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Evaluation of astigmatid mites as factitious food for rearing four predaceous phytoseiid mites (Acari: Astigmatina; Phytoseiidae)

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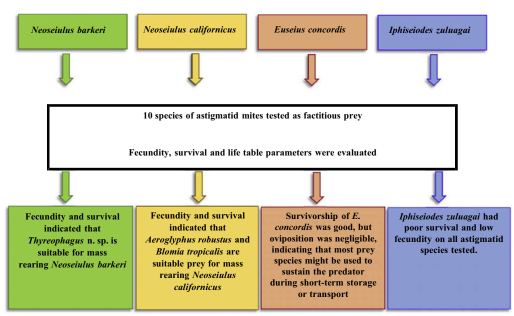
HIGHLIGHTS

- Suitable prey were identified for *Neoseiulus barkeri* and *Neoseiulus californicus*.
- *Euseius concordis* survived on astigmatids, but did not oviposit.
- No Astigmatina species tested was suitable prey for *Iphiseiodes zuluagai*.

GRAPHICAL ABSTRACT



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ABSTRACT

Phytoseiids are possibly the most important mites used in biological control and are usually produced using a tritrophic system that, although efficient, is expensive and laborious. Mites of the cohort Astigmatina (Sarcoptiformes) have been used as factitious prey in the mass rearing of phytoseiids and may allow a much simpler production system. This research evaluated the potential of ten Astigmatina species to serve as factitious food sources for *Euseius concordis* (Chant), *Iphiseiodes zuluagai* Denmark and Muma, *Neoseiulus barkeri* Hughes and *Neoseiulus californicus* McGregor, all phytoseiid species commonly found in different countries. The high fecundity and survival rates obtained suggest that *Thyreophagus* n. sp. is a suitable prey for rearing *N. barkeri* and that *Austroglycyphagus lukoschusi* (Fain) and *Blomia tropicalis* is suitable for rearing *N. californicus*. Oviposition by *E. concordis* was negligible, but survivorship was high on most prey species, suggesting that these species may be useful for maintenance of the predator. *I. zuluagai* had low fecundity and survival on all the astigmatid species evaluated and none were suitable for its rearing.

1. Introduction

Phytoseiid mites are extensively used for the biological control of pest mites and insects (McMurtry et al., 2013) and the price of commercially available species is highly influenced by their production cost. Traditional phytoseiid production systems are tritrophic: the prey, usually a *Tetranychus* species (Tetranychidae), is typically reared on a leguminous host plant. Although functional, this system is laborious and requires costly infrastructure (Gerson et al., 2003; Hoy, 2009). Therefore, the development of more economic production systems is highly desirable.

Mites of the cohort Astigmatina (Oribatida: Sarcoptiformes) have been found to be suitable factitious food for several phytoseiid species (Gerson et al., 2003; Ramakers and van Lieburg,

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1982; Schliesske, 1981). Some astigmatids can be easily produced in large numbers on flour, bran or similar substrates while maintained in relatively small containers (Griffiths, 1964; Sinha, 1964; Hughes, 1976; Ramakers and van Lieburg, 1982). This usually renders the rearing process less expensive than those using phytophagous mites as food, due to reduced requirements for space, labor and maintenance costs (Gerson et al., 2003).

The objective of this study was to evaluate Brazilian astigmatids as factitious food sources for four phytoseiid species common on crops in this country. Two of these, *Neoseiulus barkeri* Hughes and *Neoseiulus californicus* (McGregor), have been extensively used in biological control applications (Gerson et al., 2003; McMurtry et al., 2013). The other species have not been used commercially, but one of them, *Euseius concordis* (Chant), has been considered a promising predator of *Aculops lycopersici* (Masse) (Eriophyidae) on tomato (Moraes and Lima, 1983), whereas the other, *Iphiseiodes zuluagai* Denmark and Muma has been considered as potentially useful for the control of *Brevipalpus phoenicis* (Geijskes) (Tenuipalpidae) on citrus (Sato et al., 1994; Raga et al., 1996; Reis et al., 1998, 2000).

2. Material and methods

Studies were conducted between May and September 2011. Experimental units were maintained in incubators at 25 ± 1 °C, 90 ± 10% R.H., in the dark. Each experimental unit consisted of a plastic dish (2.7 cm in diameter x 1.2 cm high) about half full with a solidified paste (a mixture of nine parts gypsum to one part activated charcoal; Abbatiello, 1965), with humidity maintained by daily additions of distilled water. Each unit was sealed with a piece of transparent plastic film (Magipack®) to prevent mites from escaping.

