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The effect of temperature on the biology of *Phytoseiulus macropilis* (Banks) (Phytoseiidae) in applied biological control program

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ABSTRACT. *Phytoseiulus macropilis* (Banks) (Phytoseiidae) is a natural enemy of *Tetranychus urticae* Koch (TSSM), a common pest in several cultures, especially in greenhouses. This research aimed to know the biological parameters of a strain of *P. macropilis* from Vale do Taquari, State of Rio Grande do Sul, feeding on TSSM at different temperatures. The study was initiated with 30 eggs individualized in arenas under the temperature of 20, 25 and 30 ± 1°C and relative humidity of 80 ± 10%. The average length (T) of each generation decreased with the increase of temperature, ranging from 25.71 days at 20°C to 11.14 days at 30°C. The net reproductive rate (Ro) ranged from 45.47 at 20°C to 18.25 at 30°C; the innate capacity for increase (rm) was 0.15 at 20°C, reaching 0.26 at 30°C and the finite increase rate (λ) ranged from 1.41 to 1.82 females day^{-1} at 20 and 30°C, respectively. In the present study, it was observed that the strain of the evaluated predatory mite from mild climate of South Brazil, might present a good performance to control TSSM when exposed to a temperature range between 20 and 30°C.

Keywords: agroecology, strawberry, *Tetranychus urticae,* two-spotted spider mite.

Efeito da temperatura sobre a biologia de *Phytoseiulus macropilis* (Banks) (Phytoseiidae) em programa de controle biológico aplicado

RESUMO. *Phytoseiulus macropilis* (Banks) (Phytoseiidae) é um inimigo natural de *Tetranychus urticae* Koch (ácaro rajado), uma praga comum em diversas culturas mantidas em estufas. Esta pesquisa teve o objetivo de conhecer características biológicas de uma linhagem de *P. macropilis* do Vale do Taquari, Rio Grande do Sul, que se alimenta do ácaro rajado em diferentes temperaturas. O estudo foi iniciado com 30 ovos individualizados em arenas nas temperaturas de 20, 25 e 30 ± 1°C e umidade relativa de 80 ± 10%. A duração média (T) de cada geração diminuiu com o aumento da temperatura, variando de 25,71 dias, a 20°C, e 11,14 dias, a 30°C. A taxa líquida de reprodução (R_o) variou de 45,47, a 20°C, para 18,25, a 30°C; a capacidade inata de crescimento (r_m) foi de 0,15, a 20°C, atingindo 0,26, a 30°C, e a taxa de aumento finito (λ) variou 1,41 até 1,82 fêmeas/dia, a 20 e 30°C, respectivamente. No presente estudo, observou-se que a estirpe de predador avaliada, de clima ameno do Sul do Brasil, pode apresentar um bom desempenho para controlar TSSM quando exposta a temperatura entre 20 e 30°C.

Palavras-chave: agroecologia, morango, *Tetranychus urticae,* ácaro rajado.

Introduction

Tetranychid mites have been mentioned as the most important mites that attack plants, presenting a potential to reach a pest status (Moraes & Flechtmann, 2008). *Tetranychus urticae* Koch (two-spotted spider mite - TSSM) is a polyphagou specie that may feed on more than 600 plant species (Bolland, Gutierrez, & Flechtmann, 1998). Preferentially, this mite attacks the abaxial surface of developed leaves, spinning webs that form silvery-white spots (Lourenção, Pereira, Miranda, & Ambrosano, 2000). The importance of this mite as a possible pest of strawberries in the state of Rio Grande do Sul was reported by Ferla, Marchetti and Gonçalves (2007). The damages caused by TSSM are intensely increasing, either in greenhouse or low tunnels (Easterbrook, Fitzgerald, & Solomon, 2001; Sato, Tanaka, & Miyata, 2007), and may reduce the production yields in up to 80% (Ronque, 1999).

