Persian Journal of Acarology, Vol. 3, No. 2, pp. 153–161.

Article

Effect of temperature on development and fecundity of the brown mite, *Bryobia rubrioculus* Scheuten (Acari: Tetranychidae) on apple

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Abstract

Brown mite, *Bryobia rubrioculus* Scheuten, is one of the most important pests of apple trees in western Iran. Development and fecundity of this mite were studied on apple at five constant temperatures (20, 22.5, 25, 27.5 and 30°C), 60 ± 5% RH and a photoperiod of 16:8 h (L: D). The developmental time of immature stages ranged from 39.65 ± 0.96 days at 20°C to 18.18 ± 0.47 days at 30°C. The lower temperature threshold (*t*) and thermal constant (*k*) of the immature stages were estimated to be 12.9°C and 279.7 degree days (DD), respectively. The average adult longevity of females was determined to be 16.75 ± 1.14 days at 20°C to 8.58 ± 0.38 days at 30°C. The highest and lowest mean number of eggs per female during adult life was 4.79 ± 1.36 and 3.75 ± 1.49 at 30 and 20°C, respectively. The results of this study can be used to predict the development and population dynamics of *B. rubrioculus*.

Key words: apple, temperature, brown mite, biology, western Iran.

Introduction

The brown mite, *Bryobia rubrioculus* Scheuten (Acari: Tetranychidae), is a serious pest of a variety of crops such as apple, black cherry, sweet cherry and plum plants in western Iran (Khanjani & Haddad Irani-Nejad 2009). It causes considerable damage in some apple orchards of this area and the other parts of the world (Kasap 2008; David'yan 2009). The brown mite prefers to feed on young leaves of host plants and its feeding damage can be appeared as whitish-grey spots on the upper surface of young leaves and heavily infested plants become pale and may prematurely drop their leaves and further effects affected apple production (Ehara 1959; Herbert 1962; van de Vrie *et al*. 1972; Jeppson *et al*. 1975; Sabelis 1986b; Osakabe *et al*. 2000). The brown mite occurred on apple, black cherry, sweet cherry and plum plants in North America, Europe and Turkey, Japan and some Asian countries (Kasap 2008), and it was reported from western Iran on apple, cherry and plum (Khalil-Manesh, 1972; Keshavarze-Jamshidian 2004; Khanjani 2004; Eghbalian 2007).

Temperature is the main abiotic factor influencing the temporal and spatial distribution of insects and mites in the field (Perring *et al*. 1984; Bonato *et al*. 1990). Population growth rates largely determine the pest status of spider mites (Janssen & Sabelis 1992) and temperature strongly affects population growth (Sabelis 1986a; Roy *et al*. 2003; Mori *et al*. 2005; Gotoh *et al*. 2010). Therefore, knowing the temperature requirements of the different stages of mite pests can be used to forecast their potential distribution and abundance.

However, population development and fecundity of *B. rubrioculus* were investigated on different apple varieties but no data are available in concern of biology of brown mite at the constant temperature on apple. Therefore, the aim of the present study was to investigate the effect of temperature on development and reproduction of *B. rubrioculus.*

Material and Methods

The brown mites were collected from apple orchards in the area of Heydareh village (Hamadan, Iran; 34° 48' N, 48° 28' E, 1830 m a.s.l.). The mites were reared on apple seedling rootstocks for at least five generations in a rearing chamber (25 ± 1 °C, 60 ± 5 % RH and 16L:8D h photoperiod) prior to the study. This culture was used as the source throughout this study.

Leaves of Golab variety were placed on a layer of filter paper over a distilled water-saturated polystyrene pad in a 100 × 15 mm Petri dish. Each leaf was covered with filter paper that had a 40 mm diameter opening in the center as a barrier to prevent the mites from escaping. Water was added daily to keep the filter paper and polystyrene pad moist and to cover the base of the Petri dish to prevent the mites from escaping. During the experiments, leaves were changed with new ones every 3–4 days to reduce the effects of plants age on mite development and fecundity.

The preimaginal life history parameters of brown mite were studied at five constant temperatures: 20, 22.5, 25, 27.5 and 30°C. All experiments were carried out in an air-conditioned room with relative humidity of 65 ± 5% and a photoperiod of 16L:8D h.

A female *B. rubrioculus* was transferred from the stock culture to the leaf. Approximately 30 adult females from the stock culture were introduced onto each leaf disc and allowed to lay eggs for a 6 h period. The newly laid eggs were individually transferred to new leaf discs at the same constant temperatures using a wet paintbrush (000) for subsequent observations.