The reproductive success is directly related to food quality and significant differences in reproductive parameters can be attributed to the provision of nutritional requirements (Ranabhat et al., 2014), although the preferred host for feeding or reproduction is not necessarily the best for development and survivorship (Shah and Liu, 2013). In the first part of this study, prey were screened to determine the two allowing the highest oviposition rates. In the second, these were compared in terms of the corresponding life table parameters of each predator.

2.1. Stock colonies

Phytoseiid mites were established two months before the beginning of the tests and kept in colonies using an adaptation of the rearing unit described by McMurtry and Scriven (1965). *N. barkeri* and *N. californicus* were obtained commercially (Promip, Engenheiro Coelho, São Paulo state, Brazil); *I zuluagai* and *E. concordis* were collected respectively from citrus and cassava crops in Piracicaba, São Paulo state. Colonies of *N. barkeri* were fed with a mixture of different stages of *Tyrophagus putrescentiae* (Schrank) (Astigmatina: Acaridae) on pieces of commercial dog food (Delidog®); *N. californicus* were fed with a mixture of different stages of *Tetranychus urticae* Koch (Acari: Tetranychidae) reared on *Canavalia ensiformis* (L.) (Fabaceae) as well as on *Typha angustifolia* L. (Typhaceae) pollen; *I. zuluagai* and *E. concordis* were fed *T. angustifolia* pollen and a 10% honey solution.

Species evaluated as prey were: Acaridae: *Aleuroglyphus ovatus* (Tropeau), *Cosmoglyphus oudemansi* (Zachvatkin), *Sancassania berlesei* (Michael), *Thyreophagus* n. sp. and *T. putrescentiae*; Echimyopodidae: *Blomia tropicalis* Bronswijk, de Cock and Oshima; Chortoglyphidae: *Chortoglyphus arcuatus* (Tropeau); Pyroglyphidae: *Dermatophagoides pteronyssinus* (Trouessart); Aeroglyphidae: *Austroglycyphagus lukoschusi* (Fain); Glycyphagidae: *Glycyphagus domesticus* (De Geer); Suidasiidae: *Suidasia nesbitti* Hughes and *Suidasia pontifica* Oudemans. All species were maintained in plastic containers adapted from Freire and Moraes (2007) and fed a mixture of 50% of yeast and 50% of wheat germ.

2.2. Oviposition tests

Using a stereomicroscope (Leica MZ12.5), 100 nymphs of each predator species were transferred from their respective stock colony to a similar rearing unit in which they were held until reaching the adult stage. Recently-molted males and females were held as pairs (n = 30) in experimental units and fed *ad libitum* with a mixture of all stages of the evaluated prey. Eventual dead males were replaced with new males from the respectively stock colony.

Each experimental unit was examined daily for 11 consecutive days to count the number of eggs laid and refresh the food. Eggs laid on the first day were excluded from analysis because they were presumed to reflect effects of pre-trial feeding. For diet evaluation of *N. californicus*, *C. oudemansi* and *G. domesticus* were replaced by *A. lukoschusi* and *B. tropicalis*, given that the former species were evaluated for this predator by Castagnoli et al. (2006).

Oviposition rates were classified as very low (<0.1 eggs/day), low (0.1–0.7), regular (0.9–1.8) and high (2.0–3.4) based on what was reported in numerous papers about phytoseiid oviposition rates (e.g. Sabelis, 1985).

2.3. Life tables

The study was initiated with eggs of similar ages, obtained by transferring 50 gravid females from the respective stock colony to each experimental unit; twelve hours later, the unit was examined removing the female and the excess eggs, leaving a single egg in each experimental unit. Post-embryonic stages of the predators were fed *ad libitum* with a mixture of all prey stages and units were observed three times a day to determine the duration of each immature stage. After predators reached adulthood, units were examined once a day to assess oviposition and the duration of the adult phase. Eggs laid by females of a species were grouped in a new experimental unit, where the mites were reared to adulthood to determine sex ratio. Other 30 recently-molted females of each species were isolated in experimental units without food as controls. All units were observed daily up to a maximum of 11 days to determine predator longevity and possible oviposition.

2.4. Data analysis

Statistical analysis of oviposition. Life stage duration, fecundity and survival (R Core Team, 2013). Because the data did not satisfy the assumptions of normality (Shapiro Wilk's test) and homoscedasticity (Levene test), nonparametric tests were used to compare treatments. Oviposition test and some life table results (developmental periods, duration of adult phases and oviposition) were compared using Kruskal–Wallis ANOVA and, for oviposition test, if significant ($p < 0.05$), treatments were separated using Mann–Whitney U test. Proportional data (survivorship and sex ratio) were analyzed using the Chi-square tests. Life table were elaborating according to Birch (1948) and parameters [net reproductive rate (R_0), intrinsic rates of population increase (r_m) and finite rate of increase (λ)] were compared according to Maia et al. (2000), SAS 9.2 version, (2008); means were compared using Student's t test.