rather than pursuing their prey. The selection of a favorable site for the construction of these traps is based mainly on the availability of dry and sandy soil, the availability of prey and intraspecific competition (Prado et al., 1993; Faria et al., 1994). If one of these factors negatively affects their foraging, larvae may migrate in search of more favorable locations. However, in this case the antlion larva must bear a high energy cost because the decision of sit-and-wait predators to relocate their trap is analogous to the decision of active predators to leave their present patch to find a more attractive one (Harwood et al., 2003; Miyashita, 2005).

Griffiths (1985) observed that the maintenance of traps constructed by antlion larvae of the species *Myrmeleon quinquemaculatus* Hagen, 1853 required a high energy cost and larvae that had their funnel destroyed had a 50% lower growth rate compared to larvae whose funnel suffered no disturbance. Additionally, Lucas (1985) observed that the metabolic cost associated with the construction of traps increased positively with the size of the trap and negatively with temperature. Thus, the metabolic cost for maintenance of traps affected the size of the builders of these traps.

In addition to affecting the size of the larva, the energy cost to maintain the trap can affect adult size. In many orders of insects the size of the adult has a strong genetic component and their growth is determinant. However, in other orders the adult's size can be affected by the size of the larva and its nutritional quality (Boggs and Freeman, 2005; Kolss et al., 2009). As a consequence, antlion larvae that have their trap destroyed and consequently show reduced growth may result in smaller adults. Aside from a lower growth rate and success in capturing prey their reproductive success also can be affected because final size tends to be related to female fecundity (Honek, 1993).

Given that the larvae *Myrmeleon brasiliensis* (Návas, 1914) select protected sites to build their traps and that trap maintenance has a high energy cost (Lima and Faria, 2007), we expected that constant maintenance and reconstruction of the trap would negatively affect larval development and the adult emergency conditions since the larvae would cease to accumulate the energy resources required for their full development. Based on the these considerations, the objective of this study was to observe, under laboratory conditions, how the energy cost of the maintenance of traps of *M. brasiliensis* larvae affected: 1) larval development time, 2) time spent in the pupal stage, 3) larval mortality rate and 4) adult size.

2. Material and Methods

Myrmeleon brasilienses larvae were collected in Aquidauana, Mato Grosso do Sul, Brazil, in an Area of Permanent Protection (APA) (20° 26'25"S, 55° 39'21"W) belonging to the State University of Mato Grosso do Sul. The experiments were conducted in the Zoology laboratory of the Federal University of Mato Grosso do Sul (UFMS) on the campus in Campo Grande, Mato Grosso do Sul, Brazil.

Collections of larvae of *M. brasilienses* were made on October 15, 2008, February 5, 2009, May 3, 2010 and June 17, 2010. Search for the larvae was done ramdomly and when found they were collected with the aid of a spoon and placed in plastic bags with sand from the collection site and then were brought to the laboratory of Zoology of the UFMS. In the laboratory, larvae were measured (head-abdomen) by a digital caliper (resolution of 0.01 mm), to confirm the larval instar. Only the first instar larvae were used in the experiments. Approximately 50 larvae were collected on each day.

In the laboratory each larva was placed in an individual transparent plastic containers (13 cm deep and 10 cm in diameter), containing sterilized sand brought from the collection site. The plastic containers containing the larvae were in laboratory conditions of temperature, humidity and ambient light.

After the larvae were placed in plastic containers, an accomodation period of 24 hours was maintained to permit trap formation by the larvae. After this period, all larvae were fed daily by manually placing one *Drosophila melanogaster* Meigen, 1830 larva into the center of the funnel of each antlion larva.

The effect of disturbance on the development of *M. brasiliensis* larvae was tested experimentally. In the control treatment, larvae did not have their trap disturbed. In the manipulated experiment, *M. brasiliensis* had their traps disturbed three times a week, respecting a minimum time of one hour after they were fed. The trap handling consisted in a total destruction with the aid of a brush, so that the hopper cannot be perceived, i.e. the sand surface being uniform. The handling procedure lasted approximately 10 seconds. Each larva was accompanied until adult emergence and any larva that did not complete its development within a maximum period of 200 days was excluded from the analyses.

Larval development time was considered as the time elapsed from the date of the collection until the moment when the larvae stopped building their funnels to pupate. Pupal development time lasted from the time when the larvae stopped building funnels (as explained above) until adult emergence. The number of larvae that died during the experiments was also recorded.