The developmental stages were carefully checked at least once per day until they grew up to adulthood. After emergence of the adults, duration of pre-oviposition, oviposition and post-oviposition periods as well as longevity, daily fecundity and total fecundity were also recorded.

Data analysis

The differences in developmental time, adult longevity and fecundity of the brown mite at various constant temperatures were compared using one-way ANOVA. If significant differences were detected, multiple comparisons were made using the Tukey's multiple range test ($P < 0.05$). Statistical analysis was carried out using SPSS software (SPSS 2007). The relationship between temperature and the developmental rate was described using simple linear regression:

$$Y = a + bx ,$$

where Y is the developmental rate, x is the temperature, a is the intercept and b is the slope of the line.

Results

Egg incubation period decreased from 17.35 ± 0.58 days at 20°C to 8.03 ± 0.26 days at 30°C, which was significantly different at various temperatures and no eggs hatched at 17.5 and 32.5°C ($F_{4, 208} = 134.71$, $P < 0.0001$) (Table 1). The mean development time of larva varied from 1.27 ± 0.07 days at 27.5°C to 3.35 ± 0.24 days at 20°C ($F_{4, 208} = 18.06$, $P < 0.0001$). The longest and shortest development time of protonymph were recorded at 20°C (3.59 ± 0.27 days) and 27.5°C (1.49 ± 0.09 days), respectively ($F_{4, 208} = 13.64$, $P < 0.0001$). There was a significant difference between developmental time of deutonymph with increasing temperature from 20–30°C decreased ($F_{4, 208} = 17.55$, $P < 0.0001$). Developmental times of *B. rubrioculus* at constant temperatures are shown in Table 1. The developmental time decreased from 39.65 ± 0.96 days at 20°C to 18.18 ± 0.04 days at 27.5°C ($F_{4, 208} = 212.85$, $P < 0.0001$) (Table 1).

The linear regression equation for the developmental rate in relation to temperature is Y = 0.0033x – 0.0391 (Fig. 1). The lower developmental threshold (*t*) for *B. rubrioculus* was estimated from the linear regression equation to be 12.9°C. The thermal constant has been estimated from the linear equation to be 279.7 degree-days (DD).

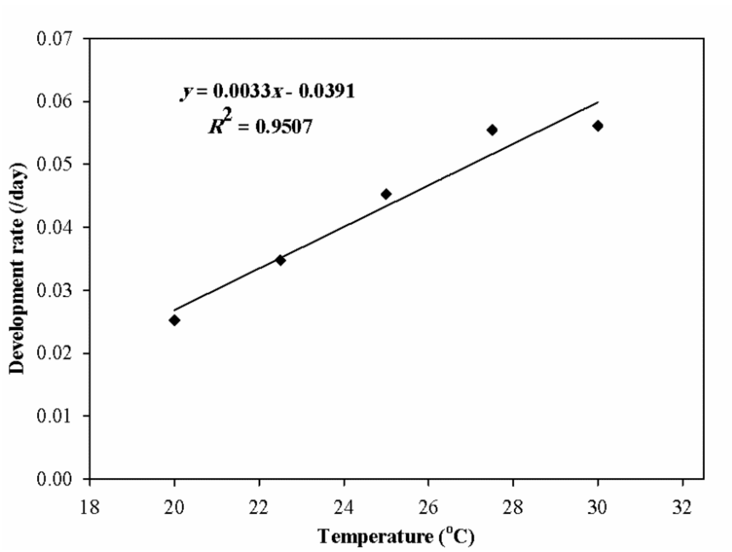

Figure 1. Developmental rate (1/development time) of immature stages of *Bryobia rubrioculus* at different temperatures.

Table 1. Mean (±SE) duration (day) of different life stages of *Bryobia rubriculus* and its fecundity at five constant temperatures.

Stages	Temperature (°C)				
	20	22.5	25	27.5	30
Egg	17.35 ± 0.58a	13.44 ± 0.32b	9.97 ± 0.18c	8.44 ± 0.19d	8.03 ± 0.26d
Larva	3.35 ± 0.24a	2.13 ± 0.19b	2.00 ± 0.12b	1.27 ± 0.07c	1.54 ± 0.12c
Protochrysalis	3.65 ± 0.29a	2.63 ± 0.11b	2.03 ± 0.08c	1.60 ± 0.08d	1.51 ± 0.10d
Protonymph	3.59 ± 0.27a	2.21 ± 0.25b	1.79 ± 0.10bc	1.49 ± 0.09c	1.69 ± 0.12bc
Deutochrysalis	3.47 ± 0.27a	2.88 ± 0.08b	2.17 ± 0.08c	1.40 ± 0.06d	1.51 ± 0.12d
Deutonymph	3.88 ± 0.36a	2.25 ± 0.21b	1.67 ± 0.11c	1.60 ± 0.09c	1.74 ± 0.11bc
Teliochrysalis	4.35 ± 0.25a	3.25 ± 0.08b	2.45 ± 0.11c	2.24 ± 0.08c	1.47 ± 0.11d
Immature	39.65 ± 0.96a	28.77 ± 0.67b	22.09 ± 0.31c	18.04 ± 0.28d	18.18 ± 0.47d

Means in a row followed by the same letter do not differ significantly at $P < 0.05$ level (Tukey's test).

