ACAROLOGY

Life History of *Amblyseius herbicolus* (Chant) (Acari: Phytoseiidae) on Coffee Plants

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História de Vida de *Amblyseius herbicolus* (Chant) (Acari: Phytoseiidae) em Cafeeiro

RESUMO - O ácaro predador *Amblyseius herbicolus* (Chant) é o segundo fitoseídeo mais abundante em cafeeiro (*Coffea arabica* L.), após *Euseius alatus* DeLeon, na região de Lavras, MG, associado ao vetor do vírus da mancha-anular, *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae). Sua história de vida foi estudada levando em conta aspectos biológicos, tabela de vida, atividade predatória e respostas funcional e numérica em função da densidade de presa. Foi constatada longevidade de 38 dias para fêmeas adultas quando alimentadas com *B. phoenicis*. A estimativa da capacidade inata de crescimento da população (r_m) foi 0,150 e a duração média de uma geração (T) 25,3 dias. A população dobrou a cada 4,6 dias. Trinta ácaros *B. phoenicis* /arena de folha de cafeeiro (3 cm de diâmetro) foram oferecidos separadamente para um espécime de cada fase do ácaro predador. Fêmeas adultas foram mais eficientes na predação de todas as fases do desenvolvimento do ácaro-presa, seguidas das fases ninfais. Para o estudo das respostas funcional e numérica, a presa foi oferecida nas densidades de 0,14 a 42,3 formas imaturas de *B. phoenicis* /cm^2 de arena, por serem preferidas para predação. A predação e oviposição de *A. herbicolus* aumentam com o aumento da densidade de presa, com uma correlação positiva e altamente significativa. A análise de regressão realizada sugere uma resposta funcional do tipo II, com uma predação máxima diária de aproximadamente 35 *B. phoenicis* /cm^2 /fêmea adulta.

PALAVRAS-CHAVE: Biologia, fitoseídeo, resposta funcional, resposta numérica, *Coffea arabica*

ABSTRACT - The predaceous mite *Amblyseius herbicolus* (Chant) is the second most abundant phytoseiid on coffee plants (*Coffea arabica* L), after *Euseius alatus* DeLeon, in Lavras, MG, Brazil, associated to the vector of the coffee ring spot virus, *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae). Its life history was studied taking into account biological aspects, life table, predatory activity and functional and numerical responses in relation to the density of the prey. The adult female has longevity of 38 days when supplied with *B. phoenicis*. The intrinsic rate of population increase (r_m) was 0.150 and the mean generation time (T) 25.3 days. The population doubles every 4.6 days. Thirty mites *B. phoenicis* /3-cm diameter coffee leaf arenas were separately offered to one specimen of each predator phase. Adult females were more efficient in killing all developmental phases of *B. phoenicis*, followed by the nymph stages. For the functional and numerical responses studies, from 0.14 to 42.3 immature specimens of the prey /cm^2 of arena were submitted to the predator, the preferred phase for predation. Predation and the oviposition of *A. herbicolus* increased with increasing prey density, with a positive and highly significant correlation. Regression analysis suggests a functional type II response, with a maximum daily predation near 35 *B. phoenicis* /cm^2 /one adult female.

KEY WORDS: Biology, phytoseiid, functional response, numerical response, *Coffea arabica*

Phytoseiid mites are the most important and one of the most studied natural enemies of pest mites (McMurtry *et al*. 1970, Moraes 1991, McMurtry & Croft 1997) factor to be considered in integrated pest management. The predatory mite *Amblyseius herbicolus* (Chant) (Acari: Phytoseiidae) is one of the more frequent and abundant phytoseiid in Brazilian coffee crops (*Coffea arabica* L.) associated to the pest mites *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae) and *Oligonychus ilicis* (McGregor) (Acari: Tetranychidae) (Pallini *et al.* 1992, Reis 2002).

Moraes *et al*. (1991) reported 55 species (*A. herbicolus* among them) of phytoseiids in Latin America, and Lin *et* *al*. (2000) cited its presence in China. This species was also found in Brazil associated to Arecaceae (Santana & Flechtmann 1998, Gondim & Moraes 2001), Euphorbiaceae (Zacarias & Moraes 2001), and native plants of the State of Rio Grande do Sul (Ferla & Moraes 2002).