When the larvae stopped building funnels the plastic containers were covered with a fine plastic mesh screen to prevent escape of the adults. After emergence each adult was collected and had its body size (head-abdomen), anterior and posterior wing span and width measured using digital calipers (resolution of 0.01 mm).

Comparison of adult body size (head-abdomen), anterior and posterior wing span and width, larval developmental time and pupal development time between treatments was made using a Mann-Whitney test. The comparison between treatments regarding the number of dead larvae was evaluated by 2X2 contingency table using a G Test.

3. Results

A total 121 *M. brasiliensis* larvae were subjected to the control treatment. Of these, 88 developed to adult emergence and 33 died. In the manipulated treatment 96 larvae were accompanied. Fifty developed to adult emergence, 30 larvae died and 16 remained in the larval stage for the length of the experiment (200 days).

The duration of larval development was higher among manipulated larvae ($U = 474.00$, $p < 0.001$). Among the larvae in control treatment the larval stage lasted 50.24 ± 29.01 days, and the larvae that were manipulated at the larval phase lasted 110.06 ± 47.81 days (see Figure 1).

Unlike the larval developmental time that was higher for the larvae whose funnels were disturbed, the pupal development time was lower for larvae that were part in this treatment ($U = 990.50$, $p = 0.0011$). For the larvae in the control treatment the pupal development time was 30.1 ± 7.48 days while for the ones in the manipulated treatment the pupal development time was 27.28 ± 11.05 days (see Figure 2).

There was no significant difference in mortality between treatments. In the control treatment from a total of 33 larvae, died (27.3%). In the manipulated treatment a total of 30 larvae died (31.25%).

The body size (head-abdomen), anterior and posterior wing span and width were significantly lower among adults emerged in the manipulated treatment (as shown in Table 1).

4. Discussion

The results of this study indicated that the high energy cost, represented by the constant cost of reconstruction of traps, by *M. brasiliensis* larvae increased development time of larvae but decreased pupal development time. Probably these changes in development are due to the fact that the energy spent in the constant maintenance of the trap did increase the time that the larvae required to accumulate the sufficient amount of energy reserves to meet the minimum size that would allow them to change phase. At the same time, smaller energy savings may have afforded a more rapid metamorphosis, as the emerging adults in this situation (of constant disturbance) were smaller. Missirian et al., (2006) observed that although the size of adult *M. brasiliensis* may be affected by diet quality, the pupal development time did not change.

In general, insects need to attain a certain size or a certain energy reserve for changes such as pupation and

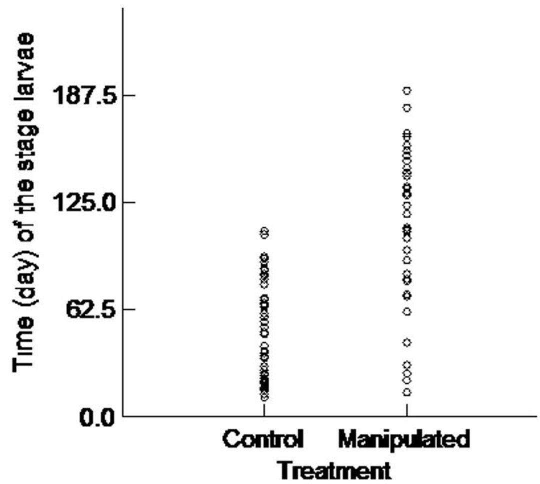

Figure 1. Distribution of *M. brasiliensis* larvae in the control and manipulated treatments in accordance with time (day) of larval development.

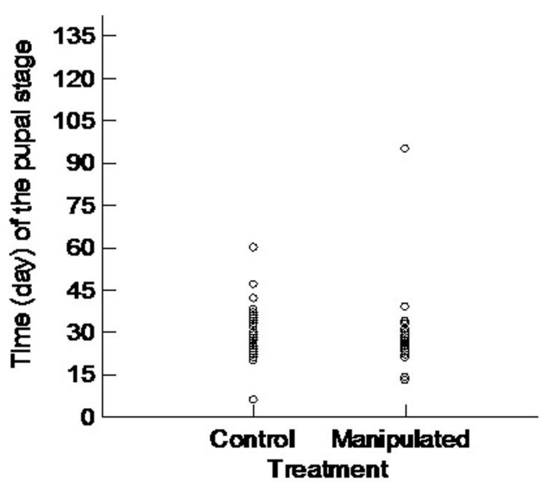

Figure 2. Distribution of *M. brasiliensis* larvae in the control and manipulated treatments in accordance to the time (day) of pupal development stage.