Adult longevity, encompassing the three phases pre-oviposition, oviposition and post-oviposition (Table 2), decreased with increasing temperature, with significant differences between the constant temperature (Table 2). Maximum longevity of 16.75 ± 1.14 days was recorded at 20°C. At 30°C, adult lifetime was only 8.58 ± 0.38 days ($F_{4, 208}$ = 28.7, P < 0.0001).

Table 2. The mean (±SE) various adult stages (pre and post-oviposition periods, adult longevity, life span and fecundity) of *Bryobia rubriculus* at five constant temperatures.

Temperature (°C)	Pre-oviposition	Oviposition	Post-oviposition	Adult longevity	Life Span	Total Fecundity	Daily Fecundity
20	4.00 ± 0.57a	7.00 ± 2.94a	5.75 ± 1.10a	16.75 ± 1.14a	54.40 ± 1.63a	3.75 ± 1.49b	0.21 ± 0.09b
22.5	3.47 ± 0.31a	4.81 ± 0.64ab	6.50 ± 0.71a	14.78 ± 0.50b	43.55 ± 0.88b	3.94 ± 0.57b	0.99 ± 0.08ab
25	2.24 ± 0.19b	3.49 ± 0.46b	5.84 ± 0.37a	11.57 ± 0.43b	33.66 ± 0.40c	4.03 ± 0.72b	1.20 ± 0.11a
27.5	1.84 ± 0.20b	3.94 ± 0.89b	4.41 ± 0.30ab	10.19 ± 0.42c	28.23 ± 0.48d	4.59 ± 0.71a	1.31 ± 0.10a
30	2.05 ± 0.32b	3.16 ± 0.57b	3.37 ± 0.43b	8.58 ± 0.38d	26.76 ± 0.59d	4.79 ± 1.36a	1.29 ± 0.14a

Means in a column followed by the same letter do not differ significantly at P < 0.05 level (Tukey's test).

The pre-oviposition period, oviposition period, post-oviposition period, adult longevity and daily egg production (eggs/female/day) were strongly affected by temperature. The pre-oviposition, oviposition and post-oviposition periods decreased with increaseing temperature from 20 to 30°C (Table 2). The longest pre-oviposition was observed as 4.00 ± 0.57 and 3.47 ± 0.31 days at 20 and 22.5°C, respectively ($F_{4, 123}$ = 7.6, P < 0.0001). The longest and the shortest oviposition period were recorded as 7.00 ± 2.94 and 3.16 ± 0.57 at 20 and 30°C, respectively (Table 2) ($F_{4, 123}$ = 1.83, P = 0.1272). The life span ranged from 54.40 ± 1.63 days at 20°C to 26.76 ± 0.59 days at 30°C. Daily fecundity increased according to the temperature from 20 to 27.5°C, where the maximum was attained (1.31 ± 0.10 eggs/female/day) ($F_{4, 123}$ = 2.24, P = 0.0681) (Table 2). The total number of eggs laid per female followed the same pattern and was highest (4.79 ± 1.36 eggs per female) at 30°C ($F_{4, 123}$ = 1.16, P = 0.3312).

Discussion

Temperature is a key abiotic factor that regulates the arthropod population dynamics, rates of development, reproduction, mortality, survival (Logan *et al*. 1976). Our data clearly showed the effects of temperature on the developmental time, mortality, survival, longevity, and fecundity of *B. rubrioculus.*

Following an increase in temperature, egg incubation period of the brown mite has decreased, which is in accordance with the study of certain authors (Honarparvar *et al*. 2012). Incubation period was 9.97 days at 25°C, which relatively close to those reported for same mite on two different apple varieties (8.7 days on Golden Delicious and 9.3 days on Starking Delicious) (Kasap 2008), on black cherry (9.68 ± 0.66 days) (Eghbalian 2007), and on sweet cherry (10.6 days) (Honarparvar *et al*. 2012) at the same temperature. In the survey, most eggs of brown mite were not hatched at 17.5 and 32.5°C, therefore the temperatures are not favorable for egg development whereas similar study did not confirm our result and eggs were hatched in 15, 17.5 and 32.5°C on sweet cherry (Honarparvar *et al*. 2012).

