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[saa] Editor Decision

Dr Rostislav Zemek <rosta@entu.cas.cz> Wed, Oct 24, 2018 at 5:33 AM
To: Diana M Rueda-Ramirez <dianaru@gmail.com>
Cc: Diana M Rueda-Ramirez <dianarue@usp.br>, Diana M Rios-Malaver <driosmal@uniminuto.edu.co>, Amanda Varela-Ramirez <avarela@javeriana.edu.co>, "Gilberto J. de Moraes" <moraesg@usp.br>

Dear Diana M Rueda-Ramirez,

Thank you very much for revised version of your submission to Systematic and Applied Acarology, "BIOLOGY AND PREDATION CAPACITY OF A COLOMBIAN POPULATION OF Gaeolaelaps aculeifer (ACARI: MESOSTIGMATA: LAELAPILIDAE) ON THE EDAPHIC PHASES OF Frankliniella occidentalis (THYSANOPTERA: THRIPIDAE)".

Your manuscript has been improved and can be now accepted for publication after minor revision. Please see the reviewer's comments in MS file. I suggest you either omit section “Morphological and behavioral details of the predator” or modify the text to emphasize new findings and put them into context of whole study. If you have any measurements (morphological parameters) or photos to support these observations it would be appreciated you include them in this section. Also it looks more convenient to move this section in front of Results. References should be avoided in Results so I suggest to move (Lesna & Sabelis 1999; Usher & Davis 1983) into Discussion where morphological and behavioral details should be discussed (e.g. to show there were/were not differences of Colombian strain from other strains).

Thank you for your effort and I am lookig forward to final version of your submission.

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Reviewer B:
The manuscript has been corrected substantially and it could be considered for publication in SAA after minor changes. The comments have been suggested within text body.

SYSTEMATIC AND APPLIED ACAROLOGY:
2017 impact factor is 1.696 (rank 26 of 96 entomology journals in JCR June 2018 edition).

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Colombian population of the mite *Gaeolaelaps aculeifer* as a predator of the thrips *Frankliniella occidentalis* and the possible use of an astigmatid mite as its factitious prey

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Abstract

Gaeolaelaps aculeifer (Canestrini) is a well-known generalist predator currently commercialized to control several edaphic organisms, including Diptera larvae and thrips pre-pupae and pupae. The recent detection of this species in the Bogotá plateau of Colombia raised the interest to investigate details about the biology of this new population and evaluate its potential as a biological control agent for use in that country against *Frankliniella occidentalis* Pergande (Thripidae), the western flower thrips. The objective of this study was to evaluate experimentally the biological characteristics of the Colombian population of *G. aculeifer* and its predation capacity on *F. occidentalis*, as well as the possibility to use a factitious prey for its mass production or as complementary food in predator field releases. The study was conducted with three diets: *F. occidentalis* (T), *Aleuroglyphus ovatus* (A), and *A. ovatus* + *F. occidentalis* (TA), in a randomized design experiment using *G. aculeifer* females. Predation rate was about 2.6 pre-pupae/pupae of *F. occidentalis*/female/day when only thrips was available as prey, reducing to

2.0 when thrips was combined with *A. ovatus*. Oviposition was the same when fed each of those prey and their combination (2.5 - 2.9 eggs/female/day). Some differences between diets were observed for duration of some periods of the life cycle, but no differences were observed for life table parameters. The greatest differences observed between this population and what has been reported for other populations of the same predator (evaluated when feeding other prey) refer to duration of deutonymphal period and R_o (respectively longer and higher in the former). It is concluded that the Colombian population is able to feed, develop, and reproduce on pre-pupae and pupae of *F. occidentalis* and that *A. ovatus* can be used for its small scale mass production and as a complementary diet in predator field releases.

Keywords: Laelapidae, Colombia, biological control, life cycle, predation, mite diet.

Introduction

Gaeolaelaps aculeifer (Canestrini, 1883) is a soil-dwelling predatory mite used commercially for the control of dipterans, thrips and mites since 1996 (van Lenteren 2011). This species has been reported from a wide variety of soils (Evans & Till 1966) in different countries, especially in temperate areas (Bahrami *et al.* 2011; Barczyk & Madej 2014; Fenda & Schniererová 2005; Kevan & Sharma 1964; Kordeshami *et al.* 2015; Majidi & Akrami 2013; Manu 2010; Manu & Honciuc 2010; Moraza & Peña 2005; Navarro-Campos *et al.* 2012; Salmane 2001; Skorupski & Luxton 1998; Wissuwa *et al.* 2012), but also in subtropical areas of South America (Da Silva *et al.* 2013; Silva *et al.* 2018). It has been recently found in soils of rose fields and surrounding natural vegetation in the Bogota plateau (Rueda-Ramirez *et al.* in preparation), whose climate is classified as Cfb (Köppen-Geiger classification; Peel *et al.* 2007), typical of temperate areas where the species was previously found.

In Colombia, thrips are among the most important rose pests, especially the western flower thrips, *Frankliniella occidentalis* Pergande (Thripidae), not only for negatively affecting rose yield and quality (Valencia 2013), but also for causing rejection of shipments when found in quarantine at importing countries (Attavian 2014). Chemical control is not sufficiently effective and other control measures are considered necessary. In several countries, thrips have been controlled biologically, with the use of the plant inhabiting phytoseiid mites *Amblyseius swirskii* Athias-Henriot and *Amblydromalus limonicus* (Garman and McGregor) (Buitenhuis *et al.* 2015; van Lenteren 2011) and the predatory insect *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) (Avellaneda *et al.* 2016; van Lenteren 2011). However, thrips pre-pupae and pupae are mostly found on the soil. Buitenhuis and Shipp (2008) showed that up to 93% of the pupation of *F. occidentalis* takes place on the soil. Soil inhabiting predatory mites, such as *G. aculeifer* and the macrochelid *Macrocheles robustulus* (Berlese) (van Lenteren 2011; Messelink & Holstein-saj 2008), have also been used for thrips control (Berndt *et al.* 2004a). *Gaeolaelaps aculeifer* has been reported to prey on mites of the cohort Astigmatina (Krantz 2009; Lesna *et al*. 1995, 1996, 2000), commonly found in stored food and shown as suitable for mass production of this predator (Glockemann 1992; Lobbes & Schotten 1980; Navarro-Campos *et al.* 2016) and other biological control agents (Barbosa & de Moraes 2015; Barbosa & Moraes 2016; Gerson *et al.* 2003). Astigmatina species have also been used as complementary food in field releases (Grosman *et al.* 2011; Muñoz-Cárdenas *et al.* 2017a,b). To date, none of the above strategies with predatory mites have been explored in Colombia for thrips control.