Table 1. Mean (± SD) of body measurements of *M. brasiliensis* and results of the Mann-Whitney test in the control and manipulated treatments.

	Treatment control	Treatment manipulated	Result Mann-Whitney test	
			U	P
Body size (head-abdomen)	20.1 ± 2.18	16.0 ± 2.36	312.00	p < 0.0001
Anterior wings span	50.0 ± 4.42	42.5± 3.86	89.00	p < 0.0001
Posterior wings span	44.5 ± 4.74	37.7 ± 3.49	92.50	p < 0.0001
Width forewing	5.6 ± 0.83	4.6± 0.46	218.50	p < 0.0001
Width hindwing	4.6 ± 0.61	3.8 ± 0.40	61.00	p < 0.0001

adult emergence to occur (Gullan and Cranston, 2007). In the case of the antlion larvae, the duration of developmental stages (larval, pupal and adult) depends on several factors such as photoperiod, temperature, prey availability and body size (Scharf et al., 2009b) and this developmental process can be accelerated or retarded. Data from Eltz (1997) suggest that the process of change in *Myrmeleon mobilis* Hagen, 1888 can be accelerated in individuals that are well nourished and suffer less disruption to their traps. Missirian et al., (2006) observed that *M. brasiliensis* fed with a high energy diet also had an accelerated development. In contrast, it is possible that organisms that live in unstable environments show lower growth rates, even when prey are provided. This occurs because individuals who grow in adverse conditions are not adapted for a significant increase in their growth rate, even when exposed to better conditions (Scharf et al., 2009b).

Although most *M. brasiliensis* larvae pupate and emerged as adults, some larvae that had their traps destroyed did not complete their development over the time period of the study and remained in the larval stage. For many insects it is common to observe that in adverse situations their development can be interrupted by a period of dormancy called diapause (Gullan and Cranston, 2007). In the case of *M. brasiliensis* larvae there was no interruption in the activities of trap maintenance and feeding, probably what happened was just a reduction of their metabolic activities, which is common among predators they face a period of low energy reserves (Wang et al., 2006). Furunishi and Masaki (1981, 1982) observed that *Myrmeleon formicarius* L. antlion larvae can reduce their metabolic rate to very low levels and that larval development can vary from three months to two years depending on the food supply.

Another reaction of the larvae to the disturbance of their traps is relocation. When subjected to a stress situation such as the continual destruction of the trap, the antlion larva can react by relocating or reducing the size of their traps, or decreasing their respiratory rate during the ambush (Eltz, 1997). It is interesting to note that in no circumstance the larva stopped building its trap. This characteristic ensures that the larvae complete their development. However, a longer developmental time exposes the antlion larvae to risks such as cannibalism (Griffiths, 1991, 1993) and the attack by parasitoids (Uchôa and Missirian, 2014).

As for mortality rate, it was expected that the constant rebuilding of the trap would increase this parameter since the larva would use more energy for the maintenance of the funnel. However, this study showed no difference in mortality between control and manipulated treatments. Possibly since these *M. brasiliensis* larvae were in the laboratory, away from weather and intra-specific competition, mortality depended only on intrinsic characteristics of each individual (morphological changes, for example). Studies with spiders have shown that the energy cost due to constant rebuilding of trap might affect aspects of their lifestyle, such as mortality (e.g. Venner et al., 2000, 2003). Lubin et al. (1993) observed a 40% increase in mortality when spiders needed to move to rebuild its traps. Probably in the natural environment, antlion larvae that must leave a site to build a trap in a more favorable area face problems such as lack of space for the construction of the funnel, intra-specific competition and cannibalism, that would result in a higher mortality rate. In the laboratory under controlled conditions, migration was not an influential factor on mortality.

Regarding adult size, the data from this study showed a negative relationship between the disturbance of the traps and the adult size of *M. brasiliensis*. A smaller adult size can affect the fitness of these organisms, since for many insect species, there is a strong and positive relationship between female size and fecundity (Sokolovska et al., 2000). Moreover, large size may favor life expectancy, sexual selection and reduce the risk of predation and increase resistance to periods of starvation (e.g. Blanckenhorn et al., 2007; Scharf et al., 2009a). The size of the adults can also affect their ability to fly, since these characteristics are related (e.g., larger wings provide longer flight) (Souza et al., 2009).

