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Biological performance of the predatory mite *Neoseiulus idaeus* (Phytoseiidae): a candidate for the control of tetranychid mites in Brazilian soybean crops

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Abstract

The soybean (*Glycine max* (L.): Fabaceae) is considered the most important agricultural crop in Brazil. Phytophagous tetranychid mites as *Mononychellus planki* McGregor, *Tetranychus ludeni* Zacher and *T. urticae* Koch have been considered pest in soybean crops. *Neoseiulus idaeus* Denmark & Muma (Phytoseiidae) is a predatory mite of *T. ludeni* and *T. urticae*. The aim of the present study was to evaluate the biological performance of *N. idaeus* when fed on *T. urticae, T. ludeni* and *M. planki*, coming from the Northwest region of Rio Grande do Sul state, Brazil. The study was conducted in the laboratory with individual predators supplied with different preys. The mean duration (days) of *N. idaeus* egg-adult development was similar independently of supplied prey (*T. ludeni* - 5.29±0.03; *M. planki* - 5.34±0.05 and *T. urticae* - 5.23±0.03 days). Female viability was 90% when fed on *M. planki* and 100% when fed on *T. ludeni* and *T. urticae*. Mean fecundity of *N. idaeus* was lower when fed on *M. planki* (4.6±1.58 eggs/female) and higher when fed on *T. ludeni* (21.8±3.22) and *T. urticae* (26.2±2.41). The mean generation time (T) was lower when *N. idaeus* fed on *M. planki* than when fed on *T. ludeni* and *T. urticae*. The net reproductive rate (R_o) was 4.42±0.49 on *M. planki*, 17.77±0.55 on *T. ludeni* and 20.59±0.48 on *T. urticae*. The innate capacity for increase (r_m) was lower when *N. idaeus* was fed on *M. planki* (0.09) and higher when such predator was fed on *T. ludeni* (0.20) and *T. urticae* (0.22 females/females/day). These results demonstrated that *N. idaeus* is able to reach the complete development feeding on all the three tetranychid species. *Mononychellus planki* demonstrated to provide a sub-optimal diet if compared to *T. ludeni* and *T. urticae*.

Keywords: biological control, life table, *Tetranychus urticae*, *Tetranychus ludeni*.

Desempenho biológico do ácaro predador *Neoseiulus idaeus* (Phytoseiidae): um candidato no controle de ácaros tetraniquídeos em soja brasileira

Resumo

Soja (Glycine max (L.): Fabaceae) é a mais importante cultura agrícola brasileira. Tetraniquídeos fitófagos são pragas na cultura, *Mononychellus planki* McGregor, *Tetranychus ludeni* Zacher e *T. urticae* Koch. *Neoseiulus idaeus* Denmark & Muma (Phytoseiidae) é o ácaro predador de *T. ludeni* e *T. urticae*. Este estudo teve como objetivo avaliar o desempenho biológico de *N. idaeus* quando alimentado com *T. urticae*, *T. ludeni* e *M. planki* da região noroeste do Rio Grande do Sul, Brasil. O estudo foi realizado em laboratório com predadores individualizados com diferentes presas. A duração média (dias) de *N. idaeus* desenvolvimento ovo-adulto foi semelhante independentemente da presa fornecida (*T. ludeni* – 5.29 ± 0.03; *M. planki* – 5.34 ± 0.05 e *T. urticae* – 5.23 ± 0.03 dias). Viabilidade feminina foi de 90% quando alimentados com *M. planki* e 100% em *T. ludeni* e *T. urti*cae. Fecundidade de *N. idaeus* foi menor com *M. planki* (4.6 ± 1.58 ovos / fêmea) e maior com *T. ludeni* e *T. urticae*, 21.8 ± 3.22 e 26.2 ± 2.41, respectivamente. O tempo médio de uma geração (T) foi menor quando *N. idaeus* alimentados com *M. planki* do que quando em *T. ludeni* e *T. urticae*. A taxa líquida de reprodução (Ro) foi de 4.42 ± 0.49 em *M. planki*, 17.77 ± 0.55 em *T. ludeni* e 20.59 ± 0.48 no *T. urticae*. A capacidade inata de aumento (rm) foi menor em *M. planki* (0.09) e maior quando alimentados com *T. ludeni* (0.20) e *T. urticae* (0.22 fêmeas / fêmea / dia). Estes resultados demonstraram que *N. idaeus* é capaz de utilizar e desenvolver em todas as três espécies de tetraniquídeos. *Mononychellus planki* demonstrou ser a presa menos adequada para este predador do que *T. urticae* e *T. ludeni*.