Since the Convention on Biological Diversity in 1992 (CBD; see www.cbd.int), importation of exotic organisms has been restricted in many countries (van Lenteren *et al.* 2011), including Colombia (Gutiérrez-Bonilla 2006; López-Ruiz *et al.* 2012; Ministerio de Ambiente y Desarrollo Sostenible 2012; Ministerio del Medio Ambiente 1993). The restriction has also been applied to the importation of biological control agents. Hence, evaluations of native potential biological control agents are warranted, especially of those that have been successfully used in other countries, as *G. aculeifer* for thrips control. The evaluation suggests the new population to be effective, it could not only be used in its country of origin, but also in other countries in which regulations for importantion is less restrictive. The first step in such evaluations should be the conduction of basic biological studies of the local population, comparing it with other populations.

The objective of this research was to evaluate the biological characteristics of a Colombian population of *G. aculeifer* on *F. occidentalis*, its predation capacity on the same prey and the possibility to use a factitious prey for small scale mass production or as complementary food in field releases. The hypotheses raised in this study were: 1) the biological characteristics and predation potential on *F. occidentalis* of the Colombian population of *G. aculeifer* is comparable to those of populations of other countries; and 2) the provision of a complementary prey (astigmatine mite) for this predator does not affect significantly its performance as a predator of *F. occidentalis*.

Material and Methods

The work was conducted at "Laboratorio de Entomologia, Universidad Nacional de Colombia", Bogota, between May and November 2017, in a growth chamber at 21 ± 1 °C, 65 ± 10% RH, in darkness. The temperature and humidity levels were selected considering the observed conditions in representative areas of rose production in the Bogotá plateau (personal observation). Voucher specimens used in the study were deposited in the mite reference collections of "Museo Javeriano de Historia Natural, Pontificia Universidad Javeriana" (MJHN-PUJ), Bogota, Cundinamarca, Colombia, and "Departamento de Entomologia e Acarologia, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo", Piracicaba, São Paulo state, Brazil.

<u>Colony of *Gaeolaelaps aculeifer*</u>

Mites used in this study were taken from a colony established with about 30 specimens originally collected between June and December 2016 from soil of rose cultivations in greenhouses at Cogua (05°03'23.3"N 073°55'44.4"W), Fatacativá (04°46'39.4–40.7"N 074°19'23.9–24.8"W), Guasca (04°50'38.3"N 073°53'07.9"W), Nemocón (05°07'03.1-03.2"N 073°51'31.7–31.9"W) and Tocancipá (04°59'19.3"N 073°54'15.9"W), in the Bogota plateau. The colony was maintained in rearing units corresponding to an adaptation of what was described by Abbatiello (1965) and Freire and Moraes (2007). It consisted of a plastic container (10 cm diameter and 7 cm high), whose bottom was covered with a layer about 1.5 cm thick of a mixture of nine parts of gypsum and one part of activated charcoal. The mites were fed with a mixture of all stages of an unidentified free-living rhabditid nematode on pieces of bean pods (*Phaseolus vulgaris* L.) serving as their growing substrate (Moreira *et al.* 2015), and a mixture of all developmental stages of the mite *Aleuroglyphus ovatus* (Troupeau) (Sarcoptiformes, Astigmatina, Acaridae) on pieces of the commercial dog food Purina® (Freire & Moraes 2007b). The units were maintained permanently humid by daily additions of distilled water to the base, and closed with a plastic film.

Colony of *Frankliniella occidentalis*

A stock colony of *F. occidentalis* was maintained on bean and cucumber (*Cucumis sativus* L.) plants. Pre-pupae and pupae were obtained in auxiliary chambers each consisting of a plastic container (1 litre) whose top had an opening covered with fine fabric to allow ventilation and whose bottom was covered with a few sheets of paper towel. Bean and cucumber leaves and flowers containing thrips immatures were periodically transferred to a chamber, together with chrysanthemum (*Chrysanthemum* sp.) flowers that served as oviposition and mating sites (Kiers *et al.* 2000). Post-embryonic immatures from the leaves moved down to the paper towel sheets to molt to pre-pupae and pupae, which then were easily collected for the studies described below. The flowers were from time to time transferred back to the bean and cucumber plants to provide new progeny to the stock colony.

Predation and oviposition on different prey

This experiment consisted of three treatments (33–35 replicates each), each corresponding to a different type of diet. Each experimental unit consisted of a small Petri dish (4 cm in diameter and 1.3 cm in height) whose bottom was covered as described for the units to maintain *G. aculeifer* stock colony, and contained a 5–6-day-old gravid predator female. Prey offered to the predator were: treatment T, five pre-pupae/pupae of *F. occidentalis*; treatment A, 7-10 nymphs or adults of *A. ovatus*; and treatment TA, five pre-pupae/pupae of *F. occidentalis* plus 7-10 nymphs or adults of *A. ovatus*. No effort was done to offer pre-pupae separately from pupae because of the short duration of these stages in comparison with the length of time between observations.

Predator females were obtained by rearing mites from the egg stage (each egg in a unit), associating each with a male at least for 24 h and making sure mating occurred. Females were then starved for 24 h and then the prey corresponding to each treatment were transferred to each unit. The numbers of consumed prey and of eggs laid were counted daily, when consumed and surviving prey were replaced by new ones. Evaluation was done for 10 consecutive days. Distilled water was added daily to each unit to maintain humidity. Means were compared using generalized linear mixed models with replicates (females) as random factor and day and diet as fixed factors, with statistical software R (version 3.4.4, 2018).

Life Tables

Each of 60 *G. aculeifer* females taken from the stock colony was isolated in an experimental unit of the type described in the previous test. After 12 h, the female and the eggs it laid were removed, leaving a single egg per unit. The units were divided into three groups of 20 units, each group being randomly assigned to be fed with one of the food types mentioned for the predation and oviposition test. Food was provided only from the protonymphal stage, as larvae were observed not to feed in preliminary tests. Numbers of prey offered daily to each predator were: treatment T, five pre-pupae/pupae of *F. occidentalis*; treatment A, 7-10 nymphs or adults of *A. ovatus*; treatment TA, five pre-pupae/pupae of *F. occidentalis* plus 7-10 nymphs or adults of *A. ovatus*. Determination of the duration of the immature stages was done by searching for exuviae in the units every 12 h. At each search, mites of each stage were examined to determine basic morphological and behavioral characteristics under a stereomicroscope (up to 50 x). The units were examined only once a day after mites reached adulthood, to determine duration of reproductive phases as well as oviposition.

Raw data were analyzed using the age-stage, two-sex life table procedure with the TWOSEX-MSChart program (Chi 1988, 2016; Chi & Liu 1985). Calculated life table parameters were intrinsic rate of increase (r_m), net reproduction rate (R_o), finite rate of increase (λ), mean generation time (T), fecundity and sex ratio.

The estimates and standard errors of population parameters were obtained through the bootstrap technique, with 100,000 bootstraps. The differences between treatments for longevity, oviposition periods, fecundity, and population parameters were assessed using paired bootstrap test with the same program described above. The figures were prepared using software R (version 3.4.4, 2018). Differences between treatment for developmental time were assessed using Wilcoxon / Kruskal-Wallis test, with statistical software R (version 3.4.4, 2018), since ANOVA assumptions were not met.

