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Article

Trophic breadth niche, prey preference and developmental time of a *Balaustium* sp. (Acari: Erythraeidae) from Argentina

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ABSTRACT

Trophic breadth niche, prey preference and developmental time of an unidentified *Balaustium* sp. (Acari: Erythraeidae) were studied under laboratory conditions. The prey offered consisted of immature and adult stages of *Tetranychus urticae* Koch, *Bemisia tabaci* (Gennadius), *Frankliniella occidentalis* (Pergande) and *Macrosiphum euphorbiae* (Thomas). The breadth of the trophic niche increased as mites developed. All active stages of *Balaustium* sp. consumed more than one kind of prey. Adults were the most generalist while larvae can be considered oligophagous. Larval instar significantly selected *T. urticae* eggs, deutonymphs substantially chose whiteflies, and thrips nymphs and adults were non-selective, eating any type of prey they could catch. Details of the development of the different stages are provided.

KEY WORDS: Developmental stages; horticultural crops; laboratory conditions; prey selectivity; red velvet mites.

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INTRODUCTION

Predators can be classified either as generalist or specialist based on the wide or narrow range of species they consume (Schoener 1971). Many arthropods are predatory and many species are quite generalized in their feeding (Snyder and Evans 2006). An advantage of generalist predators is that they can feed on other than the target prey, thereby enabling the persistence of their populations even in periods of low prey density. However, a disadvantage is that they can attack non-target prey or other predators through intraguild predation or higher-order predation (Rosenheim *et al.* 1995; Rosenheim 1998; Messelink *et al.* 2011). Messelink *et al.* (2010) have demonstrated that predatory arthropods with a wide trophic niche can enhance biological control through increased predator densities. This is probably due to a strong numerical response of the predator and the interactions of preys.

Food preferences are the result of a complex interaction of external and internal factors. Among the external factors is the resource availability, while the internal factors are related to metabolic, nutritional and behavioural aspects (Stephens and Krebs 1986). Benefits of consuming one type of food may be manifested in an increase in the survival, longevity, fertility and a decrease in developmental time of predatory arthropods which would result in a greater number of offspring for the next generation.

The genus *Balaustium* von Heyden, 1826 (Acari: Erythraeidae) has worldwide distribution (Mağol *et al.* 2012). These mites are common inhabitants of litter, stones, and plants in orchards, especially on sunny days and when pesticides are not applied (Putman 1969; Cadogan and Laing 1977; Childers and Rock 1981; Welbourn 1983; Welbourn and Jennings 1991; Muñoz Cárdenas *et al.* 2014; Yoder *et al.* 2017). They are primarily generalist predators that feed on a variety of arthropods and can be natural regulators of pests on plants (Muñoz-Cárdenas *et al.* 2015). The active forms (post-larval, deutonymphs and adults) are voracious predators of soft-bodied arthropods. Pollen may also be a common component of their diet (Newell 1963; Welbourn 1995). The availability of pollen is especially important during the larval stage before suitable amounts of plant prey are present (Yoder *et al.* 2017).

In previous study conducted in orchards in Olmos, Los Hornos and Colonia Urquiza (Buenos Aires, Argentina), we observed that mites belonging to the genus *Balaustium* sp. were naturally present, and often collected, on sweet pepper (*Capsicum annuum* L.), cucumber (*Cucurbita pepo* L.) and bean (*Phaseolus vulgaris* L.), as well as in weeds such as *Convolvulus arvensis* L. (Convolvulaceae), *Picris echioides* L., *Sonchus oleraceus* L. (Asteraceae) and *Portulaca oleracea* L. (Portulacaceae) (Nolasco *et al.* 2012). In orchards, *Balaustium* sp. were associated with important pests in this productive area, such as spider mites (*Tetranychus urticae* Koch), a complex of whiteflies (*Bemisia tabaci* (Gennadius), *Trialeurodes vaporariorum* (Westwood)), thrips (*Frankliniella occidentalis* (Pergande) and *Caliothrips phaseoli* (Hood)) and aphids (*Macrosiphum euphorbiae* (Thomas) and *Aphis gossypii* Glover).

In the present contribution, we report observations of the trophic niche breadth, prey selectivity and developmental time of this unidentified *Balaustium* sp. (Acari: Erythraeidae). A greater understanding of this mite would improve our knowledge about its predatory potential.

MATERIAL AND METHODS

Prey and predator colonies

Laboratory colonies of prey species and *Balaustium* sp. were formed using individuals collected from horticultural farms located in the surroundings of La Plata, Buenos Aires province, Argentina (35° 00' S, 58° 00' W). *Tetranychus urticae*, *B. tabaci*, *M. euphorbiae*, and *F. occidentalis* were reared individually on sweet pepper leaves in a greenhouse at CEPAVE. *Balaustium* sp. colony was built according to Muñoz Cárdenas *et al.* (2014).