Palavras-chave: controle biológico, tabela de vida, *Tetranychus urticae*, *Tetranychus ludeni*.

1. Introduction

The soybean (*Glycine max* (L.): Fabaceae) is the most important agricultural crop in Brazil, since the country produced 86 tons during 2013 and 2014, being considered the second largest world soybean producer. Soybean production is widely distributed in Brazilian territory. However, the largest acreages are located in the Midwest and South regions; especially in the states of Mato Grosso, Paraná and Rio Grande do Sul. During 2013 and 2014, Rio Grande do Sul produced approximately twelve millions of tons. Such amount represent 15% of the Brazilian soybean production (CONAB, 2014).

This crop is susceptible to herbivorous attacks, which may cause substantial damage and production losses. Despite several animals might affect soybean crops, a special group responsible to such damage are phytophagous tetranychids mites. This affirmation is reinforced by recent studies that have been reporting high populations of tetranychids mites species (*Mononychellus planki* McGregor, *Tetranychus desertorum* Banks, *T. gigas* Pritchard & Baker, *T. ludeni* Zacher and *T. urticae* Koch) in soybean crops (Guedes et al., 2007; Reichert et al., 2014; Rezende et al., 2014; Roggia et al., 2008).

Tetranychids may cause damage to several plants species (Bolland et al., 1998; Silva et al., 2009). These mites feed on parenchyma and extract the cell contends, causing a reduction of the plant photosynthetic capacity, affecting directly the grain production (Moraes and Flechtmann, 2008). Under temperatures around 30° C, *T. ludeni* increase drastically its reproduction and fecundity rates, leading to highly economic damage in regions with such climate (Silva, 2002). Despite its growing population, until recently *M. planki* was not mentioned as a mite of economic importance (Moraes and Flechtmann, 2008). However, currently such mite specie has been considered the most frequent and abundant in soybean crops (Reichert et al., 2014; Rezende et al., 2014).

Predatory mites of Iolinidae, Phytoseiidae and Stigmaeidae have been commonly associated to Brazilian soybean crop (Reichert et al., 2014; Rezende et al., 2014). However, Phytoseiid are the most common and abundant mites in such crop. Considered as generalist predators, this mite family may feed on spider mites, insects, nematodes, fungus, pollen and plant exudates (McMurtry et al., 2013; Marafeli et al., 2014), but rarely on vegetable tissues (Magalhães and Bakker, 2002; Sengonca et al., 2004). Several members of this mite family have been considered of great importance in applied biological control of mites and thrips in greenhouse crops production (Zhang, 2003) and orchards (Moraes et al., 2004).

Phytoseiid mites of the genus *Neoseiulus* have been commonly observed on soybean crops (Reichert et al., 2014; Rezende et al., 2014). *Neoseiulus anonymus* Chant & Baker, *N. californicus* McGregor and *N. idaeus* Denmark & Muma are common mite species in Rio Grande do Sul State (Reichert et al., 2014). However, available information about this mite family in soybean crops of Rio Grande do Sul State is scarce. Recently, Reichert et al. (2014) mentioned *N. idaeus* as the most common mite specie in Rio Grande do Sul state soybean crops. *Neoseiulus idaeus* is reported as the main predator associated to *Mononychellus tanajoa* (Bondar) (green cassava mite) in northeast of Brazil (Moraes et al., 1990). In cassava crops such predator mite demonstrated capacity to control *T. urticae* population (Moraes et al., 1994).

Phytoseiid are commonly observed in association with phytophagous mites in annual, perennial and native vegetation (Ferla and Moraes, 2002). However, studies regarding the biological capacity of *N. idaeus* to control phytophagous mites are scarce in South Brazil. In this way, the present study attempts to investigate the biological performance of *N. idaeus* when fed on *T. urticae, T. ludeni* and *M. planki.* This study might help to identify a natural enemy that could be used in applied biological control of phytophagous tetranychids mites in soybean crops from Northwest region of Rio Grande do Sul state, Brazil.