The predaceous *A. herbicolus* was cited previously as *Typhlodromus* (*Amblyseius*) *herbicolus* Chant, *Amblyseius deleoni* Muma & Denmark and *Amblyseius impactus* Chaudhri, according to Gondim & Moraes (2001), Zacarias & Moraes (2001) and Moraes *et al*. (2004).

A question raised is if phytoseiids can reduce high population densities of phytophagous mites, and the studies that answer such question are those of functional (number of prey consumed per time unit) and numerical (progeny produced by time unit or other change in predator density) responses (Solomon 1949, Mori & Chant 1966, Laing & Osborn 1974). The last two authors found that the two responses are correlated and should be considered together.

Holling (1959, 1961) reported that three basic types of functional response to prey density could be identified in general: linear, convex and sigmoid. In type I (linear) the number of prey consumed increases linearly up to a maximum; in type II (convex) the number of consumed prey increases with the number of prey offered but begins to decrease when a maximum point is reached, that is, begins to show a reduction in consumed prey rate with the increase of its density, and in type III (sigmoid) predation result in a sigmoid form with the increase of prey density up to a maximum. The first type of response is supposedly typical in aquatic invertebrates, the second in predator and parasitoids arthropods and the third of vertebrate predators (Hassel 1978).

According to Holling (1959) the basic factors that affect functional response are: the time of exposure to predator and prey, search rate, identification, capture, and prey consumption. Other factors like predator stimulation due to prey interference or the kind of learning response (Sandness & McMurtry 1970), the confusion effect and hunger are subsidiary but important because they can trigger part or all basic factors.

As for the life table determination it's known that they help both, as in the dynamics population species comprehension and in the natural enemies impact evaluation causes over population (Lenteren & Woets 1988, Bellows Jr *et al*. 1992). Yet, life table, functional and numerical responses are basic requirements for the evaluation of the predatory potential of a predator for its use as biological control agent (Thongtab *et al*. 2001).

Among phytophagous mites, *B. phoenicis* is considered of great importance in Brazil as citrus leprosis (Chiavegato *et al*. 1982) and coffee ring spot virus vector (Chagas 1973). The control threshold for this species is very low because it is a disease vector, resulting in frequent sprays of coffee crops with phytossanitary products which bring, as a consequence in most cases, failure due to resistance acquired easily by the mites to the product used, in addition to the biological disruption caused to the environment.

This work was carried out to evaluate the predatory potential of *A. herbicolus* as biological control agent of *B. phoenicis* through studies of its biology, fertility life table, predatory capacity and study of functional and numerical responses.

Material and Methods

All bioassays and rearing of mites were carried out under 25 ± 2ºC, 70 ± 10% RH and 14h photophase in the Laboratório de Acarologia of the Centro de Pesquisa em Manejo Ecológico de Pragas e Doenças de Plantas - EcoCentro, of the Empresa de Pesquisa Agropecuária de Minas Gerais - EPAMIG, located at the Universidade Federal de Lavras - UFLA *campus*.

Stock rearing. All mites, predator and prey, used in the functional and numerical responses bioassays were collected in the field in a crop of the Catuaí cultivar of coffee (*C. arabica*), which had received no phytossanitary treatments for the past three years, and kept in the laboratory as maintenance rearing.

Stock rearing of *A. herbicolus* to be used in the experiments was made in arenas which consisted of 6-cm coffee leaf disks floating in distilled water in 15-cm diameter petri dishes. In the middle of each arena there was a small hole to allow the passage of a pin that was glued with the head on the bottom of the dish, with adhesive of silicon, and with the point up. This allowed the arenas to move inside of the petri dish fluctuating up and down according to the water level, preventing them of touching the border of the dishes. Each arena contained a 20 x 20-mm microscope slide cover glass over cotton fibers, which served as shelter, oviposition site and local for placing pollen of castor bean plant (*Ricinus communis* L.) (Reis & Alves 1997). Pollen and immature stages of *B. phoenicis* were supplied to the mites.

The stock rearing of *B. phoenicis* in the laboratory was made on paraffin-coated citrus fruits (*Citrus sinensis* Osbeck) except in approximately 3-cm diameter areas. These areas were cleaned up by using a small brush and immediately surrounded by a BioStick® barrier to prevent mites from escaping (Chiavegato 1986).

Biological aspects. Data referring to the biology of *A. herbicolus* were obtained in 3-cm diameter arenas, made with coffee leaf from the third apical pair and branches from the median third plant part, fluctuating in distilled water in 15-cm petri dishes, according to methodology reported by Reis *et al*. (1998) for biological studies of *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae). Observations were daily made at 8 am and 4 pm. Egg, larva, protonymph and deutonymph stage duration were evaluated, as well as adult female longevity. Nourishment was the same used in stock rearing, except pollen, in other words, *B. phoenicis* immature stages only.