Results

<u>Predation and oviposition</u>

The mean number of *F. occidentalis* pre-pupae and pupae killed by *G. aculeifer* was significantly higher when those were not combined with *A. ovatus* (χ^2 = 17.5, d.f. = 1, P-value < 0.0001; Table

1). Mean daily oviposition (2.5–2.9 eggs) rates were not statistically different between treatments ($Chi^2 = 20.6$, d.f. = 2, P-value > 0.05).

Table 1. Daily predation and oviposition of *Gaeolaelaps aculeifer* on different prey at 21 ± 1°C, 60 ± 15% RH and in darkness.

Diet	Predation (prepupae-pupae killed/female/day)	Oviposition (eggs/female/day)
F. occidentalis pre-pupae and pupae	2.6 ± 0.1a	2.9 ± 0.1a
Aleuroglyphus ovatus	-[1]	2.5 ± 0.1a
A. ovatus + *F. occidentalis* pre-pupae and pupae	2.0 ± 0.1b	2.9 ± 0.1a

[1] not evaluated; in each column, treatments whose means are followed by a same letter are not significantly different (Generalized Linear Mixed Models, p<0.05).

Morphological and behavioral details of the predator

Some behavior details were newly recorded and morphological characteristics were confirmed, as follows: eggs were whitish, ovoid and smooth, and usually laid in protected places in the rearing unit (depressions or next to loose particles of the mixture of gypsum and activated charcoal, Figure 1a). These were often partially covered by the female with particles close to the eggs, with the help of their palpi and first pair of legs. Larvae (Figure 1b) and protonymphs (Figure 1c) were also whitish, the latter moving more quickly than the former. Deutonymphs were cream-yellowish, lightly sclerotized and very similar in shape to adults (Figure 1d), allowing sex recognition soon after molting; at this stage, they moved more quickly than protonymphs. Adult females were ovoid, with a well-defined sub-triangular brownish dorsal shield that partially covered the idiosoma and that was surrounded by a whitish unsclerotized cuticle (Figure 1e); they moved very quickly. Adult males were smaller than adult females and had idiosoma posteriorly truncate and totally covered by the brownish dorsal shield (Figure 1f); they moved much more slowly than adult females. The need for insemination to allow oviposition was not evaluated in detail in this study. However, observations of a few females indicated and confirmed that unfertilized females produced male offspring (arrhenotokous parthenogenesis), while fertilized females produced both female and male offspring.

Figure 1. *Gaeolaelaps aculeifer* Canestrini. **a.** Eggs, **b.** larva, **c.** protonymph, **d.** deutonymph, **e.** female, **f.** male

<u>Life table</u>

Protonymphs, deutonymphs and adults were observed to feed on both prey types. Although not quantified in detail, observations of a few adult females indicated that each of them consumed up to four pre-pupae or pupae per day, while adult males consumed each a maximum of two pre-pupae or pupae in the same period. Survivorship of immatures (Table 2) was always very high (≥95% for each stage and for the whole immature phase); only two mites died during the study, one in the larval stage, when fed with *F. occidentalis*, the other in the protonymphal stage, when fed with *F. occidentalis* + *A. ovatus* (Table 2, Figure 2). Duration of the deutonymphal stage was significantly longer when prey was *F. occidentalis* than when it was *A. ovatus* (Chi^2 = 5.85, d.f. = 2, P-value = 0.04). As a consequence, duration of the total immature phase was also significantly longer on *F. occidentalis* (Chi^2 = 7.35, d.f. = 2, P-value = 0.02). No other significant differences were observed for duration of immatures. The larval stage was the shortest (1.8–1.9 days), while the deutonymphal stage, the longest (8.6–9.5 days).

Table 2. Mean duration of the different developmental stages, pre-oviposition, oviposition and post-oviposition periods (days ± SE), survivorship (%, in parentheses) and fecundity (number of eggs per female ± SE) of *Gaeolaelaps aculeifer* fed with *Frankliniella occidentalis*, *Aleuroglyphus ovatus* and a mixture of these prey, at 21 ± 1 ° C, 60 ± 15% RH, in darkness (n= 20/diet).

	Prey		
	F. occidentalis	***A. ovatus***	***F. occidentalis* + *A. ovatus***
Egg[ⱡ]	4.6 ± 0.2 (100) a	4.4 ± 0.2 (100) a	4.6 ± 0.2 (100) a

Larva[ǂ]	1.9 ± 0.1 (95) a	1.8 ± 0.08 (100) a	1.9 ± 0.09 (100) a
Protonymph[ǂ]	3.3 ± 0.3 (100) a	3.7 ± 0.3 (100) a	3.2 ± 0.2 (95) a
Deutonymph[ǂ]	9.5 ± 0.3 (100) a	8.6 ± 0.3 (100) b	9.1 ± 0.2 (100) ab
Egg – Adult[ǂ]	19.2 ± 0.3 (95) a	18.5 ± 0.2 (100) b	18.8 ± 0.2 (95) ab
Pre-oviposition[§]	1.9 ± 0.1 a	1.5 ± 0.1 b	1.7 ± 0.1 ab
Oviposition[§]	36.8 ± 2.7 b	49.0 ± 1.4 a	36.7 ± 1.2 b
Post-oviposition[§]	15.4 ± 3.1 b	14.0 ± 2.1 b	25.8 ± 1.9 a
♀ longevity[§]	61.8 ± 4.5 b	73.8 ± 0.6 a	70.0 ± 1.6 b
♂ longevity[§¤]	88.0 ± 17.2 a	79.2 ± 11.0 a	85.3 ± 16.8 a
Number of ♀*	16	15	16
Number of ♂*	3	5	3

In each row, means followed by a same letter are not significantly different ([ǂ]Wilcoxon/Kruskal-Wallis test or [§]Paired bootstrap test, p> 0.05). *Number of parental eggs. [¤]Longevity calculated with few males (3–5).

Pre-oviposition period was significantly longer when prey was *F. occidentalis* than when it was *A. ovatus* (F = 36.9, d.f. = 2, P-value = 0.03), and the opposite occurred for oviposition period (F = 215.6, d.f. = 2, P-value = 0.0002) and female longevity (F = 74.5, d.f. = 2, P-value = 0.03; Table 2). No significant differences were observed for fecundity on the different prey types. Sex ratio was 84% female when diet included *F. occidentalis* and 75% female when it included only *A. ovatus* (Table 2).

On the three diets, variation in duration of each immature stage between mites was low, as indicated by the slight overlap of the curves showing the proportions of prevailing specimens in pairs of successive stages (cited as survival rates, S_{xj}, by Chi & Liu 1985) (Figure 2). Also, in the three types of diets, the adult emergence began on day 16 from the beginning of the cycle and lasted about 4 days. Female emergence started shortly before emergence of males, which in turn lived longer than females (Table 2, Figure 2).

