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Research Article

Preimaginal development and fecundity of *Gaeolaelaps aculeifer* (Acari: Laelapidae) feeding on *Rhizoglyphus echinopus* (Acari: Acaridae) at constant temperatures

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Abstract: The laelapid mite, *Gaeolaelaps aculeifer* (Canestrini) is widespread in soil habitats and feeds on different small arthropods, fungi and nematodes. The development and fecundity of *G. aculeifer* feeding on *Rhizoglyphus echinopus* (Fumouze & Robin) as prey was studied at eight different constant temperatures which include: 16, 17.5, 20, 22.5, 25, 27.5, 30 and 32.5 ºC, with relative humidity of 60 ± 5%, and a 16:8 h (Light: Dark) photoperiod. The results showed that the development time of immature stages were 30.80 ± 0.68, 30.57 ± 0.42 days at 16 °C; 8.66 ± 0.09, 8.20 ± 0.18 days at 30 °C and 9.86 ± 0.19, 9.77 ± 0.22 days at 32.5 °C for females and males, respectively. The pre-oviposition period considerably varied from 7.60 ± 3.02 days at 16 °C to 0.81 ± 0.09 days at 30 °C and then increased to 2.07 ± 0.25 days at 32.5 °C. The oviposition period decreased with increasing temperature from 36.93 ± 2.66 days at 20 °C to 17.67 ± 1.90 days at 32.5 °C. The average life span of females was 102.40 ± 8.08 days at 16 °C and 37.21 ± 1.98 days at 32.5 °C. The mean daily oviposition per female increased from 0.49 ± 0.14 at 16 °C to 3.76 ± 0.13 at 30 °C and decreased to 1.88 ± 0.15 at 32.5 °C.

Keywords: bulb mite, immature, oviposition, predator, longevity

Introduction

The species of the genera *Rhizoglyphus* (Claparéde) and *Tyrophagus* (Oudemans) are the most important in the family Acaridae (Astigmata) feeding on stored products and sometimes attack the roots of crops (Zhang, 2003). Bulb mites of the genus *Rhizoglyphus* (Acari: Acaridae) are known as the most devastating pests of plants with bulbs, corms, and tubers, among the members of the Acaridae family (Diaz *et al*., 1999). *Rhizoglyphus echinopus* (Fumouze and Robin) and *Rhizoglyphus robini* (Claparède) are probably the two most common cosmopolitan species that cause harm to many crops such as onions (*Allium cepa*), garlic (*Allium sativum*), *Lilium* spp., *Hyacinthus* spp. and also other vegetable crops, cereals, and ornamentals in storage, greenhouse and field (Diaz *et al*., 1999). *Gaeolaelaps aculeifer* is a polyphagous predator commonly found in Europe, Asia and North America (Hughes, 1976; Deng *et al.*, 1993) and it feeds on different types of small arthropods, and nematodes inhabiting soil (Kagusa *et al.*, 2006; Zhang, 2003).

In the past fumigation with methyl bromide was used to control bulb mites (Meyer, 1996). However, Methyl bromide was withdrawn because it is colorless, odorless and highly poisonous and therefore could pose a threat to

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humans and animals (UNEP Ozone Action Programme, 2009). Solar and water heating was also implemented to rid infested bulbs of mites (Gerson *et al*., 1981; Meyer, 1996). *Rhizoglyphus echinopus*, and *R. robini* were reported as prey for *G. aculeifer* (Kevan and Sharma, 1964; Ragusa and Zedan, 1988; Lesna *et al.,* 1995). *Gaeolaelaps aculeifer* has been successfully utilized as a biological control agent against bulb mites (*Rhizoglyphus*), sciarid flies, and pupae of thrips and mold mites (*Tyrophgus*) in soil (Zhang, 2003; Ragusa and Zedan, 1988; Lesna *et al.,* 1996; Yedgard, 1997).

In this survey some demographic parameters of *G. aculeifer* have been studied to determine the optimal temperature range for the effective control of *R. echinopus*.

Materials and Methods

Adult mites of *G. aculeifer* were originally collected from soil by Tullgren funnel and reared on bulb mite in the germinator at 25 ± 1 °C, 60 ± 10% relative humidity and a photoperiod of 16L: 8Dh to lay their eggs and then adults were removed after oviposition. The second generations (F2) were used for further examination. *Rhizoglyphus echinopus* was also reared as a prey on yeast powder at the same temperature and relative humidity and a photoperiod of 16L: 8Dh. The colony of *G. aculeifer* was established in plastic pots (40 cm diameter and 30 cm height) filled with gladiolus corms along with *R. echinopus*, collembolans and fungus-eating flies at 25 ± 1 °C and 60 ± 10% RH.