The TSSM is most effectively controlled with miticides. However, consumers oppose this method due to its insecticide toxicity, and the negligence of the farmers in the application of such pesticides. Among the natural enemies of tetranychids, it is possible to highlight the predatory mites of the families Phytoseiidae and Stigmaeidae (Moraes, McMurtry, Denmark, & Campos, 2004; Chant & Mcmurtry, 2007; Mcmurtry, Moraes, & Sourassou,

2013). As an alternative for toxic miticides, several studies have been demonstrating that phytoseiid mites may efficiently control strawberry infestations of TSSM. In Brazil, *Phytoseiulus fragariae* Denmark and P. Schicha, *longipes* Evans and *P. macropilis* (Banks) are reported (Moraes et al., 2004).

Phytoseiulus macropilis Banks, described from Florida, is considered the most common predator mite specie in that region (Saba, 1974). Such mite also has been reported in several countries of Europe, Africa and America (Moraes et al., 2004). In Brazil, this specie occurs naturally in all regions, and is generally associated to tetranychid populations (Denmark & Muma, 1973; Moraes et al., 2004; Oliveira et al., 2007).

The evaluating of *P. macropilis* as a natural enemy to control TSSM presented promising results under laboratory conditions (Oliveira et al., 2007). The fitness of this predator increases when more than five preys are presented (Ferla, Marchetti, Johann, & Haetinger, 2011). The present study has the aim to know the strain fitness of *P. macropilis* from Vale do Taquari, Rio Grande do Sul, when feeding on TSSM under different temperatures and under laboratory conditions.

Material and methods

Phytoseiulus macropilis specimens were collected from strawberry leaves from Anta Gorda County's, Rio Grande do Sul, five months before the beginning of the research. The rearing stock was maintained in a germination chamber within plastic trays. The TSSM were fed on bean plants at temperature 25 ± 1°C, photophase of 12 hours and 80 ± 10% of relative humidity. The arenas were covered with a glass plate to control the relative humidity. Moreover, such arenas were weekly renewed.

The adult females of *P. macropilis* were individualized in arenas during a period of six hours to obtain eggs. Thereafter, the females were removed and only an egg per arena was maintained. The research was initiated with 30 eggs for each temperature of 20, 25 and 30 ± 1°C, totalizing 90 eggs. The tests were performed in arenas of 2.5 cm diameter and 1.5 cm height, with paper discs dampened and upon them, a bean leaf with TSSM.

The arenas were covered with plastic parafilm to avoid the drying of the leaves and the mite escaping. Such arenas were renewed every four days. The evaluations were realized three times a day in immature phases at 7, 12 and 18 hours, while in adulthood once at 14 hours, as well evaluated the number of eggs and the survival. The females were mated with males obtained from rearing stock and the eggs transferred to another arena to evaluate the sex ratio. Tukey test was utilized to compare the averages, at a significance level of 5%, with the software Bioestat 5.0 (Ayres, Ayres, Ayres, & Santos, 2007).

The data obtained in the present study was organized for life table calculations according to Toldi, Ferla, Dameda, & Majolo (2013). The net reproductive rate ($R_o = \Sigma mx.lx - mx$: total eggs/number of females; lx: live specimens/total specimens), the average generation length ($T = \Sigma mx.lx.x / \Sigma mx.lx$), the innate capacity for increase ($rm = log\ Ro / T.0.4343$) and the finite increase rate ($\lambda = antilog\ rm$) were calculated (Silveira, Nakano, Barbin, & Nova, 1976).

Results and discussion

The average length of the immature phases decreased with the increase of temperature, presenting higher length at 20°C and lower at 30°C. In the three temperatures, significant differences between the stages were observed. The average length of egg-adulthood period changed between 7.18 days at 20°C and 3.28 days at 30°C. The average development time and average of immature stages changed in each phase and between the sexes at every temperature. The egg-adulthood period was similar between male and female in all temperatures. The incubation and larval periods were higher at 20°C and lower at 30°C. However, the protonymph and deutonymph phases were similar at 25 and 30°C. The females presented different incubation length, while larval, protonymph and deutonymph stages presented similarities at the temperature of 25 and 30 °C (Table 1).