Fertility life table. Fertility life table for the predatory mite was built using survival data (l_x), specific fertility (m_x) and sex ratio (Birch 1948, Dinh *et al*. 1988), after female deutonymphs. Each deutonymph was placed on a 3-cm in diameter arena of coffee leaf (Reis *et al*. 1998) and observed at 24h intervals, removing the eggs laid and registering the dead mites. Twenty-two females originated from the stock rearing were observed. Thirty immatures of *B. phoenicis* by day, both larvae and nymphs, were supplied to the predaceous mite.

The following parameters were calculated: $R_o = \sum m_x.l_x$ (net reproductive rate or the number of times to the population increases in each generation); $T = \sum m_x.l_x.x / \sum m_x.l_x$ (mean generation time); r_m (approximate) = ln R_o /T (estimate of the intrinsic rate of population increase) and $\lambda = e^{rm}$ (finite rate of increase, which represents the number o individuals added to the population /time unit /female which will originate a female).

The true value of r_m was calculated interactively through Lotka equation (Carey 1993):

$$\sum_{x=0}^{T} l_x m_x e^{-r_m(x+1)} = 1$$

After obtaintion of the true value of r_m, the mean duration of one generation was recalculated, T = ln R_o /r_m.

The number of days needed for the population to duplicate was also calculated, and according to Tanigoshi *et al*. (1975) is equal to ln 2 /r_m.

Predatory activity. The experiments were conducted in 3-cm diameter arenas of coffee leaf, fluctuating in distilled water in 15-cm diameter petri dishes (Reis *et al*. 2000). Four experiments were performed, one for each phase of development of *B. phoenicis* - egg, larva, nymph (protonymph plus deutonymph) and adult - with a completely randomized design and five treatments: control, larva, nymph and *A. herbicolus* adult female. Thirty *B. phoenicis* were placed /arena, for one predaceous mite specimen according to the phase to be tested, with 10 replicates. After 24h following the introduction of the mites in the arenas, predated, partially predated, naturally dead, dead in water and live *B. phoenicis* were counted. Both, predator and prey species were obtained from the stock rearing which allows to obtain mites of the same age.

Functional and numerical responses. An adult female of *A. herbicolus* was confined during eight days in a 3-cm diameter coffee leaf arena (7.1 cm^2) fluctuating in distilled water in a 15-cm diameter and 2-cm deep petri dish. Eight arenas were placed in each dish at equal distances from each other and kept in place by a small hole in the middle to accommodate an upside down pin with the head glued in the bottom, described previously. Immatures of *B. phoenicis* were placed in the following densities 0.14, 0.28, 0.70, 1.4, 2.8, 4.2, 4.9 (with seven replicates); 6.3 (with four replicates); 7.7 (with three replicates); 9.8, 14.1, 17.6, 28.2 and 42.3 / cm^2 (with two replicates). Larvae and nymphs were used due to the preference for immature stages of the prey for predation by phytoseiids (Gravena *et al*. 1994, Reis *et al*. 2000). The same number of *B. phoenicis* was used as control treatment in the arenas, but in absence of the predator for natural mortality observation.

The number of dead prey and eggs laid by the predatory mite were evaluated every 24h with removal of dead prey not consumed and eggs. The number of prey was brought to the original one every day during eight days.

Results and Discussion

Biological aspects. The average duration of egg stage was 1.5 ± 0.31 days, with 100% viability. Other developmental stage average durations were 1.2 ± 0.31 days for the larvae, 1.0 ± 0.26 day for the protonymph and 1.3 ± 0.32 days for the deutonymph. Development from egg to adult was lasted 6.9 ± 0.64 days and female longevity 37.9 ± 5.47 days (Table 1). The sex ratio was equal to 1 (100% of females) and no males was found in *A. herbicolus* colonies. The absence of *A. herbicolus* males was related in other papers, confirming therefore the reproduction of this species by telitoky (Moraes & Mesa 1988).