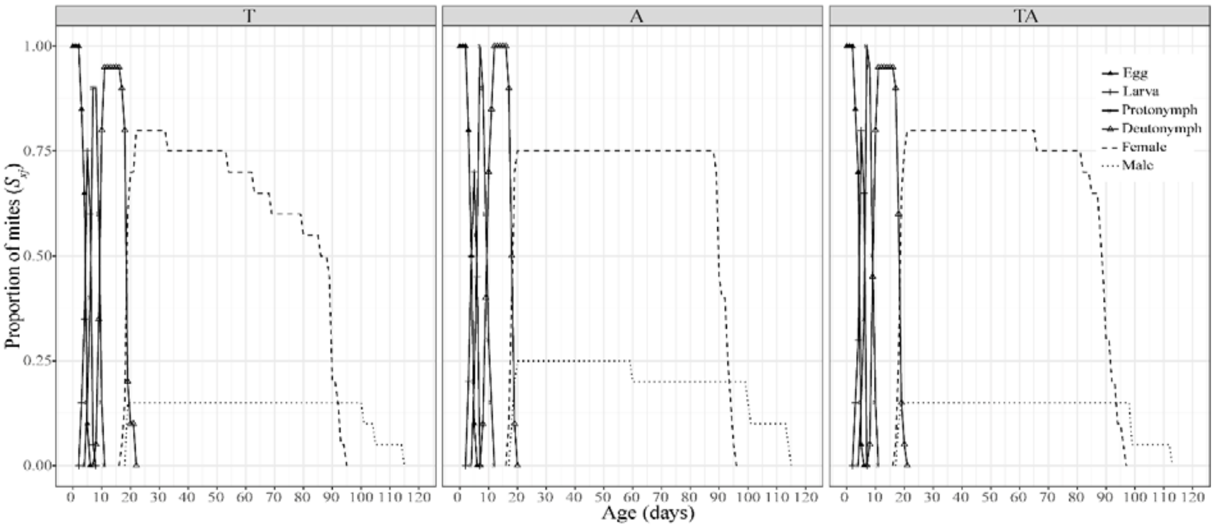

Figure 2. Proportion of *Gaeolaelaps aculeifer* in each developmental stage at each day (cited as survival rate, S_{xj}, by Chi & Liu 1985), in relation to the maximum number of each stage obtained in the study, when fed with *Frankliniella. occidentalis* (T), *Aleuroglyphus ovatus* (A), and a mixture of the two prey (TA), at 21 ± 1 ° C, 60 ± 15% RH in darkness (Day 0: oviposition).

For all diets, daily fecundity reached the highest rates at the beginning of the oviposition period, slowly reducing thereafter, reaching very low levels at the end of the third month (Figure 3). In all treatments, 80% of the fecundity was reached in the first 25 days of the oviposition period. More than 50% of the females were alive on day 72.

Maximum daily fecundity was lowest when the predator was fed only *A. ovatus* than when diet included *F. occidentalis*. However, this was compensated by the longer oviposition period on the former prey, so that total fecundity was statistically the same on all three food types (Figure 3,

Table 3). The lowest oviposition rate coincided with the longer survivorship of predators fed *A. ovatus*.

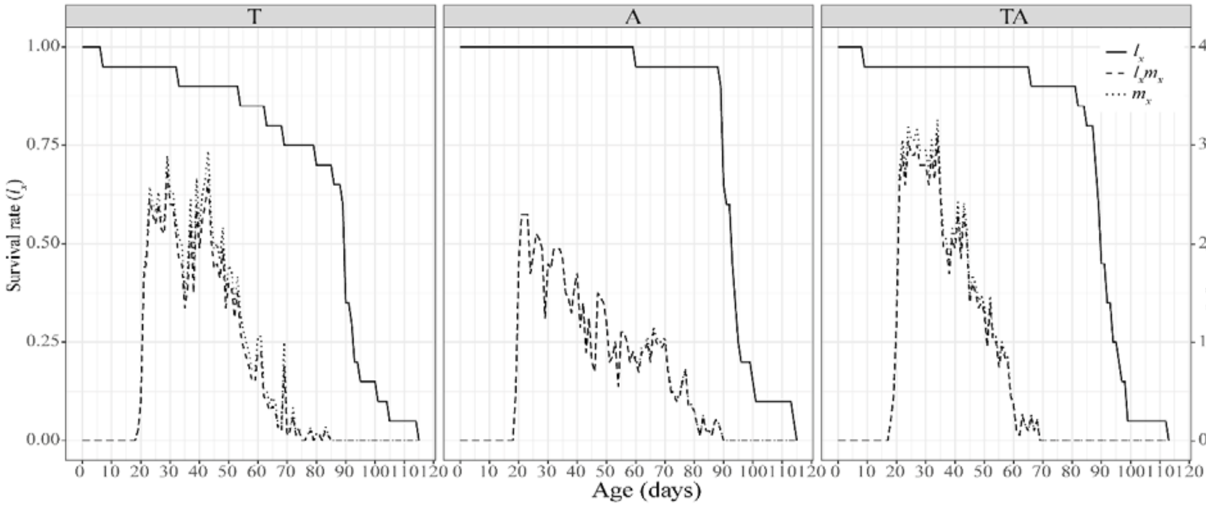

Figure 3. Age-specific survival rate (l_x), fecundity (m_x) and maternity (l_xm_x) of *Gaeolaelaps aculeifer* fed with *Frankliniella occidentalis* (T), *Aleuroglyphus ovatus* (A) and a mixture of these two diets (TA), at 21 ± 1 °C, 60 ± 15% RH, in darkness.

Predator population was shown to be able to increase approximately 75–80 times in each generation (R_o), with no significant differences between food types (Table 3). The intrinsic growth rate (r_m) and the finite increase rate (λ) were not significantly different between treatments, but the generation time (T) was shorter for predators fed with the combination of both prey (Table 3).

Table 3. Life table parameters (± SE) of *Gaeolaelaps aculeifer* fed with *Frankliniella occidentalis*, *Aleuroglyphus ovatus*, and a mixture of these two prey at 21 ± 1 ° C, 60 ± 15% RH, in darkness. For each prey, n= 20.

	Prey		
	F. occidentalis	***A. ovatus***	***A. ovatus* + *F.***

			occidentalis
Fecundity	95.0 ± 6.8 a	99.8 ± 4.1 a	100.3 ± 2.1 a
R_0	74.9 ± 10.1a	74.9 ± 10.1a	80.2 ± 9.1a
r_m	0.13 ± 0.004a	0.13 ± 0.005a	0.14 ± 0.004a
λ	1.13 ± 0.005a	1.14 ± 0.006a	1.15 ± 0.005a
T	33.2 ± 0.4a	32.7 ± 0.6a	30.9 ± 0.5b

R_o: net reproduction rate (offspring/individual); r_m: the intrinsic rate of increase (day^{-1}); λ: finite rate of increase (day^{-1}); T: mean generation time (days). In each row, means followed by the same letter are not significantly different (Paired bootstrap test, $p > 0.05$).