The life cycle of *G. aculeifer* was observed at eight constant temperatures (16, 17.5, 20, 22.5, 25, 27.5, 30, 32.5 °C, 16L: 8D photoperiod and 60 ± 5 % RH in transparent plastic bottles (4 cm diameter) filled with a mixture of Paris plaster and charcoal (7: 1). The opening of each bottle was covered with 0.1 mm mesh. The immature stages of the mites were fed with 50 mites of different stages of *R. echinopus*, and kept moist with drops of water added every 2-3 days. Also the number of *R. echinopus* was determined with pre-test. The developmental times of immature stages and fecundity were recorded every day. When adult females emerged, an adult male was introduced into the cells to fertilize them.

Data Analysis

SAS software v 9.1 was used for data analysis. One-way ANOVA was run to determine the significant differences between development times, adults' longevity and fecundity of *G. aculeifer* at eight constant temperatures. If there were significant differences, the Tukey's multiple range test at ($P < 0.05$) was used for multiple comparisons.

Results

The survey showed that *G. aculiefer* was able to develop, oviposit and feed at 16-32.5 °C on bulb mites but failed to complete its life cycle at temperatures outside that range. No embryonic development was observed at 33.5 °C. The mite also could not complete life cycle at 15 °C. The results of the study showed that the development time of all stages decreased with increasing temperature until the optimal temperature was reached at 30 °C. However, it increased at 32.5 °C (Table 1). Furthermore, no significant difference was observed between male and female stages. Incubation period decreased from 8.80 ± 0.39 (♀), 9.0 ± 0.31 (♂) days at 16 ºC to 2.69 ± 0.05 (♀), 2.85 ± 0.11 (♂) days at 30 ºC but was significantly different at the various temperatures (F = 260.88, df = 7, 196, $P <$ 0.0001, F = 133.54, df = 7, 72, $P <$ 0.0001). The mean development time of larvae varied from 3.73 ± 0.30 (♀), 3.71 ± 0.36 (♂) days at 16ºC to 0.69 ± 0.04 (♀), 0.65 ± 0.08 (♂) days at 30ºC (F = 72.88, df = 7, 196, $P <$ 0.0001, F = 27.07, df = 7, 72, $P <$ 0.0001). The shortest development times for the protonymphal stage recorded were 2.78 ± 0.08 (♀), 2.50 ± 0.07 (♂) at 30ºC days and 2.92 ± 0.07 (♀), 2.89 ± 0.18 (♂) days at 27.5 ºC, respectively (F = 184.72, df = 7, 196, $P <$ 0.0001, F = 167.08, df = 7, 72, $P <$ 0.0001).

The development time of the deutonymphal stage decreased from 9.67 ± 0.50 (♀), 8.14 ± 0.34 (♂) days at 16 ºC to 2.49 ± 0.07 (♀), 2.20 ± 0.08 (♂) days at 30 ºC (F = 201.59, df = 7, 196, P □ 0.0001, F = 92.49, df = 7, 72, P □ 0.0001). Also, the longest and shortest development time of immature stages were 30.80 ± 0.68 (♀), 30.57 ± 0.42 (♂) days at 16 ºC and 8.66 ± 0.09 (♀), 8.20 ± 0.18(♂) days at 30 ºC (F = 989.83, df = 7, 196, P □ 0.0001, F = 40.65, df = 7, 72, P □ 0.0001) (Table 1).

The pre-oviposition period, oviposition period, post-oviposition period, adult longevity and daily egg production (eggs/female/day) were strongly affected by temperature (Table 2). The longest and shortest pre-oviposition time recorded were 7.60 ± 3.02 at 20 ºC and 0.81 ± 0.09 at 30°C respectively (F = 37.51, df = 7, 196, P □0.0001). The longest and shortest oviposition time were 11.33 ± 4.14 and 36.93 ± 2.66 days at 16 and 20 ºC, respectively (F = 14.78, df = 7, 196, P □ 0.0001). Daily fecundity increased from 0.49 ± 0.14 eggs at 16 ºC to 3.76 ± 0.13 eggs at 30 ºC (F = 29.13, df = 7, 196, P □ 0.0001).