The number of eggs per female decreased with the increasing of temperature, being noted an average of 62.33 eggs female^{-1}, at 20°C, and 25.19, at 30°C (Table 2). However, the number of eggs female^{-1} day^{-1} was higher at the temperature of 30°C. The female longevity differed statistically in all temperatures, being maximum longevity observed at 20°C, with average of 40.22 days and minimum at 30°C, when observed on average 12.16 days. The longevity of male and female was different, since the males lived 50.81days at 20°C and 15.68 at 30°C, while females lived on average 40.22 days at 20°C and 12.16 days at 30°C. In pre oviposition period at 20°C, females laid eggs after 4.72 days, while at 30°C they laid eggs after 1.85 days. Greater oviposition and post oviposition periods were observed at 20°C and lower at 30°C. In the temperature of 20°C, a long high oviposition period is observed, while in the others temperatures the oviposition is high during a short period in the beginning, being subsequently followed by a sharp decline (Figure 1).

Table 1. Average duration, in days (±SD), of immature instars of *Phytoseiulus macropilis* feeding on TSSM at temperature of 20, 25 and 30ºC with photophase of 12 hours and relative humidity of 80 ± 10%.

		N	Egg	Larva	Protonymph	Deutonymph	Egg-adult
20°C	♀	18	2.85 ± 0.06 a	1.04 ± 0.06 a	1.60 ± 0.06 a	1.69 ± 0.05 a	7.18 ± 0.10 a
	♂	10	2.92 ± 0.13 A	0.99 ± 0.13 A	1.53±0.13 A	1.69 ± 0.15 A	7.15 ± 0.16 A
25°C	♀	20	1.67 ± 0.02 b	0.72 ± 0.02 b	0.92 ± 0.04 b	0.64 ± 0.04 b	3.96 ± 0.03 b
	♂	10	1.65 ± 0.03 B	0.73 ± 0.03 B	0.72 ± 0.06 B	0.63 ± 0.02 B	3.74 ± 0.06 B
30°C	♀	17	1.52 ± 0.00 c	0.39 ± 0.00 c	0.60 ± 0.00 c	0.77 ± 0.04 b	3.28 ± 0.04 c
	♂	12	1.52 ± 0.00 C	0.39 ± 0.00 C	0.77 ± 0.12 B	0.76 ± 0.12 B	3.43 ± 0.23 C

N, mite number evaluated. Averages (±SD) followed by the same capital letter or lowercase letter in the line do not differ statistically from each other by the test t Student, at a significance level of 5%.

Table 2. Female and male longevity and adulthood phases of *Phytoseiulus macropilis* at temperature of 20, 25 and 30 ºC, photophase of 12 hours and 80±10% relative humidity.

Parameters	Temperatures (°C)					
	N	20	N	25	N	30
Fecundity (eggs female^{-1})	18	62.33 ± 2.18 a	18	35.2 ± 4.8 b	16	25.19 ± 4.32 b
Eggs female^{-1} day^{-1}	18	2.20 ± 0.09 ab	18	1.98 ± 0.14 b	16	2.68 ± 0.33 a
Pre oviposition	18	4.72 ± 0,64 a	18	3.78 ± 0.03 a	16	1.85 ± 0.18 b
Oviposition	18	23.57 ± 2.6 a	18	14.66 ± 1.8 b	16	7.62 ± 1.02 c
Post oviposition	18	4.37 ± 0.98 a	18	2.11 ± 0.9 ab	16	1.00 ± 0.52 b
Female longevity	18	40.22 ± 3.22 a	18	22.57 ± 2.7 b	16	12.16 ± 0.93 c
Male longevity	10	50.81 ± 4.06 a	10	23.19 ± 5.82 b	12	15.68 ± 1.69 b

N, mite number evaluated. Average followed by the same letter in the column does not differ by Tukey test at 0.05 significance.