2. Material and Methods

2.1. Stock colony

The present study was carried out at the Acarology Laboratory of UNIVATES, Lajeado, Rio Grande do Sul State, Brazil. The predator mite *N. idaeus* was collected from soybean plant leaves at a commercial production site located in Northwest of Rio Grande do Sul State. These mites have been maintained in laboratory on bean plant (*Phaseoulus vulgaris* L.), and fed on *T. urticae* coming from strawberry, for two months before the beginning of the studies. *M. planki, T. ludeni* and *T. urticae* also were maintained on bean plants in laboratory. The rearing stocks were conducted in a germination chamber under 25±1°C with 12-hour photophase and 70±5% relative humidity.

2.2. Experimental design

The biological study was carried out with 90 predator eggs individualized in arenas with different prey. Additionally, 30 eggs for each food type were added. In each arena, we added 15 specimens of different developmental stages of *T. ludeni, M. planki* and *T. urticae*. The experiment started with the addition of three *N. idaeus* females from the rearing stock in each arena. They were removed four hours later, leaving just one predatory mite egg/arena.

The immature stages have been observed at 7, 11, 15 and 19 hours respectively. In such observations, the duration of life stages was checked. During the adult stage, females were maintained mated with the rearing stock males and the evaluations, to determine the number of eggs laid as well as the survival rate, were performed once a day, at 11 hours. With the aim of determine F1 sex ratio, the laid eggs were collected and transferred to other arenas. The obtained data were compared by Tukey test at a 5% significance level, with the use of Bioestat 5.0 software (Ayres et al., 2007). The arenas have been maintained in the same environment conditions presented in the rearing stock.

The data obtained in the study were organized for life table calculations (Silveira et al., 1976). Subsequently, the values regarding to the reproductive rate net ($R_o = \Sigma mx.lx$ – *mx: total eggs/females number; lx: specimens alive/specimens total*), generation time ($T = mx.lx.x/mx.lx \Sigma$), innate capacity for increase ($r_m = \log R_o/T.0.4343$), and finite increase rate (λ = antilog r_m) were calculated. The mean and standard deviation of each life table parameter was calculated using Bootstrap analysis (Efron and Tibshirani, 1994). A total of thirty random choices, with replacement at every drawn number, were made. In this way, mean and standard deviation could be calculated with the random values.

3. Results

The evaluation of *N. idaeus* strain demonstrate that, when fed on *M. planki*, *T. ludeni* and *T. urticae*, such predator mite may reach the adult phase and lay eggs. These results were similar when *N. idaeus* was fed on *T. ludeni* and *T. urticae* and lower, especially in the adult phase, when *N. idaeus* was fed on *M. planki*.

The mean duration (days) of females egg-adult phase was similar in the three prey evaluated (Table 1). The viability was 90% when fed on *M. planki* and 100% when fed on *T. ludeni* and *T. urticae*. The mean duration of incubation phase (days), was longer when the predator was fed on *T. ludeni* and shorter when fed on *M. planki*. The duration of larvae and deutonymph stages was similar when the predator fed on all the preys. However, the protonymph stage was longer when the predator was fed on *M. planki*. For males, egg-adult phase was longer on *T. ludeni* and lower on *T. urticae*.

The mean fertility of *N. idaeus* was lower when fed on *M. planki* (4.6±1.58 eggs/female) and higher when fed on *T. ludeni* and *T. urticae* (21.8±3.32 and 26.2±2.4).

The mean time duration (days) of pre-oviposition was longer when *N. idaeus* was fed on *M. planki,* while fertility, oviposition and longevity of females was lower (Table 2). Generally, when *T. ludeni* and *T. urticae* have been offered as prey, the adult phases were longer.

The sex ratio in the first generation of the predator was 0.80. The mean generation time (T) was lower when *N. idaeus* was fed on *M. planki* than when fed on *T. ludeni* or *T. urticae* (Table 3). The net reproductive rate (R_o) and innate capacity for increase (r_m) were lower when *N. idaeus*

Table 1. Duration in days (mean ± SE) of immature stages of *Neoseiulus idaeus* feeding on *Mononychellus planki, Tetranychus ludeni* and *Tetranychus urticae*, at 28±1°C in photophase and 22±1°C in scotophase and 70±5% relative humidity.