Discussion

Morphological and behavioral details of the live Colombian specimens were not different from other populations of this species previously described (Evans & Till 1966; Lesna et al. 1995, 1996, 2000; Lesna & Sabelis 1999); however, we report important additional details to recognize this live mite during its entire life cycle. Our observations about arrhenotokous parthenogenesis confirm what had already been reported for this species by Usher & Davis (1983) and Lesna & Sabelis (1999).

Despite studies on the life cycle and possible use of *G. aculeifer* for the control of soil pests, including thrips (van Lenteren 2011), this is the first work to determine the life table parameters of this predator on *F. occidentalis*. The results obtained were generally similar to those reported by Amin *et al*. (2014), when the predator was fed the acarid *Rhizoglyphus echinopus* Fumouze and Robin, at 20 and 22.5 ºC. Most important differences referred to the distinctly shorter duration of the deutonymph (about half as long) and the slightly lower (ca. 15%) fecundity in that study. The results are also similar to those of Kasuga *et al*. (2006) for predators fed the acarid *Tyrophagus similis* Volgin, except for the similar durations of protonymphs and deutonymphs in that study (respectively 6.0 and 6.5 days) and different durations in this study (respectively 3.2–3.7 and 8.6–9.5 days), at 20 ºC. A comparison of the results of this study with those of Kevan and Sharma (1964) for predators fed *Tyrophagus putrescentiae* (Schranck) is hampered by the much different temperatures (17 ºC in that case); yet, despite the lower temperature, the incubation period was much shorter in that study (ca. 34%).

Life table parameters of *G. aculeifer* where also calculated by Ajvad *et al*. (2018) on larvae of the dipteran *Lycoriella auripila* Winnertz (Sciaridae), by Chi (1981) on the collembolan *Onychiurus fimatus* Gisin (Onychiuridae), and by Barker (1969) on the mites *T. putrescentiae* and *Glycyphagus domesticus* (deGeer) (Glycyphagidae), at slightly higher temperatures (22–24°C). In all cases, R_o was much lower than found in the present study, which was related to the lower fecundity and shorter oviposition period. Differences in methodology and units of time preclude further comparisons with these studies.

The long duration of the deutonymphal period, resulting in a prolonged immature phase of almost three weeks, seems uncommon. This period seems considerably longer than observed for other mites of the cohort Gamasina (Lindquist *et al.* 2009), possibly because of the lower temperature in the present study (21 ºC) compared to other studies (close to 25 °C), on laelapids (Freire & Moraes 2007a; Moreira *et al.* 2015), Macrochelidae (Azevedo *et al.* 2018), Phytoseiidae (Fouly & Abdel-Baky 2015; Li *et al.* 2006; Marafeli *et al.* 2014; McMurtry *et al.* 1970) and Rhodacaridae (Castilho *et al.* 2009). In terms of prey consumption, this does not seem to be necessarily a problem, as our preliminary observations indicated that deutonymphs can kill almost the same number of pre-pupae and pupas as adults. However, the long immature stage most certainly had a significant bearing on the calculated rates of population increase, which were not particularly high.

The results of the first part of this study (predation and oviposition experiment) showed the ability of *G. aculeifer* to use pre-pupae and pupae of *F. occidentalis* as food, and these not only allowed survivorship of the predator during the experimental period, but also its oviposition. These results also indicated a comparable ability of the predator to survive and reproduce when fed with *A. ovatus*. Mean daily predation rates of *G. aculeifer* in this study were lower than reported for the same predator fed second-instar larvae, pre-pupae and pupae (Berndt *et al.* 2004b) or larvae (Navarro-Campos *et al.* 2016) of *F. occidentalis* (respectively about 3.5 and 4.0 prey/day). However, mean daily oviposition were higher in this study than reported in the studies of Berndt *et al.* (2004) and Navarro-Campos *et al*. (2016) (respectively about 2.5 and 2.2 eggs/day). Observations (not presented) on predation of *F. occidentalis* during the second part of this study (life cycle) confirmed the results of predation rates obtained in the first part, in which deutonymphs and adult females preyed daily upon up to four pre-pupae and pupae.

The reduction of the predation rate on *F. occidentalis* when *A. ovatus* was offered as an additional food item (Abrams & Hiroyuki 1996; van Baalen *et al.* 2001; Holt 1977) should not lead to the conclusion that it is negative in terms of pest control efficacy. Especially as the reduction was relatively small, despite the significant statistical difference. Some degree of reduction can be tolerated if the provision of another food item benefits the predator in other ways (Liu *et al.* 2006; Messelink *et al.* 2008; Muñoz-Cárdenas *et al.* 2017a; b; Settle *et al.* 1996), such as the increase of survival over time or the maintenance of it in the place of interest. The great similarity of the life table parameters observed in this study for both prey species indicates that *A. ovatus* would be suitable as to be evaluated as a factitious prey for mass rearing the predator and to maintain it in the field under the condition of eventual prey shortage, when released together with the predator. Complementary studies are necessary to prove these hypotheses. Navarro-Campos *et al*. (2016) reported the potential of some food sources, especially eggs of *Ephestia kuehniella* (Lepidoptera: Pyralidae) or cysts of *Artemia* sp. (Crustacea), for use as factitious prey for mass-rearing *G. aculeifer*. Similarly, the mite *Cosmolaelaps jaboticabalensis* Moreira, Klompen and Moraes (Laelapidae) showed adequate biological performance when fed with free-living nematodes, leading the authors to suggest the use of those organisms to favor persistence of the predator when released in the field (Moreira *et al*. 2015).

In conclusion, *G. aculeifer* was shown to develop and reproduce when fed pre-pupae and pupae of *F. occidentalis*. The life table parameters of the Colombian population are comparable to those reported for other populations of *G. aculeifer* (perhaps with the exception of the duration of the deutonymph), suggesting its potential for use for biological control of *F. occidentalis* in Colombia. The supplementation of *A. ovatus* in the system resulted in a slight reduction in predation rate of *F. occidentalis* pre-pupae and pupae, suggesting that *A. ovatus* can be used as factitious food for mass rearing or as complementary food in periodic releases, when the pest in not abundant.

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References

Abbatiello, M.J. (1965) A culture chamber for rearing soil mites. *Turtox News* 43, 162–164.