Predator rearing units consisted of plastic containers (13.5 cm diameter, 7 cm height) with an opening (4 cm diameter) covered with voile for ventilation. To provide a suitable substrate for juvenile development, the bottom of the container was covered with a layer of moist peat (2 cm deep). To maintain moisture, we placed a paper towel disc on the top of the layer. Twice a week, a total of 8–10 adult predator were placed in the container and they were provided with plant material infested with all stages of whiteflies, thrips, and spider mites. Egg masses obtained from the colony were placed in a Petri dish until larvae emergence.

Developmental time

Eggs of *Balaustium* sp. were randomly selected from the colony and placed on wet cotton until hatching. Larvae were reared in Petri dishes and they were provided with *T. urticae* and whitefly eggs placed on small discs of sweet pepper leaf. Deutonymphs and adults were reared in the same manner as larvae with all developmental stages of *T. urticae*, *B. tabaci*, *F. occidentalis*. Previous experiments showed that *Balaustium* sp. cannot complete their development with only one kind of prey. We recorded the duration of each stage by making daily observations.

Trophic breadth niche

A Petri dish with a sweet pepper leaf was used as experimental unit. Preys provided to the

predator included five items of the following preys: eggs, nymphs and adult males of *T. urticae*; eggs, nymphs, and adults of *B. tabaci*; nymphs (I and II instars) and adults of *F. occidentalis* and, nymphs (I and II instars) and adults of *M. euphorbiae*. A total of 50 items were placed on a sweet pepper leaf. Preys were selected from their respective colonies. One predator with 24 hour of inanition was placed in each experimental unit with a fine brush. The predation was observed during 120 min using a stereoscopic microscope when necessary. A total of 14 replicates were performed for each active stage (larva, deutonymph, and adult) of *Balaustium* sp.

The niche breadth was based on Levin's standardized index (Krebs 1999):

$$B_A = B - 1/n - 1$$

where:

B_A = Levin's standardized niche breadth

B = Levin's measure niche breadth calculated as $B = 1/\sum p_j^2$ where p_j is the proportion individuals using resource state j

n = total number of item (resources).

B_A values vary from 0 (species consume a single item) to 1 (species exploits available items in equal proportion).

Prey preference

The relationships between consumption preferences of the active stages of *Balaustium* sp. and the different preys stages offered, were further examined by using principal components analysis (PCA) based on the correlation matrix. The magnitude and direction of each vector reflects the correlation between the variable and the preference record by each active stage of *Balaustium* sp. determined by PCA and is based on the Pearson correlation coefficient. PCA analysis was performed with R package Factominer (Husson *et al.* 2017).

Differences in the number of prey consumed by each active stage of predator were analyzed using Kruskal-Wallis test (Zar 1999).

RESULTS

We observed six developmental stages which we describe below. This result is comparable to the related species *B. putmani* (Putman 1969; Cadogan and Laing 1977), *B. hernandezii* (Mağol *et al.* 2012), and *B. leanderi* (Muñoz Cárdenas *et al.* 2014).

The developmental stages are:

Egg (Fig. 1A) – Egg masses contain approximately 13–36 eggs. Eggs are spherical, dark red, and need humidity for further development. The average duration of eggs at 25 °C was 8.1 ± 2.2 days ($n = 38$). After 6–10 days eggs change color to brownish red, and the chorion breaks exposing the deutovarial membrane and turning to deutova phase which lasts 5.3 ± 1.1 days ($n = 25$) (Fig. 1B).

Larva (Fig. 1C) – This six-legged active stage is orange with a reddish area around the eyes. The duration of the larval stage is 6.3 ± 1.4 days ($n = 24$).

Protonymph (Fig. 1D) – The protonymph is sessile and apodous and the larval cuticle remains attached to the back of the body. Dorsal knobbed setae cover the body and the future eyes are visible through the cuticle. The average duration is 4.6 ± 0.4 days ($n = 24$).

Deutonymph (Fig. 1E) – The deutonymph exhibits very fast movements and behaves as an active predator. Its color is bright red covered with a regular pattern of whitish short setae contrasting with the green of leaves. Mean average duration of this stage is 7.3 ± 1.8 days ($n = 21$).

Tritonymph (Fig. 1F) – It is similar to protonymph but larger. The exuvium of the previous stage is attached to the back of the body and setae cover the dorsal body densely. Duration of this stage is 4.5 ± 0.5 days ($n = 21$).

Adult (Fig. 1G) – It is very similar in aspect to deutonymph but much bigger and its color is bright brownish red with white short setae. A hairless fringe surrounds legs. Urnulae is very conspicuous. There were no apparent dimorphisms between sexes. No facultative parthenogenesis was observed. Isolated females did not lay eggs. When several adults got together eggs masses were observed after some days. Duration of this stage is variable, averaging 10 ± 7.5 days ($n = 15$). Two or three days after oviposition females died. The entire cycle of development from egg to adult lasted approximately 46 days.