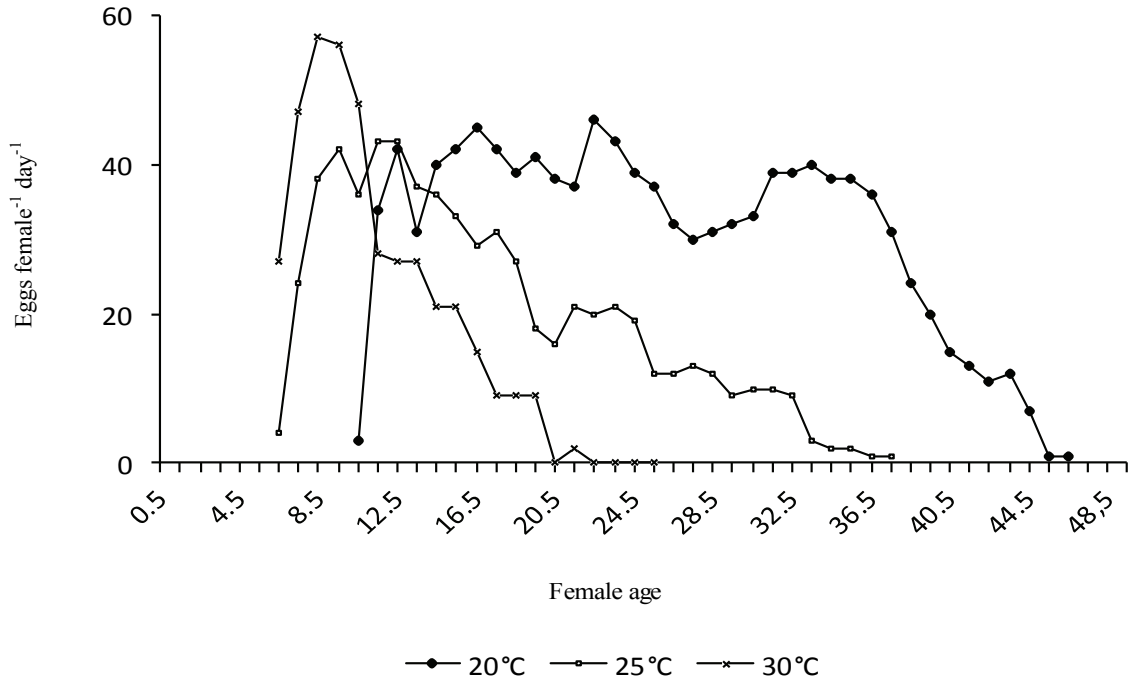

Figure 1. Oviposition rate (eggs female^{-1} day^{-1}) of *Phytoseiulus macropilis* feeding on TSSM at 20, 25 and 30ºC, photophase of 12 hours and 80 ± 10% relative humidity.

The F1 sex ratio was 0.77. The average generation length (T) decreased with the temperature increase, ranging from 25.71 days at 20°C to 11.14 days at 30°C. The net reproductive rate (R_o) ranged from 45.47 at 20°C to 18.25 at 30°C. Innate capacity for increase (r_m) was 0.15 at 20°C, reaching 0.26 at 30°C and finite increase rate (λ) ranged from 1.41 to 1.82 females day^{-1} at 20°C and at 30°C, respectively (Table 3). Higher specific fertility (*mx*) period happened between 12º and 44º day, at 20ºC (Figure 2), from 8º to 32º days, at 25ºC (Figure 3) and from 7º to 19º days, at 30ºC (Figure 4). The maximum rate of population increase was observed during the first four days of oviposition, at 20ºC (Figure 2), on the first day, at 25ºC (Figure 3) and on the first and second day, at 30ºC.