Scharf et al. (2009a) observed that adult antlions have a short life span and some do not even feed, only mate and die. Thus, to complete its life cycle they depend crucially on the body mass of larvae before pupation. Therefore, the development condition of the larva will be responsible for the characteristics of the adult.

In summary, an excessive energy cost may affect their development in negative ways (longer larval development time and reduced adult size). Thus, the reproductive success of adults depends on the performance of the larva, which should build their traps in stable environments that allow maintenance and and the same time success in capturing prey.

References

BLANCKENHORN, W.U., FANTI, J. and REIM, C., 2007. Size-dependent energy reserves, energy utilization and longevity in the yellow dung fly. *Physiological Entomology*, vol. 32, no. 4, pp. 372-381. http://dx.doi.org/10.1111/j.1365-3032.2007.00589.x.

BOGGS, C.L. and FREEMAN, K.D., 2005. Larval food limitation in butterflies: effects on adult resource allocation and fitness. *Oecologia*, vol. 144, no. 3, pp. 353-361. http://dx.doi.org/10.1007/s00442-005-0076-6. PMid:15891831.

ELTZ, T., 1997. Foraging in the ant-lion *Myrmeleon mobilis* Hagen 1888 (Neuroptera: Myrmeleontidae): behavioral flexibility of a sit-and-wait predator. *Journal of Insect Behavior*, vol. 10, no. 1, pp. 1-11. http://dx.doi.org/10.1007/BF02765471.

FARIA, M.L., PRADO, P.I., BEDÊ, L.C. and FERNANDES, G.W., 1994. Structure and dynamics of a larval population of *Myrmeleon uniformis* (Neuroptera: Myrmeleontidae). *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 54, no. 2, pp. 335-344.

FARJI-BRENER, A.G., 2003. Microhabitat selection by antlion larvae, *Myrmeleon crudelis*: effect of soil particle size on pit-trap design and capture. *Journal of Insect Behavior*, vol. 16, no. 6, pp. 783-796. http://dx.doi.org/10.1023/B:JOIR.0000018320.99463.ee.

FURUNISHI, S. and MASAKI, S., 1981. Photoperiodic response of the univoltine ant-lion *Myrmeleon formicarius* (Neuroptera, Myrmeleontidae). *Kontyu*, vol. 49, pp. 653-667.

FURUNISHI, S. and MASAKI, S., 1982. Seasonal life cycle in two species of ant-lion (Neuroptera: Myrmeleontidae). *Japanese Journal of Ecology*, vol. 32, pp. 7-13.

GRIFFITHS, D., 1985. Phenology and larval-adult size relations in the antlions *Macroleon quinquemaculatus*. *Journal of Animal Ecology*, vol. 54, no. 2, pp. 573-581. http://dx.doi.org/10.2307/4499.

GRIFFITHS, D., 1991. Intraspecific competition in larvae of the antlion *Morter* sp. & interspecific interaction with *Macroleon quinquemaculatus*. *Ecological Entomology*, vol. 16, no. 2, pp. 193-201. http://dx.doi.org/10.1111/j.1365-2311.1991.tb00209.x.

GRIFFITHS, D., 1993. Intraspecific competition in antlion (*Macroleon quinquemaculatus*) larvae in the field. *Oecologia*, vol. 93, no. 4, pp. 531-537. http://dx.doi.org/10.1007/BF00328962.

GULLAN, P.J. and CRANSTON, P.S., 2007. *Os insetos: um resumo de entomologia*. 3rd ed. São Paulo: Roca. 440 p.

HARWOOD, J.D., SUNDERLAND, K.D. and SYMONDSON, W.O.C., 2003. Web-location by linyphiid spiders: prey-specific aggregation and foraging strategies. *Journal of Animal Ecology*, vol. 72, no. 5, pp. 745-756. http://dx.doi.org/10.1046/j.1365-2656.2003.00746.x.

HONEK, A., 1993. Intraspecific variation in body size and fecundity in insects: a general relationship. *Oikos*, vol. 66, no. 3, pp. 483-492. http://dx.doi.org/10.2307/3544943.

KOLSS, M., VIJENDRAVARMA, R.K., SCHWALLER, G. and KAWECKI, T.J., 2009. Life-history consequences of adaptation to larval nutritional stress in Drosophila. *Evolution*, vol. 63, no. 9, pp. 2389-40. http://dx.doi.org/10.1111/j.1558-5646.2009.00718.x. PMid:19473389.