Previous studies indicated the mean developmental time of larvae was determined as 1.54, 1.33, 1.29, 1.16 and 1.15 at 20, 22.5, 25, 27.5 and 30°C successively on sweet cherry (Honarparvar *et al*. 2012), 1.3 days at 22°C on sour cherry (Keshavarze-Jamshidian 2004) and 3.0 and 3.7 days on Golden Delicious and Starking Delicious apple cultivars, respectively, at 25°C (Kasap 2008), which are different from the result of this study at the same temperature.

Significant differences between different life cycles of the *B. rubrioculus* including protochrysalis, protonymph, deutochrysalis, deutonymph and teliochrysalis reared at different temperatures were observed. Developmental time of the protonymph of *B. rubrioculus* was reported as 4.18 days on black cherry at 25°C (Eghbalian 2007), while it was reported to be 1.00 days at 22°C on sour cherry (Keshavarze-Jamshidian 2004) and 1.36–1.15 on sweet cherry at 20–30°C (Honarparvar *et al*. 2012). Our result is close to Honarparvar *et al*. (2012) at 30°C.

Developmental time of deutonymph decreased with increasing temperature from 20–27.5°C. Similar results were reported, namely 1.1 days on Golden Delicious (apple variety) at 18.5°C (Herbert 1962); 1.60 ± 0.06 days on sweet cherry at 20°C and 1.96 at 27.5°C (Honarparvar *et al*. 2012), and 4.62 days on black cherry at 25°C (Eghbalian 2007).

The lower developmental threshold for total immature stages was 12.9°C, which was higher than that of 4.9°C for the same mite on sweet cherry (Honarparvar *et al*. 2012). A total of 279.7 degree-days above the threshold temperature was required to complete development from egg to adult which was lower than that 400 DD for *B. rubrioculus* on sweet cherry.

According to our results, the temperature for development of *B. rubrioculus* ranges from 20–30°C. This would corroborate the high adaptability of this phytophagous mite to various environmental conditions and explain its worldwide distribution. The mean immature time (egg to adult) of *B. rubrioculus* was significantly different at various constant temperatures. This parameter of brown mite was determined as: 18.5 and 20.5 days on Golden delicious and Starking varieties of apple at 25°C, respectively (Kasap 2008), and 21.35 days on sweet cherry at 25°C (Honarparvar *et al*. 2012), which was longer than that observed in our study at the same temperature (22.09 ± 0.31 days).

Adult longevity was significantly affected by various temperatures. Honarparvar *et al*. (2012) reported adult longevity as 10.27, 8.33, 8.00, 7.33 and 6.54, days at 20, 22.5. 25, 27.5 and 30°C, respectively. Herbert (1962) recorded 13.4 days at 18.5°C, and Kasap (2008) observed 14.2 and 18.8 days at 25°C on Golden delicious and Starking (apple varsities), respectively. It seems that different host plants and various temperatures can affect adult longevity.

The oviposition periods of brown mite were strongly affected by different temperatures. The pre-oviposition, oviposition and post-oviposition periods of *B. rubrioculus* were showed as: 2.0, 9.0 and 3.2 days on Golden delicious, 1.8, 13.6 and 3.3 days on Starking (apple varieties) at 25°C (Kasap 2008), 3.16, 13.20 and 0.80 days on sour cherry at 22°C (Keshavarz-Jamshidian 2004), 2.29, 6.34 and 1.63 days at 20°C, 1.67, 5.33 and 1.33 days at 22.5°C, 1.62, 5.08 and 1.29 days at 25°C, 1.55, 4.82 and 0.96 days at 27.5°C, 1.85, 3.00 and 1.69 days at 30°C on the sweet cherry (Honarparvar *et al*. 2012). Oviposition period on apple was not similar with previous studies and it was shorter than oviposition period on the other hosts. Also, pre-oviposition and post-oviposition periods were longer than these periods on different hosts. The differences in the oviposition periods are probably due to the host plant gonotype and experimental conditions. The effects induced by the different cultivars on specific biological parameters of brown mite (i.e., oviposition rate, cycle duration, longevity, etc.) could express differences in host acceptance and they should be investigated for a wider consideration of host resistance/susceptibility, extending the observations for more successive generations in order to take in count of possible physiological adaptations of the mite to the cultivars in the long-term period (McIntyre & Whitham 2003).