Table 3. Average generation length (T), net reproductive rate (R_o), innate capacity for increase (r_m) and finite increase rate (λ) of *Phytoseiulus macropilis* feeding on TSSM, at temperature of 20, 25 and 30ºC, photophase of 12 hours and 80 ± 10 % relative humidity.

Temperature (°C)	T	R_o	r_m	□
20	25.71	45.47	0.15	1.41
25	17.00	24.40	0.19	1.55
30	11.14	18.25	0.26	1.82

The temperature affected the life cycle of *P. macropilis* in the immature and in the adulthood phases. The length of immature phases decreased with the temperature increase. Silva, Vasconcelos, Gondim Jr., and Oliveira (2005) and Ali (1998) also observed a negative correlation between temperature and length of immature phases. This predatory mite, when fed on *Tetranychus tumidus* Banks at 26°C, presented similar immature phases length of those observed in this work (Prasad, 1967). Moreover, Silva et al. (2005) also observed similar values of those obtained in the present research at 30°C.

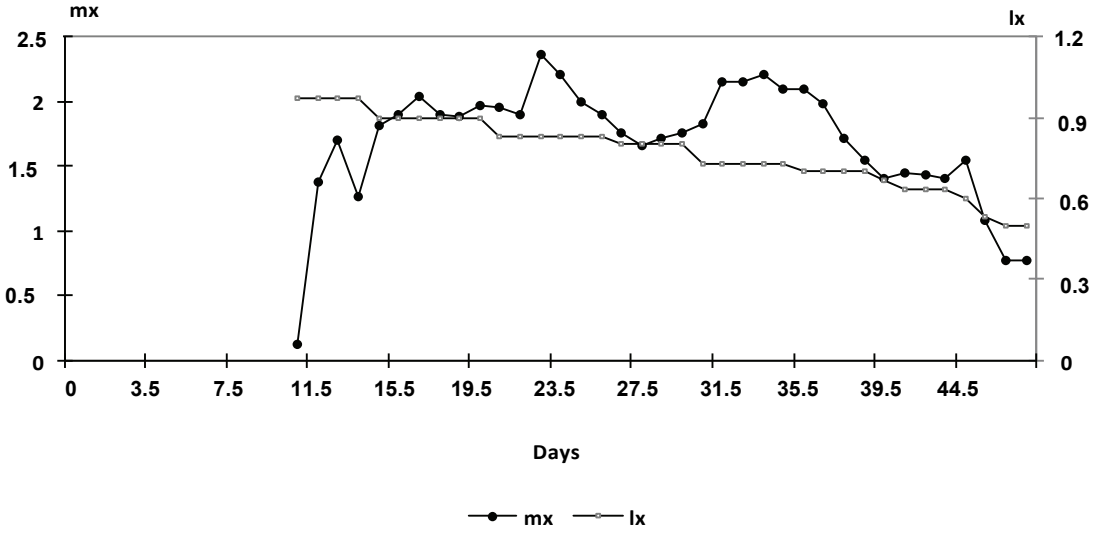

Figure 2. The specific fertility (*mx*) and survival rate (*lx*) of *Phytoseiulus macropilis* feeding on TSSM at 20ºC, photophase of 12 hours and 80 ± 10% relative humidity.