LIMA, T.N. and FARIA, R.R., 2007. Seleção de microhabitat por larvas de formiga-leão *Myrmeleon brasiliensis* (Návas) (Neuroptera: Myrmeleontidae), em uma Reserva Florestal, Aquidauana, Mato Grosso do Sul. *Neotropical Entomology*, vol. 36, no. 5, pp. 812-814. http://dx.doi.org/10.1590/S1519-566X2007000500026. PMid:18060311.

LUBIN, Y., ELLNER, S. and KOTZMAN, M., 1993. Web relocation and habitat selection in desert widow spider. *Ecology*, vol. 74, no. 7, pp. 1916-1928. http://dx.doi.org/10.2307/1940835.

LUCAS, J.R., 1985. Metabolic rates and pit-construction costs of two antlion species. *Journal of Animal Ecology*, vol. 54, no. 1, pp. 295-309. http://dx.doi.org/10.2307/4639.

MISSIRIAN, G.B., UCHÔA-FERNANDES, M.A. and FISCHER, E., 2006. Development of *Myrmeleon brasiliensis* (Navás) (Neuroptera, Myrmeleontidae), in laboratory, with different natural diets. *Revista Brasileira de Zoologia*, vol. 23, no. 4, pp. 1044-1050. http://dx.doi.org/10.1590/S0101-81752006000400009.

MIYASHITA, T., 2005. Contrasting patch residence strategy in two species of sit-and-wait foragers under the same environment: a constraint by life history? *Ethology*, vol. 111, no. 2, pp. 159-167. http://dx.doi.org/10.1111/j.1439-0310.2004.01048.x.

PRADO, I.F.L., BEDÊ, L.C. and FARIA, M.L., 1993. Asymmetric competition of antlion larvae. *Oikos*, vol. 68, no. 3, pp. 525-530. http://dx.doi.org/10.2307/3544921.

SCHARF, I., FILIN, I., BEN-YEHOSHUA, D. and OVADIA, O., 2009a. Phenotypic plasticity and variation in morphological and life-history traits of antlion adults across a climatic gradient. *Zoology (Jena, Germany)*, vol. 112, no. 2, pp. 139-150. http://dx.doi.org/10.1016/j.zool.2008.05.004. PMid:19038537.

SCHARF, I., GOLAN, B. and OVADIA, O., 2009b. The effect of sand depth, feeding regime, density, and body mass on the foraging behaviour of a pit-building antlion. *Ecological Entomology*, vol. 34, no. 1, pp. 26-33. http://dx.doi.org/10.1111/j.1365-2311.2008.01038.x.

SOKOLOVSKA, N., ROWE, L. and JOHANSSON, F., 2000. Fitness and body size in mature odonates. *Ecological Entomology*, vol. 25, no. 2, pp. 239-248. http://dx.doi.org/10.1046/j.1365-2311.2000.00251.x.

SOUZA, D.L., EVANGELISTA-RODRIGUES, A., RIBEIRO, M.N., ÁLVAREZ F.P., FARIAS, E S.L. and PEREIRA, W.E., 2009. Morphometric analyses between *Apis mellifera* from region sertão Paraiba State, Brazil. *Archivos de Zootecnia*, vol. 5, no. 221, pp. 65-71.

UCHÔA, M.A. and MISSIRIAN, G.L.B., 2014. *Myrmeleon brasiliensis* (Neuroptera: Myrmeleontidae) in the south Pantanal, Brazil. *The Florida Entomologist*, vol. 97, no. 1, pp. 313-316. http://dx.doi.org/10.1653/024.097.0149.

VENNER, S., BEL-VENNER, M., PASQUET, A. and LEBORGNE, R., 2003. Body-mass-dependent cost of web-building behavior in an orb weaving spider, *Zygiella x-notata. Naturwissenschaften*, vol. 90, no. 6, pp. 269-272. http://dx.doi.org/10.1007/s00114-003-0420-9. PMid:12835838.

VENNER, S., PASQUET, A. and LEBORGNE, R., 2000. Web-building behaviour in the orb-weaving spider Zygiella x-notata: influence of experience. *Animal Behaviour*, vol. 59, no. 3, pp. 603-611. http://dx.doi.org/10.1006/anbe.1999.1327. PMid:10715183.

WANG, T., HUNG, C.C. and RANDALL, D.J., 2006. The comparative physiology of food deprivation: from feast to famine. *Annual Review of Physiology*, vol. 68, no. 1, pp. 223-251. http://dx.doi.org/10.1146/annurev.physiol.68.040104.105739. PMid:16460272.