We obtained life span as results, which are not matched to the results of the other authors. The life span was observed as 57.37 days at 15°C to 21 days at 32.5°C on sweet cherry (Honarparvar *et al*. 2012), 45.32 at 25°C and 35.22 days at 22°C on black cherry and 31 days at 18.5°C on apple (Keshavarz-Jamshidian 2004; Eghbalian 2007).

The daily and total egg production, which observed in this survey, was lower than other studies. Honarparvar *et al*. (2012) reported 13.82 eggs per female and 1.95 per day at 20°C, 4.46 eggs per female and 1.44 per day at 30°C for *B. rubrioculus.* The values, which obtained from this study, showed the lower value than other studies (e.g. Honarparvar *et al*. 2012) for the brown mite reared on other host plants. This may be due to the fact that different hosts demonstrate various characteristics toward brown mite. Several researchers have demonstrated that spider mites produce different populations on various plant cultivars such as *Tetranychus turkestani* Ugarov & Nikolski on Melon (Javadi Khederi *et al*. 2012); *Amphitetranychus viennensis* (Zacher) (Kasap 2003) and *T. urticae* Koch on apple (Skorupska 2004), and *T. urticae* on strawberry (Suzanne & Hutchison 2003). Several potential mechanisms could be responsible for observed differences, including plant nutritional quality of the host plant and morphological or allelochemical features (van de Vrie *et al*. 1972; Sabelis 1981, 1986a; Tomczyk & Kropczynska 1986; Agrawal 2000; Balkema-Boomstra *et al*. 2003).

Finally, the current investigation has shown 22.5°C to be the most suitable temperature for *B. rubrioculus* development on apple. Accordingly, our results provided fundamental information describing the biology of brown mite at five constant temperatures on the apple and could be helpful for implementing management programs, in apple orchards, certainly, when associated with other findings and data obtained by other ecological methods.

Acknowledgements

The authors are highly appreciated to Prof. Dr. Hsin Chi (Laboratory of Theoretical and Applied Ecology, Department of Entomology, National Chung Hsing University, Taichung 402, Taiwan, Republic of China) and Dr. Alinaghi Mirmoayedi (Department of Plant Protection, Faculty of Agriculture, Razi University, Kermanshah, Iran) for their valuable help in analysis and revision of the draft version.

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Received: 17 November 2013
Accepted: 21 March 2014
Published: 15 January 2014

تأثیر دما بر رشد و نمو و زادآوری کنه قهوه‌ای پا بلند درختان میوه ***Bryobia rubrioculus*** **Scheuten** **(Acari: Tetranychidae)** روی سیب

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چکیده

کنه قهوه‌ای پابلند درختان میوه، *Bryobia rubrioculus* Scheuten، یکی از آفات مهم درخت سیب در غرب ایران محسوب می‌شود. آماره‌های زیستی و دموگرافیک این کنه در شرایط آزمایشگاهی و در دماهای ثابت (۲۰، ۲۲/۵، ۲۵، ۲۷/۵ و ۳۰ درجهٔ سلسیوس، رطوبت نسبی ۵ ± ۶۰ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی) مورد بررسی قرار گرفت. مدت زمان نمو مراحل نارس از ۰/۹۶ ± ۳۹/۶۵ روز در دمای ۲۰ و ۰/۷۴ ± ۱۸/۱۸ روز در دمای ۳۰ درجهٔ سلسیوس به دست آمد. آستانه دمایی پایین و ثابت دمایی برای مراحل رشدی پیش از بلوغ، به ترتیب ۱۲/۹ درجهٔ سلسیوس و ۲۷۹/۷ روز–درجه تعیین شد. میانگین زنده‌مانی کنه‌های مادهٔ بالغ ۱۴/ ۱± ۱۶/۷۵ روز در دمای ۲۰ درجه سلسیوس و ۰/۳۸ ± ۸/۵۸ روز در دمای ۳۰ درجهٔ سلسیوس تعیین شد. بیشترین و کمترین نرخ تخم‌گذاری به ترتیب ۱/۳۶ ± ۴/۷۹ و ۱/۴۹ ± ۳/۷۵ تخم به ازای کنهٔ ماده در دماهای ۳۰ و ۲۰ درجه سلسیوس مشاهده شد. نتایج این مطالعه می‌تواند در پیش‌آگاهی رشد و نمو و پویایی جمعیت کنه قهوه‌ای مورد استفاده قرار گیرد.

واژگان کلیدی: سیب، دما، کنه قهوه‌ای پابلند، زیست‌شناسی، غرب ایران.

تاریخ دریافت: ۱۳۹۲/۸/۲۶

تاریخ پذیرش: ۱۳۹۳/۱/۱

تاریخ چاپ: ۱۳۹۳/۱/۲۵