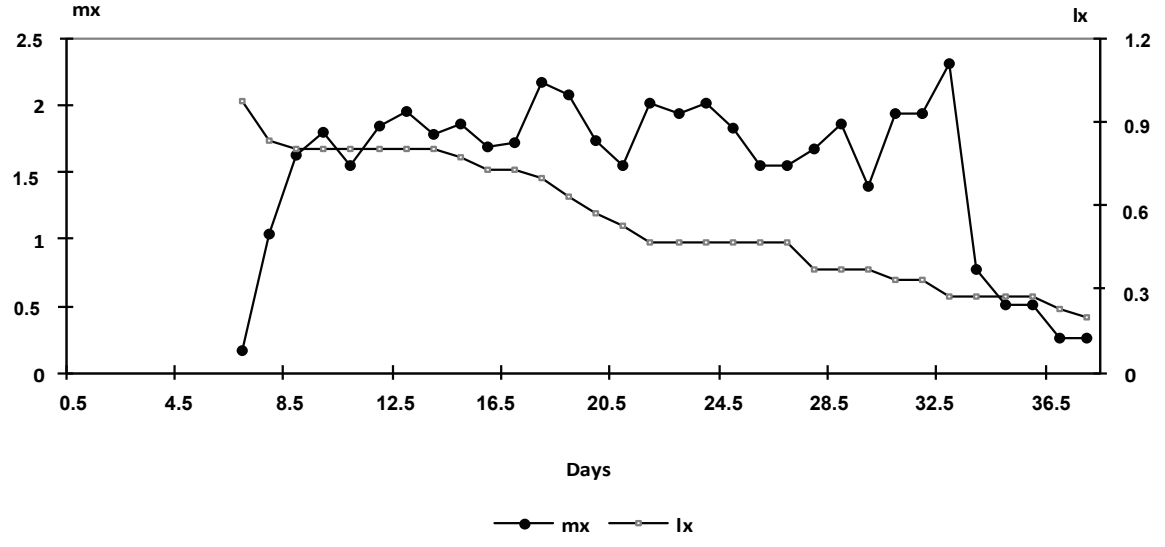

Figure 3. The specific fertility (*mx*) and survival rate (*lx*) of *Phytoseiulus macropilis* feeding on TSSM at 25ºC, photophase of 12 hours and 80 ± 10% relative humidity.

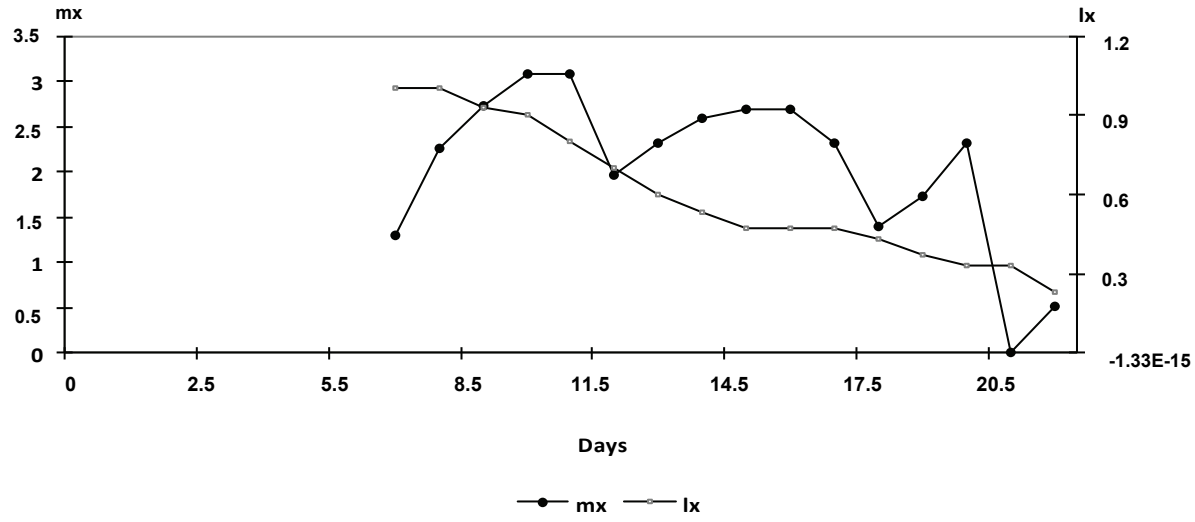

Figure 4. The specific fertility (*mx*) and survival rate (*lx*) of *Phytoseiulus macropilis* feeding on TSSM at 30ºC, photophase of 12 hours and 80 ± 10% relative humidity.