		N*	Immature stages				
			Egg	Larvae	Protonymph	Deutonymph	Egg-adult
Mononychellus planki	Females	19	2.04±0.04b**	0.81±0.04a	1.31±0.06a	1.16±0.03a	5.34±0.05a
	Males	9	2.04±0.02b	0.76±0.05a	1.24±0.06a	1.20±0.07a	5.24±0.05ab
	Viability (%)	30	100	100	90	100	90
Tetranychus ludeni	Females	22	2.16±0.03a	0.73±0.02a	1.12±0.04b	1.27±0.04a	5.29±0.03a
	Males	8	2.09±0.03ab	0.81±0.02a	1.13±0.04a	1.35±0.08a	5.39±0.06a
	Viability (%)	30	100	100	100	100	100
Tetranychus urticae	Females	19	2.11±0.02ab	0.76±0.02a	1.14±0.03b	1.22±0.04a	5.23±0.03a
	Males	8	2.11±0.03a	0.75±0.04a	1.10±0.04a	1.15±0.07a	5.18±0.06b
	Viability (%)	30	100	100	100	100	100

*N = number of mites evaluated; **Means followed by the same letter, in a column, do not differ statistically from one another by the *Tukey* test, at a significance level of 5%.

Table 2. Fertility in days (mean ± SE) and length of pre-oviposition, oviposition, post-oviposition and longevity of *Neoseiulus idaeus* feeding on *Mononychellus planki*, *Tetranychus ludeni* and *Tetranychus urticae*, at 28±1°C in photophase and 22±1°C in scotophase and 70±5% relative humidity.

Parameter	N*	*Mononychellus planki*	N	*Tetranychus ludeni*	N	*Tetranychus urticae*
Fertility	19	4.6±1.58b**	22	21.8±3.22a	19	26.2±2.41a
Pre-oviposition	9	2.6±0.86a	19	1.6±0.14b	19	1.5±0.11b
Oviposition	9	6.9±1.10b	19	10.7±1.16ab	19	11.7±3.66a
Post-oviposition	9	1.1±0.65a	19	0.5±0.21a	19	0.8±0.27a
Longevity (Females)	19	5.6±5.49b	19	11.3±1.41a	19	14.2±0.86a
Longevity (Males)	9	6.0±1.51a	8	13.0±2.75a	8	7.0±2.47a

*N = number of mites evaluated; **Means followed by the same letter, in a column, do not differ statistically from one another by the *Tukey* test, at a significance level of 5%.

Table 3. Mean generation time (T), net reproductive rate (R_o), innate capacity for increase (R_m) and finite increase rate (λ) of *Neoseiulus idaeus* feeding on M*ononychellus planki, Tetranychus ludeni* and *Tetranychus urticae,* at 28±1°C in photophase, 22±1°C in scotophase and 70±5% relative humidity.

Parameter	Prey		
	Mononychellus planki	***Tetranychus ludeni***	***Tetranychus urticae***
T	12.65±0.14b*	13.94±0.08a	13.82±0.11a
R_o	4.42±0.49c	17.77±0.55b	20.59±0.48a
r_m	0.09±0.005c	0.20±0.002b	0.22±0.001a
ƛ	1.25±0.01c	1.61±0.005b	1.66±0.003a

*Means followed by the same letter, in a column, do not differ statistically from one another by the *Tukey* test, at a significance level of 5%.

fed on *M. planki* and higher when such predator mite fed on *T. urticae*. The finite increase rate (λ) was lower with *M. planki* and higher on *T. urticae.*

Neoseiulus idaeus presented lower specific fertility and survival rate when fed on *M. planki* whether compared with to other preys, surviving during 22 days (Figure 1). The higher specific fertility occurred during the 10-13° day, while survival rate was higher during the 8-13° day.

Neoseiulus idaeus presented lower specific fertility and survival rate when fed on *T. ludeni* whether compared with *T. urticae*, surviving during 26 days (Figure 2). The higher specific fertility occurred during the 9-13° day, while survival rate was higher during the 7-11° day.

Neoseiulus idaeus presented a higher specific fertility and survival rate when fed on *T. urticae* whether compared to other preys, surviving during 30 days (Figure 3). The higher specific fertility occurred during 9-13° day, while survival rate was higher during 7-14° day.

4. Discussion

The results obtained on the present study demonstrate that *N. idaeus* populations are able to complete its development feeding on the evaluated preys, in soybean crops of the Norwest portion of Rio Grande do Sul state. The phytophagous mite *M. planki* demonstrated to be a less suitable prey if compared to *T. ludeni* and *T. urticae*.