Abrams, P.A. & Hiroyuki, M. (1996) Positive indirect effects between prey species that share predators. *Ecology*, 77, 610–616. doi: https://doi.org/10.2307/2265634

Ajvad, F.T., Madadi, H., Michaud, J.P., Zafari, D. & Khanjani, M. (2018) Life table of *Gaeolaelaps aculeifer* (Acari: Laelapidae) feeding on larvae of *Lycoriella auripila* (Diptera: Sciaridae) with stage-specific estimates of consumption. *Biocontrol Science and Technology*, 28, 157–171. doi: https://doi.org/10.1080/09583157.2018.1434613

Amin, M., Khanjani, M. & Zahiri, B. (2014) Preimaginal development and fecundity of *Gaeolaelaps aculeifer* (Acari : Laelapidae) feeding on *Rhizoglyphus echinopus* (Acari : Acaridae) at constant temperatures. *Journal of Crop Protection*, 3, 581–587.

Attavian, B. (2014) *Cut Flowers and Greenery Import Manual Cut Flowers and Greenery*. First Ed. United States Department of Agriculture - USDA. Available from: https://www.fsvps.ru/fsvps-docs/ru/importExport/usa/files/phyto_usa_flowers_new.pdf (May 5, 2018).

Avellaneda, J., Diaz, M., Acosta, D., Rodriguez, D. & Cantor, F. (2016) Colecta de antocóridos y determinación de su capacidad depredadora sobre adultos de *Frankiniella occidentails* (Pergande) (Thysanoptera, Thripidae). *Revista facultad de ciencias basicas*, 12, 8–21. doi: http://dx.doi.org/10.18359/rfcb.1850

Azevedo, L.H., Ferreira, M.P., Castilho, R. de C., Cançado, P.H.D. & Moraes, G.J. de (2018) Potential of *Macrocheles* species (Acari: Mesostigmata: Macrochelidae) as control agents of harmful flies (Diptera) and biology of *Macrocheles embersoni* Azevedo, Castilho and Berto on *Stomoxys calcitrans* (L .) and *Musca domestica* L. (Diptera: Muscidae). *Biological Control*, 123, 1–8. doi: https://doi.org/10.1016/j.biocontrol.2018.04.013

van Baalen, M., Křivan, V., van Rijn, P.C.J. & Sabelis, M.W. (2001) Alternative food, switching predators, and the persistence of predator-prey systems. *The American Naturalist*, 157, 512–524. doi: https://doi.org/10.1086/319933

Bahrami, F., Arbabi, M., Shoushtari, R.V. & Kazemi, S. (2011) Mesostigmatic mites associated with Coleoptera and biodiversity calculation of these mites phoretic on dung beetles in Golestan province (North of Iran). *Middle-East Journal of Scientific Research*, 9, 345–366.

Barbosa, M.F.C. & de Moraes, G.J. (2015) Evaluation of astigmatid mites as factitious food for rearing four predaceous phytoseiid mites (Acari: Astigmatina; Phytoseiidae). *Biological Control*, 91, 22–26. doi: https://doi.org/10.1016/j.biocontrol.2015.06.010

Barbosa, M.F.C. & Moraes, G.J. de (2016) Potential of astigmatid mites (Acari: Astigmatina) as prey for rearing edaphic predatory mites of the families Laelapidae and Rhodacaridae (Acari: Mesostigmata). *Experimental and Applied Acarology*, 69, 289–296. doi: https://doi.org/10.1007/s10493-016-0043-4

Barczyk, G. & Madej, G. (2014) Comparison of the species composition of Gamasina mite communities (Acari, Mesostigmata) in selected caves of the Kraków-Częstochowa Upland (southern Poland) and their immediate surroundings. *Journal of Natural History*, 49, 1673–1688. doi: https://doi.org/10.1080/00222933.2014.976667

Barker, P.S. (1969) The response of a predator, *Hypoaspis aculeifer* (Canestrini) (Acarina:Laelapidae), to two species of prey. *Canadian Journal of Zoology*, 47, 343–345.

Berndt, O., Meyhöfer, R. & Poehling, H.M. (2004a) The edaphic phase in the ontogenesis of *Frankliniella occidentalis* and comparison of *Hypoaspis miles* and *Hypoaspis aculeifer* as predators of soil-dwelling thrips stages. *Biological Control*, 30, 17–24. doi: https://doi.org/10.1016/j.biocontrol.2003.09.009

Berndt, O., Poehling, H.M. & Meyhöfer, R. (2004b) Predation capacity of two predatory laelapid mites on soil-dwelling thrips stages. *Entomologia Experimentalis et Applicata*, 112, 107–115. doi: https://doi.org/10.1111/j.0013-8703.2004.00185.x

Buitenhuis, R., Murphy, G., Shipp, L. & Scott-Dupree, C. (2015) *Amblyseius swirskii* in greenhouse production systems: a floricultural perspective. *Experimental and Applied Acarology*, 65, 451–464. doi: https://doi.org/10.1007/s10493-014-9869-9

Buitenhuis, R. & Shipp, J.L. (2008) Influence of plant species and plant growth stage on *Frankliniella occidentalis* pupation behaviour in greenhouse ornamentals. *Journal of Applied Entomology*, 132, 86–88. doi: https://doi.org/10.1111/j.1439-0418.2007.01250.x

Castilho, R.C., de Moraes, G.J., Silva, E.S. & Silva, L.O. (2009) Predation potential and biology of *Protogamasellopsis posnaniensis* Wisniewski & Hirschmann (Acari: Rhodacaridae). *Biological Control*, 48, 164–167. doi: https://doi.org/10.1016/j.biocontrol.2008.10.004

Chi, H. (1981) Die Vermehrungsrate von *Hypoaspis aculeifer* Canestrini (Acarina, Laelapidae) bei Ernahrung mit *Onychiurus fimatus* Gisin (Collembola, Onychiuridae) unter verschiedenen Temperaturen. *Mitteilungen der Deutschen Gesellschaft fuer allgemeine und angewandte Entomologie. Kiel*, 3, 122–125.

Chi, H. (1988) Life-Table analysis incorporating both sexes and variable development rates among individuals. *Environmental Entomology*, 17, 26–34. doi: https://doi.org/10.1093/ee/17.1.26

Chi, H. (2016) TWOSEX-MSCHART. A computer program for age stage, two-sex life table analysis.

Chi, H. & Liu, H. (1985) Two new methods for the study of insect population ecology. *Bulletin of the Institute of Zoology, Academia Sinica,* 24, 225–240.

Evans, G.O. & Till, W.M. (1966) Studies on the British Dermanyssidae (Acari: Mesostigmata). Part II Classification. *Bulletin of The British Museum (Natural History) Zoology*, 14, 109–370. doi: https://doi.org/10.1111/j.1469-8137.1944.tb05001.x

Fenda, P. & Schniererová, E. (2005) Mites (Acarina, Gamasida) in littoral zone of Jakubov fishponds (Slovakia). *Contribution to soil zoology in Central Europe I*, 9–14.