In the present study, the average length of the egg-adult phase at 20ºC was 7.18 days. Such result is similar of those obtained by Ali (1998). For Silva et al. (2005) in the same conditions, the period was 9.6 days. The egg-adult length at 25°C lasted 3.96 days in the present investigation. This result is similar of those observed by Prasad (1967) and Silva et al. (2005), with 4.2 and 4.8 days, respectively. However, Ali (1998) observed a period of 5.7 days.

The length of adulthood phases, as fecundity, pre oviposition, oviposition and post oviposition, differed between the evaluated temperatures. The oviposition and post oviposition decrease with the increase of the temperature. There was a significant reduction of the fecundity from 20 to 30°C, since at 30ºC the number of eggs female^{-1} was lower.

The temperature had a negative influence on *P. macropilis* longevity, since its increase decreased the phase length. Under the temperature of 20°C the lowest reproductive capacity (innate capacity for increase (r_m) was observed. The temperature range between 20°C and 30°C was the most appropriate.

The female longevity was influenced by the temperature increase, being that higher longevity was reached at 20°C and lower at 30°C. These results may be compared with Prasad (1967), which observed 27 days at 26°C. Silva et al. (2005) observed a higher longevity of 44 days at 26°C, and lower longevity of 22.6 days at 20°C. Higher values were observed by Ali (1998), with 57.2 days at 20°C and 36.7 days at 30°C.

Male longevity also was superior on lower temperatures. This is in agreement with Ali (1998) that observed 47.8 days at 20°C and 28.7 days at 30°C. For Silva et al. (2005), there was no difference between the temperatures of 20 and 26°C, since the mites reached 34.5 and 35.8 days, respectively. Feeding on *T. tumidus*, the male reached 30.2 days of longevity at 26°C (Prasad, 1967).

With the increase of the temperature a decrease of the generation lenght (T) and net reproductive rate (R_o) was observed. However, the innate capacity for increase (r_m) and finite increase rate (λ) presented a considerable growth, indicating that the temperature increase influenced positively in the specie reproduction.

The number of eggs female^{-1} was similar of that observed when *P. macropilis* was fed on *Mononychellus planki* McGregor (35.00 ± 1.94) at 25°C (Majolo & Ferla, 2014). Furthermore, the reproductive rate (R_o), innate capacity for increase (r_m) and finite increase rate (λ) were higher, while the generation length (T) was lower. In such study, results demonstrated that *P. macropilis* prefer TSSM instead of *M. planki*.

Under the temperatures of 20 and 25°C, the values of innate capacity for increase (r_m), length generation (T) and finite increase rate (λ) are similar to the results observed by Silva et al. (2005). Nonetheless, net reproductive rate (R_o) was higher at 20°C and lower at 25ºC. The values described in this work at 30ºC, are similar to those of Ali (1998) at 32ºC.

The temperature is one of the key factors which influence applied biological control. As observed in the present investigation, the temperature range of 20 to 30ºC is the most appropriate for *P. macropilis* control the specific prey TSSM. These results were expected, since in the collecting locality, the average temperatures during the coldest month are higher

than 11.3°C and the average temperatures during the hottest month are 26°, characterizing such climate as humid and mild (Buriol, Estefanel, Chagas, & Eberhardt, 2007). This predator mite, collected from lower temperatures between 11 and 26°C, may present a good potential to control TSSM in environments with temperatures around 30°C.

Conclusion

The evaluation of the strain of *P. macropilis* from milder climate demonstrated that such predator mite presents the capacity to control *T. urticae* under temperatures between 20 and 30°C. The temperature alteration influenced the biological parameters, however, in the analyzed temperatures, the predator may control the specific prey TSSM.

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