Fertility life table. The intrinsic rate of population increase of the predator (r_m) was 0.150 female /female /day; the mean generation time (T) 25.3 days; the net reproductive rate (R_o) 44.8 females /female and the finite rate of increase (λ) 1.16. The population is estimated to double every 4.6 days. These results demonstrate that this species is well adapted to *B. phoenicis*, presenting higher predation than *I. zuluagai* (Reis *et al*. 1998). Under laboratory conditions, considered ideal and where there is appropriate nourishment, the predator can show high reproduction capacity. On the other hand, under field conditions, one can state that several ecological factors can interfere with its reproductive capacity. It is known that, as higher is the finite increase rate higher will be the daily growth of the population, and the one showed by *A. herbicolus* (λ = 1.16) is slighter higher than for *I. zuluagai* (λ = 1.13) (Reis *et al*. 1998), species also frequently founded on coffee crops (Pallini *et al.* 1992, Reis 2002).

Predatory activity. Only nymphs and adults of *A. herbicolus* predate adults of *B. phoenicis*, but they consumed less than 30% of the 30 mites offered. Adult female was the most efficient in predating all phases of development of the prey,

Table 1. Duration in days (mean ± standard error) of all developmental phases of *A. herbicolus* fed on *B. phoenicis*, under 25 ± 2ºC, 70 ± 10% RH and 14h photofase.

Phases of life cycle	n	Mean ± SE (days)
Egg stage	68	1.50 ± 0.31
Larva	67	1.16 ± 0.31
Protonymph	67	1.00 ± 0.26
Deutonymph	64	1.26 ± 0.32
Egg - adult	64	6.88 ± 0.64
Longevity (female)	64	37.9 ± 5.47

n = Number of studied mites.

although nymphs showed also high predation (Fig. 1), similar to the results obtained with other species of phytoseiids (Gravena *et al*. 1994, Reis *et al*. 2000).

Functional and numerical responses. Results show that predation and oviposition of *A. herbicolus* increases according to the increase in prey population density, with a positive and highly significant correlation (with the determination coefficient equals to 0.98** and 0.97**, respectively), with almost 100% consumption in the population density of 7.7 *B. phoenicis* /cm^2, and egg laying of 1.7 eggs /day from 14.1 to 42.3 prey /cm^2 (Table 2; Figs. 2 and 3). Although the number of *B. phoenicis* killed increase with the increase of density of the mites offered, the percent of attack reduces (Fig. 4), similar to the results showed by Reis *et al*. (2003) with other two species of phytoseiids. Such fact may result from their satiety or interference on their predation capacity related to prey density (Mori & Chant 1966, Sandness & McMutry 1970), suggesting that *A. herbicolus* will be more efficient under low and medium prey densities. Predator-prey models in general support the idea that control by predation is very efficient, particularly under low prey density, and the mites of the group Gamasina, important group of predatory mites, are included in this class (Koehler 1999).

The regression analysis suggests a functional type II response, with a maximum daily predation near to 35 *B. phoenicis* /cm^2 /one female (Fig. 2) which, according to Hassel (1978), is typical in predatory arthropods.

Sandness & McMurtry (1970) observed that *Amblyseius largoensis* (Muma) (Acari: Phytoseiidae), species taxonomically close to *A. herbicolus* was more efficient in killing *Oligonychus punicae* (Hirst) (Acari: Tetranychidae) when compared to *Euseius concordis* (Chant) and *Galendromus floridanus* (Muma) (Acari: Phytoseiidae).

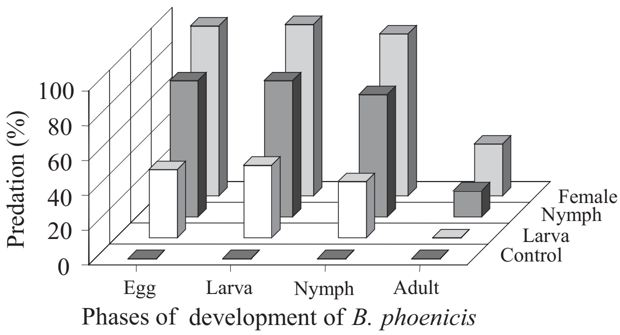

Fig. 1. Percent predation of *B. phoenicis*, on its different development stages, by larva, nymph and adult female of the predatory mite *A. herbicolus*.

A. herbicolus was shown to be an efficient predatory mite at several densities of the coffee ring spot mite, *B. phoenicis*. Its importance as an efficient natural enemy was evidenced and, therefore, among other predatory mites, it must be preserved through integrated and agroecological management programs.

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Table 2. Functional and numerical responses of the predatory mite *A. herbicolus* fed on the phytophagous mite *B. phoenicis,* under 25 ± 2ºC, 70 ± 10% de RH and 14h photophase.