The total number of eggs laid per female were highest (86.43 ± 9.28, 85.36 ± 5.38 and 83.86 ± 6.94 eggs per female) at 20, 22.5 and 30 ºC respectively (F = 17.06, df = 7, 196, P □ 0.0001). The period of immature stages of *G. aculeifer*, increased with increasing temperature from 16 to 30 ºC. Therefore, it could be concluded that the optimal temperature for the development and oviposition of this predator was about 30 ºC but a slight drop was observed in the developmental period and oviposition from 30 to 32.5 ºC.

Table 1 Developmental time in days (± SE) for immature male and female *Gaeolaelaps aculeifer* feeding on *Rhizoglyphus echinopus* at eight constant temperatures.

Temp. (°C)	No.[1]	Sex	Egg	Larva	Protonymph	Deutonymph	Total immatures
16.0	15	♀	8.80 ± 0.39 a	3.73 ± 0.0.30 a	8.60 ± 0.35 a	9.67 ± 0.50 a	30.80 ± 0.68a
	7	♂	9.00 ± 0.31 a	3.71 ± 0.36 a	9.71 ± 0.52 a	8.14 ± 0.34a	30.57 ± 0.42 a
17.5	12	♀	6.75 ± 0.13 b	2.41 ± 0.14 b	9.42 ± 0.50 b	8.75 ± 0.25 b	27.33 ± 0.48 b
	6	♂	6.17 ± 0.17 b	2.33 ± 0.21 b	9.83 ± 0.30 a	7.67 ± 0.21 a	27.16 ± 1.19 b
20.0	28	♀	5.25 ± 0.12 c	1.82 ± 0.11 c	5.93 ± 0.14 c	4.75 ± 0.19 c	16.66 ± 0.19c
	16	♂	5.31 ± 0.19 c	1.93 ± 0.25 b	4.94 ± 0.14 b	3.75 ± 0.19 b	17.94 ± 0.33 d
22.5	23	♀	3.87 ± 0.18 d	1.52 ± 0.10 c	3.87 ± 0.7 d	3.15 ± 0.10 e	12.41 ± 0.16d
	9	♂	3.89 ± 0.26 d	1.27 ± 0.15 c	3.89 ± 0.16 c	3.33 ± 0.14 c	12.38 ± 0.27 de
25.0	18	♀	3.69 ± 0.06 d	1.14 ± 0.05d	3.69 ± 0.16 d	3.88 ± 0.15 d	12.41 ± 0.18d
	7	♂	3.79 ± 0.10 de	1.07 ± 0.07 cd	3.64 ± 0.14 cd	3.43 ± 0.17 c	11.94 ± 0.22 de
27.5	36	♀	3.10 ± 0.05 e	0.92 ± 0.05 de	2.92 ± 0.07 e	2.97 ± 0.12ef	9.93 ± 0.14e
	9	♂	3.30 ± 0.12 ef	0.94 ± 0.10 cd	2.89 ± 0.18ef	3.06 ± 023 c	10.15 ± 0.30 de
30.0	44	♀	2.69 ± 0.05fg	0.69 ± 0.04 ef	2.78 ± 0.08 e	2.49 ± 0.07 f	8.66 ± 0.09 e
	10	♂	2.85 ± 0.11 f	0.65 ± 0.08 d	2.50 ± 0.07 f	2.20 ± 0.08 d	8.20 ± 0.18 e
32.5	28	♀	2.67 ± 0.05 g	0.55 ± 0.03 d	3.48 ± 0.13 d	3.21 ± 0.14 e	9.86 ± 0.19f
	16	♂	2.56 ± 0.08 f	0.56 ± 0.04 f	3.22 ± 0.14 de	3.44 ± 0.19 c	9.77 ± 0.22 d

1. Number of mites tested
Means followed by the same letters in each column are not significantly different (Tukey's test, P < 0.05).

Table 2 The mean duration (days ± SE) of pre-oviposition, oviposition, post-oviposition period, female total longevity, the mean number of eggs per female and number of eggs per female (day ± SE) of *Gaeolaelaps aculeifer* feeding on *Rhizoglyphus echinopus* at eight constant temperatures.