Fouly, A.H. & Abdel-Baky, N.F. (2015) Influence of prey types on the biological characteristics of *Cosmolaelaps qassimensis* (Acari: Laelapidae). *Journal of Entomology*, 12, 21–29. doi: https://doi.org/10.3923/je.2015.21.29

Freire, R.A.P. & Moraes, G.J. de (2007a) Description of a new species of *Cosmolaelaps* berlese (Acari: Laelapidae, Hypoaspidinae) from Brazil and its biological cycle. *International Journal of Acarology*, 33, 353–358. doi: https://doi.org/10.1080/01647950708683697

Freire, R.A.P. & Moraes, G.J. de (2007b) Mass production of the predatory mite *Stratiolaelaps scimitus* (Womersley) (Acari : Laelapidae). *Systematic & Applied Acarology*, 12, 117–119.

Gerson, U., Smiley, R.L. & Ochoa, R. (2003) *Mites (Acari) for pest control*. Blackwell Science Ltd, Oxford. 539pp.

Glockemann, B. (1992) Biological control of *Frankliniella occidentalis* on ornamental plants using predatory mites. *EPPO Bulletin*, 22, 397–404. doi: https://doi.org/10.1111/j.1365-2338.1992.tb00517.x

Grosman, A.., Messelink, G.. & Groot, E.B. de (2011) Combined use of a mulch layer and the soil-dwelling predatory mite *Macrocheles robustulus* (Berlese) enhance the biological control of sciarids in potted plants. *IOBC/WPRS Bulletin*, 68, 51–54.

Gutiérrez-Bonilla, F.D.P. (2006) *De especies invasoras: Propuesta de lineamientos para el control de los impactos*. Bogotá, D.C., Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. 158pp.

Holt, R.D. (1977) Predation, apparent competition, and the structure of prey communities. *Theoretical Population Biology*, 12, 197–229. doi: https://doi.org/10.1016/0040-5809(77)90042-9

Kasuga, S., Kanno, H. & Amano, H. (2006) Development, oviposition, and predation of *Hypoaspis aculeifer* (Acari: Laelapidae) feeding on *Tyrophagus similis* (Acari: Acaridae). *Journal of the Acarological Society of Japan*, 15, 139–143. doi: https://doi.org/10.2300/acari.15.139

Kevan, D.K.M. & Sharma, G.D. (1964) Observations on the biology of *Hypoaspis aculeifer* (Canestrini 1884), apparently new to North America (Acarina: Mesostigmata: Laelaptidae). *Acarologia*, 6, 647–658.

Kiers, E., De Kogel, W.J., Balkema-Boomstra, a & Mollema, C. (2000) Flower visitation and oviposition behavior of *Frankliniella occidentalis* (Thysan., Thripidae) on cucumber plants. *Journal of Applied Entomology*, 124, 27–32. doi: 10.1046/j.1439-0418.2000.00433.x

Kordeshami, A.B., Khajehali, J. & Nemati, A. (2015) Some edaphic mesostigmatic mites from Lordegan, Chaharmahal Bakhtiari province with their world distribution. *Journal of Crop Protection*, 4, 589–604.

Krantz, G.W. (2009) Habits and Habitats. In: G. W. Krantz and D. E. Walter (eds), *A Manual of Acarology*. Lubbock, Texas, Texas Tech University Press. pp. 64–82.

van Lenteren, J.C. (2011) The state of commercial augmentative biological control: Plenty of natural enemies, but a frustrating lack of uptake. *BioControl*, 57, 1–20. doi: https://doi.org/10.1007/s10526-011-9395-1

van Lenteren, J.C., Cock, M.J.W., Brodeur, J., Barratt, B.I.P., Bigler, F., Bolckmans, K., Haas, F., Mason, P.G. & Parra, J.R.P. (2011) Will the Convention on Biological Diversity put an end to biological control? *Revista Brasileira de Entomologia*, 55, 1–5. doi: https://doi.org/10.1590/S0085-56262011000100001

Lesna, I. & Sabelis, M.W. (1999) Diet-dependent female choice for males with “good genes” in a soil predatory mite. *Nature*, 401, 581–584. doi: https://doi.org/10.1038/44125

Lesna, I., Sabelis, M.W., Bolland, H.R. & Conijn, C.G.M. (1995) Candidate natural enemies for control of *Rhizoglyphus robini* Claparede (Acar:Astigmata) in lily bulbs: Exploration in the field and preselection in the laboratory. *Experimental and Applied Acarology*, 19, 655-669. doi: https://doi.org/10.1007/BF00145254

Lesna, I., Sabelis, M.W., Bolland, H.R. & Conijn, C.G.M. (1996) Biological control of the bulb mite, *Rhizoglyphus robini*, by the predatory mite, *Hypoaspis aculeifer*, on lilies: predatory-prey interactions at various spatial scales under storage conditions. *Journal of Applied Ecology*, 33, 369-376. doi: https://doi.org/10.2307/2404758

Lesna, I., Conijn, C.G.M., Sabelis, M.W. & van-Straalen, N.M., (2000) Biological control of the bulb mite, *Rhizoglyphus robini*, by the predatory mite, *Hypoaspis aculeifer*, on lilies: predator-prey dynamics in the soil, under greenhouse and field conditions. *Biocontrol Science and Technology*, 10, 179-193. doi: http://dx.doi.org/10.1080/09583150029314

Li, D.-Y., He, Y.-F. & Li, H.-D. (2006) Biology and life table of the predatory mite *Euseius aizawai* (Acari: Phytoseiidae). *Systematic and Applied Acarology*, 11, 159–165. doi: https://doi.org/10.11158/saa.11.2.3

Lindquist, E.E., Krantz, G.W. & Walter, D.E. (2009) Classification. In: G. W. Krantz and D. E. Walter (eds), *A Manual of Acarology*. Lubbock, Texas, Texas Tech University Press. pp. 97–103.

Liu, C., Yan, L., Li, H. & Wang, G. (2006) Effects of predator-mediated apparent competition on the population dynamics of *Tetranychus urticae* on apples. *BioControl*, 51, 453–463. doi: https://doi.org/10.1007/s10526-005-4363-z

Lobbes, P. & Schotten, C. (1980) Capacities of increase of the soil mite *Hypoaspis aculeifer* Canestrini (Mesostigmata: Laelapidae). *Zeitschrift für Angewandte Entomologie*, 90, 9–22. doi: https://doi.org/10.1111/j.1439-0418.1980.tb03497.x

López-Ruiz, N., Rodríguez-Peña, C. & Gonzales-Ibarguen, D. (2012) Revisión de la normativa actual del comercio de fauna silvestre en colombia: un análisis comparativo con España. Caldas, Antioquia, Corporación Universitaria Lasallista. 69pp.

Majidi, M. & Akrami, M.A. (2013) Corresspondence Mites associated with the date palm (*Phoenix dactylifera* L.) in Larestan (Fars province), southern Iran. *Persian Journal of Acarology*, 2, 335–339.