The mean duration of egg-adult stage (days) was higher for *N. idaeus* females which were fed on *M. planki* and lower for those which were fed on *T. urticae*. The *N. idaeus* males presented a higher mean duration of egg-adult stage (days) when fed on *T. ludeni* and a lower mean duration when fed on *T. urticae*. *Neoseiulus idaeus* from Mato Grosso do Sul state, Brazil, feeding on *M. tanajoa* and *T. urticae* demonstrated lower mean duration for females when fed on *M. tanajoa* (3.5±0.74) and on *T. urticae* (4.4±0.90). Regarding the males, such work presented a mean duration of egg-adult stage of 4.1±0.70 days when the predator was fed on *M. tanajoa* and 4.5±0.86 days when fed on *T. urticae* (Moraes et al., 1994). These results indicate that *N. idaeus* population from Northwest of Rio Grande do Sul may live longer when fed on *T. ludeni* and *T. urticae*. However, the predator strain or prey-food utilized in the test may influence these results. In addition, these results confirm that species of the genus *Mononychellus* are less suitable

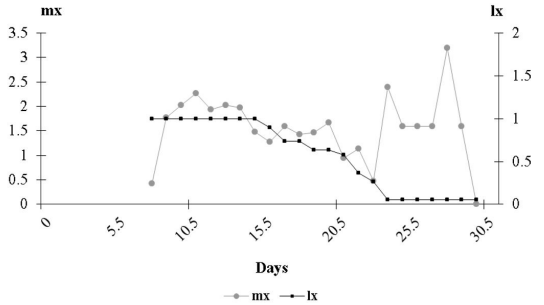

Figure 1. Specific fertility (mx) and survival rate (lx) of *Neoseiulus idaeus* feeding on *Mononychellus planki*, at 28±1°C in photophase, 22±1°C in scotophase and 70±5% relative humidity.

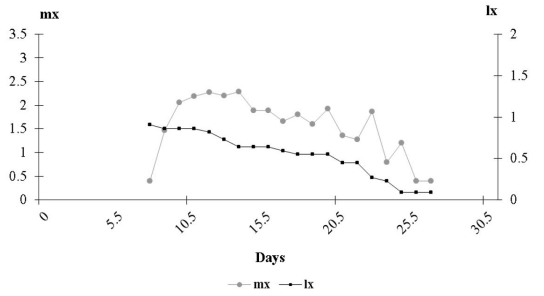

Figure 2. Specific fertility (mx) and survival rate (lx) of *Neoseiulus idaeus* feeding on *Tetranychus ludeni*, at 28±1°C in photophase, 22±1°C in scotophase and 70±5% relative humidity.

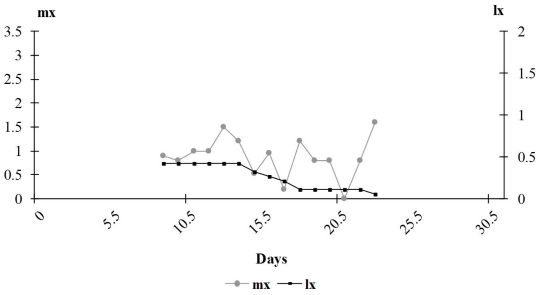

Figure 3. Specific fertility (mx) and survival rate (lx) of *Neoseiulus idaeus* feeding on *Tetranychus urticae*, at 28±1°C in photophase, 22±1°C in scotophase and 70±5% relative humidity.

preys to *N. idaeus* than species of the genus *Tetranychus*, since *M. tanajoa* and *M. planki* presented lower fitness as prey. Maintained on low relative humidity (55%) and fed on *T. urticae* eggs, the evaluation of *N. idaeus* strain from Colombia presented similar results to the this work, with female's length of 4.56±0.50 days and male's length of 4.87±0.34 days (Dinh et al., 1988). Differently, when *N. idaeus* was fed on eggs and adults *T. urticae,* inferior results on papaya (3.8 ± 0.12) and snap bean (4.0±0.08) were obtained (Collier et al., 2007). These different results may be due to the predator strain, distinct origin or different prey-food. Escudero and Ferragut (2005) observed lower egg-adult phase length testing *N. californicus* fed on *T. ludeni* (4.67 days). In contrast, when fed on *T. urticae,* such predator presented greater length (Toldi et al., 2013).

The predator mean fertility was significantly lower when fed on *M. planki* (4.6±1.58 eggs/female) and higher when fed on *T. urticae* (26.2±2.41 eggs/female). Moraes et al. (1994) obtained a high fecundity rate of *N. idaeus* with *M. tanajoa* as food source (11.8±7.44 eggs/female) and lower fecundity rate when *N. idaeus* was fed on *T. urticae* (13.8±8.85 eggs/female). Escudero and Ferragut (2005) tested *N. californicus* with *T. ludeni* as food source and obtained a lower fecundity rate (2.62 eggs/female). However, Toldi et al. (2013) tested such predator mite fed on *T. urticae*, and obtained a higher fecundity rate (38.14±5.58 eggs/female).