The range of prey eaten expanded with increasing predator active stage. Trophic niche breadth values varied from 0.12 to 1, larval stage has the lower value (0.12), deutonymphs have 0.34 while adults reached the maximum value.

The first two axes of the PCA explained 43.7% of the variation in *Balaustium* sp. consumption preferences (Axis 1= 37.2%, Axis 2= 16.5%). The variables that are loaded on axis 1 separate two groups. Indeed, the first component separates the individuals that consume many whitefly or thrips nymphs from those that consume few spider mites or whitefly eggs. The second component separates the individuals that consume spider mites, nymphs or adults of whitefly from those who consume thrips adults. In this way, there are two groups: the deutonymphs which are associated with a high consumption of whitefly or thrips nymphs, while the larvae show a high consumption of spider and whitefly eggs. The adults do not seem to show marked preferences (Fig. 2).

The number of prey consumed by larvae differed significantly as to the type of prey that was offered (Kruskal-Wallis test = $H(3, N=56) = 42.85, p < 0.05$). Larvae have a relatively limited niche, they preferred spider mite eggs at first and whiteflies and nymphs eggs of both pests later. Likewise, deutonymphs' choice of prey depended on the type of prey offered (Kruskal-Wallis test = $H(6, N = 98) = 54.63, p < 0.05$), thrips nymphs and whiteflies were preferred. Except for spider mite eggs and adults of whiteflies, that were barely consumed, the choice of prey was similar (Kruskal-Wallis test = $H(5, N=72) = 6.40, p > 0.05$). Aphids were rejected by all active forms of *Balaustium* sp. (Table 1).

Table 1. Number (mean \pm SE) of preys consumed by immature and adult stages of *Balaustium* sp. in 2 h.

Consumed prey in 2h	Larva (n = 14)	Deutonymph (n = 14)	Adult (n = 14)
Tu eggs	3.07 ± 0.10	0.57 ± 0.07	0.14 ± 0.07
Tu nymphs	0.79 ± 0.05	0.43 ± 0.07	0.78 ± 0.25
Tu adults	0	0.71 ± 0.14	0.28 ± 0.06
WF eggs	1.21 ± 0.05	0.36 ± 0.10	0.28 ± 0.10
WF nymphs	0.36 ± 0.07	1.71 ± 0.10	0.86 ± 0.16
WF adults	0	0	0.14 ± 0.03
Thrip nymphs	0	1.79 ± 0.17	0.64 ± 0.10
Thrip adults	0	0.50 ± 0.07	0.43 ± 0.15
Aphid nymphs	0	0	0
Aphid adults	0	0	0