Manu, M. (2010) Predatory mites (Acari: Mesostigmata-Gamasina) from soil of some spoilt areas from Retezat and Tarcu-Petreanu mountains. *Studia Universitatis Vasile Goldis Arad, Seria Stiintele Vietii*, 20, 89–94.

Manu, M. & Honciuc, V. (2010) Rank correlations at the level of soil mites (Acari: Gamasida; Oribatida) from central parks of Bucharest city, Romania. *Acta entomologica serbica*, 15, 129–140.

Marafeli, P., Reis, P., Silveira, E. da, Souza-Pimentel, G. & Toledo, M. de (2014) Life history of *Neoseiulus californicus* (McGregor, 1954) (Acari: Phytoseiidae) fed with castor bean (*Ricinus communis* L.) pollen in laboratory conditions. *Brazilian Journal of Biology*, 74, 691–697. doi: https://doi.org/10.1590/bjb.2014.0079

McMurtry, J.A., Huffaker, C.B. & de Vrie, M. (1970) Ecology of tetranychid mites and their natural enemies: a review. I. Tetranychid enemies: their biological characters and the impact of spray practices. *Hilgardia*, 40, 331–390. doi: https://doi.org/10.3733/hilg.v40n11p331

Messelink, G. & Holstein-saj, R. Van (2008) Improving thrips control by the soil-dwelling predatory mite *Macrocheles robustulus* (Berlese). *Integrated Control in Protected Crops*, 32, 135–138.

Messelink, G.J., Maanen, R. van, van Steenpaal, S.E.F. & Janssen, A. (2008) Biological control of thrips and whiteflies by a shared predator: Two pests are better than one. *Biological Control*, 44, 372–379. doi: https://doi.org/10.1016/j.biocontrol.2007.10.017

Ministerio de Ambiente y Desarrollo Sostenible (2012) Política nacional para la gestión integral de la biodiversidad y sus servicios ecosistémicos (PNGIBSE) República de Colombia and Ministerio de ambiente y desarrollo sostenible (eds). *Ministerio de ambiente y desarrollo sostenible, República de Colombia*, 134.

Ministerio del Medio Ambiente (1993) Diario Oficial *Ley 99 De 1993*. Colombia, 44pp.

Moraza, M.L. & Peña, M. a. (2005) Ácaros Mesostigmata (Acari, Mesostigmata) de hábitats seleccionados de La Gomera (islas Canarias, España). *Graellsia*, 61, 109–114. doi: https://doi.org/10.3989/graellsia.2005.v61.i1.9

Moreira, G.F., de Morais, M.R., Busoli, A.C. & de Moraes, G.J. (2015) Life cycle of *Cosmolaelaps jaboticabalensis* (Acari: Mesostigmata: Laelapidae) on *Frankliniella occidentalis* (Thysanoptera: Thripidae) and two factitious food sources. *Experimental and*

Applied Acarology, 65, 219–226. doi: https://doi.org/10.1007/s10493-014-9870-3

Muñoz-Cárdenas, K., Ersin, F., Pijnakker, J., van Houten, Y., Hoogerbrugge, H., Leman, A., Pappas, M.L., Duarte, M.V.A.A., Messelink, G.J., Sabelis, M.W. & Janssen, A. (2017a) Supplying high-quality alternative prey in the litter increases control of an above-ground plant pest by a generalist predator. *Biological Control*, 105, 19–26. doi: https://doi.org/10.1016/j.biocontrol.2016.11.004

Muñoz-Cárdenas, K., Rueda-Ramirez, D., Ersin, F., Faraji, F. & Janssen, A. (2017b) Alternative food for little-inhabiting predators decreases pest densities and above-ground plant damage. In: K. Muñoz-Cárdenas (ed), *What lies beneath? Linking litter and canopy food webs to protect arnamental crops*. Ph.D. Thesis. University of Amsterdam, The Netherlands, pp. 9–26.

Navarro-Campos, C., Pekas, A., Moraza, M.L., Aguilar, A. & Garcia-Marí, F. (2012) Soil-dwelling predatory mites in citrus: Their potential as natural enemies of thrips with special reference to *Pezothrips kellyanus* (Thysanoptera: Thripidae). *Biological Control*, 63, 201–209. doi: https://doi.org/10.1016/j.biocontrol.2012.07.007

Navarro-Campos, C., Wäckers, F.L. & Pekas, A. (2016) Impact of factitious foods and prey on the oviposition of the predatory mites *Gaeolaelaps aculeifer* and *Stratiolaelaps scimitus* (Acari: Laelapidae). *Experimental and Applied Acarology*, 70, 69–78. doi: https://doi.org/10.1007/s10493-016-0061-2

Peel, M.C., Finlayson, B.L. & McMahon, T.A. (2007) Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11, 1633–1644. doi: https://doi.org/10.5194/hess-11-1633-2007

Salmane, I. (2001) A check-list of Latvian Gamasina mites (Acari , Mesostigmata) with short notes to their ecology. *Latvijas Entomologs*, 38, 27–38.

Settle, W.H., Ariawan, H., Astuti, E.T., Cahyana, W., Hakim, A.L., Hindayana, D. & Lestari, A.S. (1996) Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology*, 77, 1975–1988. doi: https://doi.org/10.2307/2265694

Silva, D.E., Silva, G.L. Da., Nascimento, J.M. Do & Ferla, N.J. (2018) Mite fauna associated with bird nests in Southern Brazil. *Systematic & Applied Acarology*, 23, 426–440. doi:

http://doi.org/10.11158/saa.23.3.2

Da Silva, G.L., Rocha, M.D.S. & Ferla, N.J. (2013) First new species of the *Phytoseius horridus* group (Acari: Phytoseiidae) described from Brazil, with a key to the Brazilian species of *Phytoseius*. *Zootaxa*, 3681, 595–599. doi: https://doi.org/10.11646/zootaxa.3681.5.9

Skorupski, M. & Luxton, M. (1998) Mesostigmatid mites (Acari: Parasitiformes) associated with yew (*Taxus baccata*) in England and Wales. *Journal of Natural History* 32, 419–439. doi: https://doi.org/10.1080/00222939800770221

Usher, M. & Davis, P.R. (1983) The Biology of *Hypoaspis aculeifer* (Canestrini) (Mesostigmata): Is there a tendency towards social behaviour? *Acarologia* XXIV:243–250. doi: https://doi.org/10.1051/acarologia/20142144

Valencia, E. (2013) Control y manejo de los Thrips en los sistenas de floricultura colombiana. *Florycultura Colombiana: Revista de la Asociación Colombiana de Floricultores*, 1, 45–49.

Wissuwa, J., Salamon, J.A. & Frank, T. (2012) Effects of habitat age and plant species on predatory mites (Acari, Mesostigmata) in grassy arable fallows in Eastern Austria. *Soil Biology and Biochemistry*, 50, 96–107. doi: https://doi.org/10.1016/j.soilbio.2012.02.025