Prey density (mites /cm^2)	Mean ± SE		Range		Predation (%)	Natural mortality (%)
	Consumption (preys /day)	Eggs laid /day	Preys	Eggs		
0.14	0.86 ± 0.06	0.14 ± 0.01	0-1	0-1	86.00	0.00
0.28	1.93 ± 0.10	0.27 ± 0.03	1-2	0-1	96.50	0.00
0.7	4.92 ± 0.08	0.25 ± 0.06	4-5	0-2	98.40	0.00
1.4	9.87 ± 0.50	0.23 ± 0.06	7-10	0-2	98.70	0.00
2.8	19.37 ± 0.03	0.60 ± 0.09	14-20	0-2	96.85	0.00
4.2	28.14 ± 1.20	0.75 ± 0.09	17-30	0-2	93.80	4.17
4.9	33.07 ± 1.20	1.09 ± 0.10	15-35	0-3	94.48	1.07
6.3	43.78 ± 1.15	1.22 ± 0.09	38-45	0-2	97.29	0.28
7.7	54.50 ± 2.69	1.08 ± 0.12	53-55	0-2	99.09	1.59
9.8	61.68 ± 2.50	1.43 ± 0.15	50-70	1-2	88.11	0.71
14.1	87.37 ± 2.35	1.68 ± 0.18	70-96	1-2	87.37	2.00
17.6	82.99 ± 2.65	1.56 ± 0.17	68-96	1-3	66.39	1.80
28.2	101.50 ± 3.05	1.62 ± 0.17	88-120	1-3	50.75	0.19
42.3	127.81 ± 6.01	1.68 ± 0.18	82-184	1-3	42.60	3.46

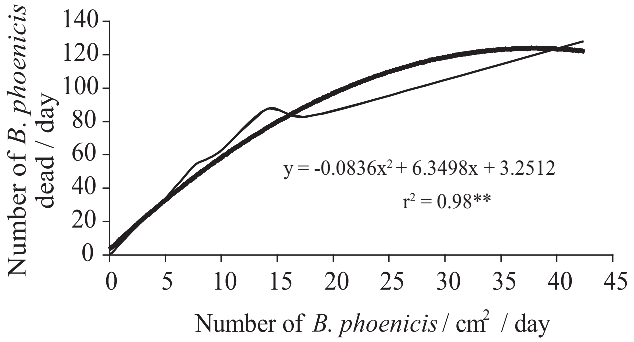

Fig. 2. Number of *B. phoenicis* preyed upon by one female of *A. herbicolus* according to the density offered.

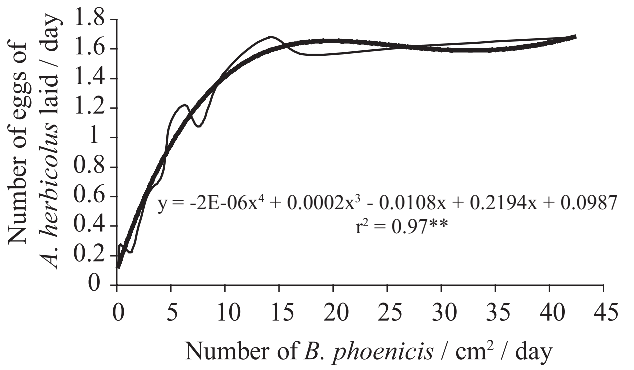

Fig. 3. Number of eggs laid by one female of *A. herbicolus* according to the density of *B. phoenicis* offered.

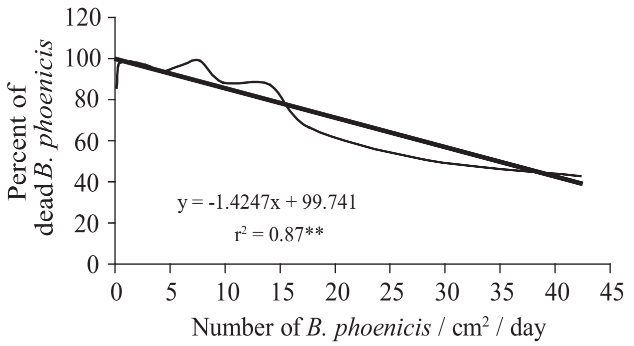

Fig. 4. Percent of *B. phoenicis* preyed upon by one female of *A. herbicolus* according to the density offered.

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