In the present study, the longevity of *N. idaeus* females and males was significantly lower with *M. planki* as food source, and higher on *T. urticae* females and *T. ludeni* males. Moraes et al. (1994) obtained higher results on *M. tanajoa* females (9.3±3.79 days) and lower results on *T. urticae* (12.1±6.24 days). In regarding to the males, such work described higher results on *M. tanajoa* (9.0 ±4.49 days) and lower results on *T. urticae* (10.9±6.59 days).

All life table parameters presented higher values when the predator fed on *T. urticae*, except the length average of every generation (T), which was higher on *T. ludeni* and lower on *M. planki*, indicating that the last prey is less adequate to *N. idaeus*.

In the present study, the duration of each generation was longer than that obtained by Moraes et al. (1994) studying *M. tanajoa* and *T. urticae*, Dinh et al. (1988) studying *T. urticae* eggs and Collier et al. (2007) investigating *T. urticae* eggs and adults. Escudero and Ferragut (2005) studied *N. californicus* fed on *T. ludeni* and obtained higher results. Toldi et al. (2013) also obtained higher results when *N. californicus* was fed on *T. urticae*.

The net reproductive rate (R_o) observed was lower for *M. planki* and higher for *T. urtcae*. In contrast, Moraes et al. (1994) observed higher R_o for *M. tanajoa* and lower R_o for *T. urticae*, while Dinh et al. (1988) described a significantly higher R_o for *T. urticae*. After Collier et al. (2007), the R_o was lower when fed on eggs and adults T. *urticae*. *Neoseiulus californicus* fed on *T. ludeni,* presented higher net reproductive rate (Escudero and Ferragut, 2005) than the net reproductive rate presented in this work. However, Toldi et al. (2013) observed a similar result, when such predator was fed on *T. urticae*.

The innate capacity for increase (r_m) obtained in the present study with *N. idaeus*, was lower on *M. planki* (0.09±0.005) and higher on *T. urticae* (0.22±0.001). The r_m obtained by Moraes et al. (1994) was higher for *M. tanajoa* and *T. urticae.* Dinh et al. (1988) observed higher r_m for *T. urticae* and Collier et al. (2007) described lower rm when the predator fed on eggs and adults of *T. urticae*. Escudero and Ferragut (2005), obtained higher results utilizing *N. californicus* feeding on *T. ludeni*. Toldi et al. (2013) also studied *N. californicus* fed on *T. urticae*, however they obtained lower results than those presented by Escudero and Ferragut (2005).

Neoseiulus idaeus presented a high increasing population capacity when fed on *T. ludeni* and *T. urticae*. This demonstrate that such predator mite belong to type II, as a predator which present an strong aggregation response to leaves infested with Tetranychus species (McMurtry et al., 2013). We also observed that fecundity, net reproductive rate and innate capacity for increase were lower when *N. idaeus* was fed on *M. planki*, demonstrating that such prey is less adequate. The production of web on leaf circles after the transference of the prey may have favored the predation capacity of *T. ludeni* and *T. urticae*. This could partially explain the difference observed in the present study with *M. planki*. Studies have demonstrated that some phytoseiid mites improve its predation rate when reared on leaves infested by tetranychids mites that produce more web (McMurtry et al., 2013). Saito (2010) described the genus *Mononychellus* as mites which presented LW-f type spin without production of threads and webs, and lay its eggs under dense leaves.

The predator mite *N. idaeus* may be utilized in biological control of *T. ludeni*, *T. urticae*. *M. planki* demonstrated to be an alternative prey that might support the predator development until the adult phase, in quick life cycle with oviposition. However, to be validated, these laboratory results have to be tested at field level. *Neoseiulus idaeus* can be considered as a potential natural enemy to use in an applied biological control program in soybean crops of Rio Grande do Sul state. However further studies to define release methods, answer to predation and fitness at field level are necessary.

5. Conclusion

T. ludeni and *T. urticae* are suitable prey for *N. idaeus* while *M. planki* was less adequate as prey. The life table parameters indicate a strong association of *N. idaeus* with prey of the genus *Tetranychus*. However, *N. idaeus* reached the adult phase and laid eggs, presenting a quick life cycle when fed only on *M. planki*.

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