Temp. (°C)	N♀,♂	Pre-ovipositional Period (Days)	Ovipositional Period (Days)	Post-ovipositional Period (Days)	Total fecundity (eggs)	Daily Fecundity (eggs)	Whole life Span for female (Days)	Whole life Span for male (Days)
16.0	15,7	7.60 ± 3.02 a	11.33 ± 4.14 d	14.47 ± 4.36 b	7.07 ± 3.11 e	0.49 ± 0.14g	102.40 ± 8.08 a	95.14 ± 11.99 b
17.5	12,6	4.17 ± 1.25 b	15.91 ± 4.10 dc	28.58 ± 7.61 a	18.25 ± 5.00 de	1.16 ± 0.23 f	77.67 ± 9.23 b	118.83 ± 13.56 a
20.0	28,16	2.32 ± 0.24 c	36.93 ± 2.66 a	8.21 ± 1.47 c	83.86 ± 6.94ab	2.40 ± 0.16ed	65.50 ± 3.04 c	66.56 ± 4.154 c
22.5	23,9	2.13 ± 0.24 cd	28.52 ± 2.77 b	6.52 ± 1.26 cd	86.43 ± 9.28 a	3.08 ± 0.23bc	50.93 ± 3.01 d	58.83 ± 4.44 cd
25.0	18,7	1.50 ± 0.25 de	20.88 ± 3.25 c	3.56 ± 0.74 cd	61.33 ± 11.49c	2.74 ± 0.34 cd	39.42 ± 2.77 e	45.93 ± 2.90 de
27.5	36,9	1.33 ± 0.12 de	18.86 ± 1.39 c	3.42 ± 0.37 cd	63.69 ± 5.31bc	3.49 ± 0.19 ab	33.58 ± 1.38 e	44.28 ± 3.83 de
30.0	44,10	081 ± 0.09 e	23.00 ± 1.38bc	2.14 ± 0.23 d	85.36 ± 5.38ab	3.76 ± 0.13 a	34.68 ± 1.45 e	48.90 ± 3.55 de
32.5	28,16	2.07 ± 0.25 cd	17.67 ± 1.90 c	3.75 ± 0.52 cd	32.96 ± 5.04 d	1.88 ± 0.15 e	37.21 ± 1.98 e	37.41 ± 2.41 e

Means followed by the same letters in each column are not significantly different (Tukey's test, $P < 0.05$).

Discussion

In this survey, the duration of immature stages period of *G. aculeifer* was calculated as 16.6 days at 20 °C while Kasuga *et al.* (2006) reported its value for the same mite on *T. similis* Volgin as 44.7, 20.6, 13.8 and 12.6 days at 15, 20, 25 and 30 °C and 15.7 days at 20 °C on *T. putrescentiae* (Shrank) respectively. The short immature development time of *G. aculeifer* on *T. putrescentiae* and *R. echinopus* may be caused by high nutritive quality of these preys compared to that of *T. similis*. The deutonymph and protonymph periods of *G. aculeifer* on *T. similis* was higher than bulb mite (Kasuga *et al.,* 2006).

In other similar study, Ragusa and Zendan (1988) have studied the development time and adulthood periods of *G. aculeifer* on the different stages of the same prey at 27 °C. They reported immature period as 11.0 - 13.9 days when it was reared on protonymph and egg respectively. But our observation wasn't close to that at the same temperature. It may be caused by free or non-free choice selection by *G. aculeifer* when it is rearing on one or more stages of the bulb mites. Based on this reasoning, non-choice preying could be effective on mite's fitness and reduction of these periods. In addition, Chi (1981) has reported the immature stages of *G. aculeifer* on *Onycbiurus fimatus* preys as 39.9, 15.7 and 11.8 days at three temperatures of 15, 22 and 28 °C respectively. In contrast, our experiment has shown shorter time than that at the close temperatures. Our observation on immature stages periods of *G. aculeifer* on bulb mites indicated shorter time than the other ones and it appears to be owing to high food quality of prey.

The daily fecundity increased with increasing temperature, and its minimum and maximum rates were obtained as 0.49 and 3.76 eggs per day at 16 and 30 °C. Beyond 30

C its rate reduced to 1.88 eggs per day at 32.5 °C. This result was in agreement with the findings of Kasuga *et al.* (2006) who reported that the daily fecundity of *G. aculeifer* increased with increasing temperature. They found that with the increasing temperature from 15-30 °C, the number of daily fecundity increased from 1.2-3.8 eggs per day on *T. similis* and 3.2 eggs per day on *T. putrescentiae* at 20 °C.

Our findings are in agreement with theirs indicating that the quality of both preys: *T. similis* and *T. putrescentiae* didn't have impact on daily fecundity of *G. aculeifer*.

The pre-oviposition and post-oviposition periods decreased with increasing temperature (Table 2). The daily fecundity increased with increasing temperature but its value slightly decreased at 32.5 °C. Some researchers recorded pre-ovipositional, ovipositional and post-ovipositional periods ranged from 2-2.2, 24-50.2 and 10.4-19.5 days for *G. aculeifer* by feeding on different stages of bulb mites at 27 °C (Ragusa and Zendan, 1988). They recorded daily fecundity and total fecundity as 1.5-3.3 and 71-114.9 per female at the same temperature. Ragusa and Zendan, (1988) determined the mean adult longevity of *G. aculeifer* as 37.9-71 days which it's close to our result.

Furthermore, data analysis did not show significant difference between male and female's development times. However, there were significant differences between life span of male and female. According to results of some researchers male life span was longer than female (Ragusa and Zendan, 1988; Chi, 1981; Ydergaard *et al*., 1997). The male life span of the mites was higher than females at all temperatures except 16, 20 and 32.5 °C at which the females and males had equal life span.

Finally, it can be concluded that *G. aculeifer* could be used as an effective predator in the natural environment and greenhouse conditions when temperatures are above 20 °C; although it requires more detailed investigation in future studies.

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دوره نمو پیش از بلوغ و باروری کنه *Gaeolaelaps aculeifer* (Acari: Laelapidae) با تغذیه از کنه *Rhizoglyphus echinopus* (Acari: Acaridae) در دماهای ثابت

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چکیده: کنه شکارگر *Gaeolaelaps aculeifer* پراکنش وسیعی داشته و در زیستگاه‌های خاکی از طعمه‌های مختلف شامل بندپایان کوچک، نماتدها و قارچ‌ها تغذیه می‌کند. رشد نمو و باروری کنه با تغذیه از طعمه *Rhizoglyphus echinopus* (Fumouze and Robin) در هشت دمای ثابت شامل۱۶، ۱۷/۵، ۲۰، ۲۲/۵، ۲۵، ۲۷/۵، ۳۰ و ۳۲/۵ °C، رطوبت نسبی ۵٪ ± ۶۰ و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی مورد بررسی قرار گرفت. نتایج حاصل از این پژوهش نشان داد که طول دوره قبل از بلوغ در دمای ۱۶ °C، ۰/۶۸ ± ۳۰/۸۰ و ۰/۴۲ ± ۳۰/۵۷ روز در دمای ۳۰°C ۰/۰۹ ± ۸/۶۶ و ۰/۱۸ ± ۸/۲۰ روز و در دمای ۳۲/۵ °C ۰/۱۹ ± ۹/۸۶ و ۰/۲۲ ± ۹/۷۷ به‌ترتیب برای ماده‌ها و نرها بود. دوره پیش از تخم‌گذاری از ۳/۰۲ ± ۷/۶۰ روز در دمای ۱۶ °C تا ۰/۰۹ ± ۰/۸۱ روز در دمای ۳۰ درجه متفاوت بود که با افزایش دما به ۳۲/۵ °C این مقدار افزایش یافته و به ۰/۲۵ ± ۲/۰۷ روز می‌رسد. دوره تخم‌گذاری با افزایش دما از ۲۰°C ۲/۶۶ ± ۳۶/۹۳ روز به ۱/۹۰ ± ۱۷/۶۷ روز در دمای ۳۲/۵ °C کاهش می‌یابد. میانگین طول عمر در ماده‌ها در ۱۶ °C، ۸/۰۸ ± ۱۰۲/۶۰ روز به ۱/۹۸ ± ۳۷/۲۱ روز در دمای ۳۲/۵ °C کاهش می‌یابد. میانگین تعداد تخم‌های گذاشته شده روزانه از ۰/۱۴ ± ۰/۴۹ تخم در دمای ۱۶ °C به ۰/۱۳ ± ۳/۷۶ تخم در دمای ۳۰ °C افزایش یافت و سپس به ۰/۱۵ ± ۱/۸۸ تخم در دمای ۳۲/۵ °C کاهش یافت.

واژگان کلیدی: کنه پیاز، دوره‌ی قبل از بلوغ، تخم‌گذاری، شکارگر، طول عمر