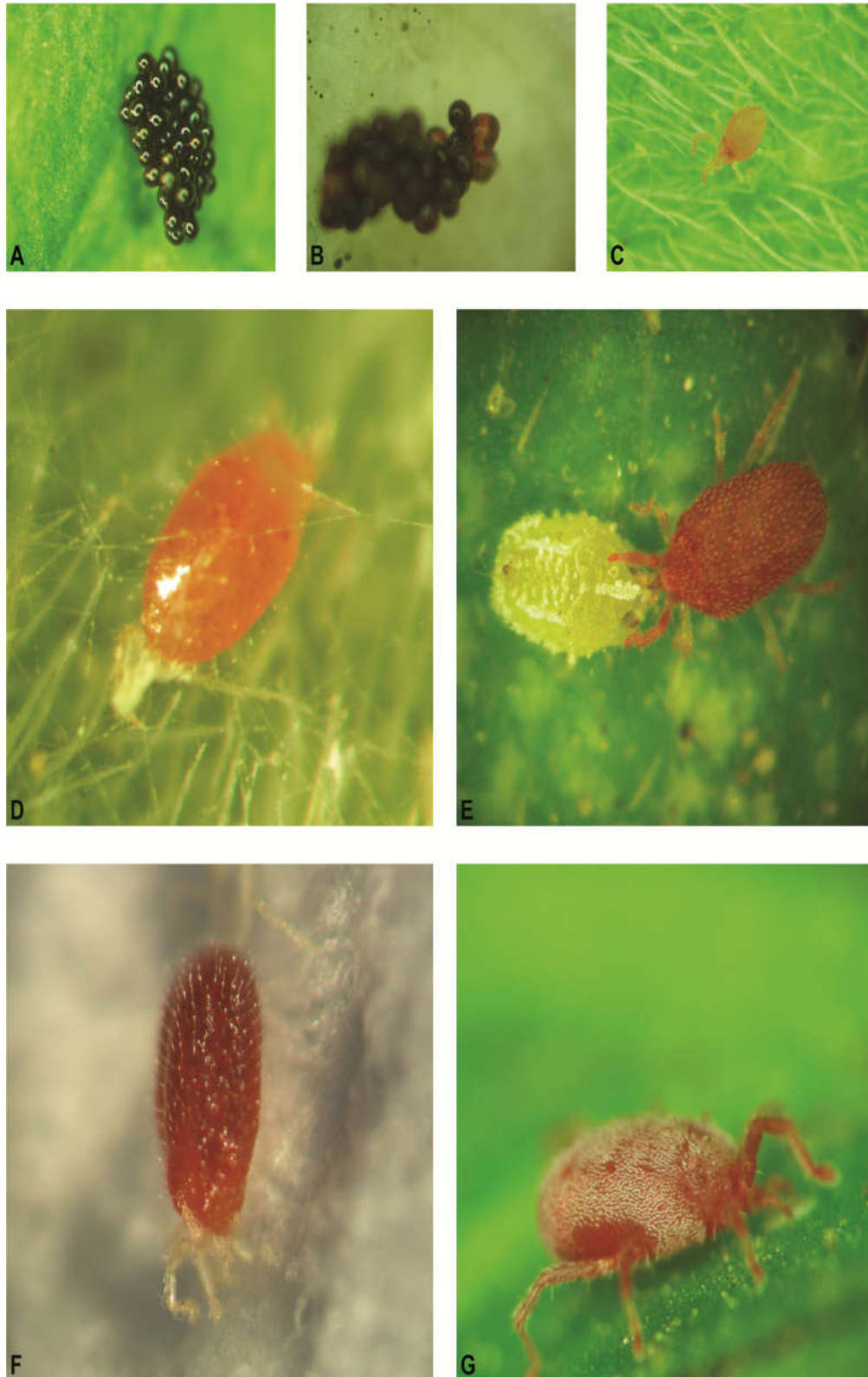


Figure 1. Developmental stages of *Balaustium* sp. – A. Eggs; B. Deutova; C. Larva; D. Protonymph; E. Deutonymph; F. Tritonymph; G. Adult.

TROPHIC BREADTH NICHE, PREY PREFERENCE AND DEVELOPMENTAL TIME OF *BALAUSTIUM* SP.

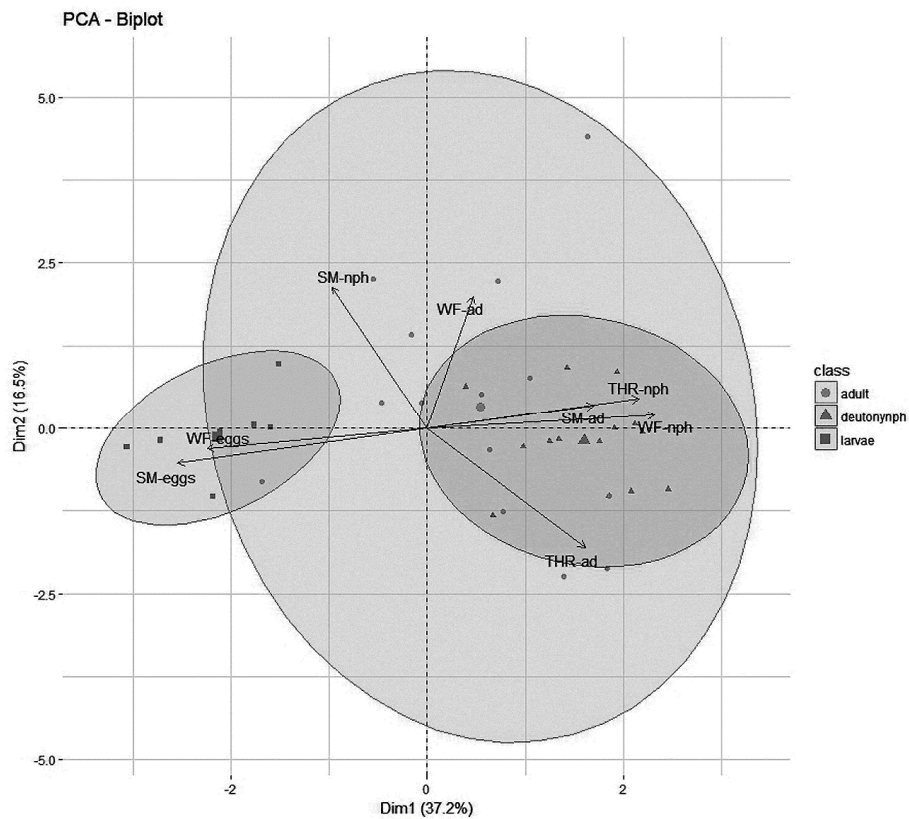


Figure 2. Ordination diagram of principal components analysis showing the distribution of preys consumption by larvae, deutonymphs, and adults of *Balaustium* sp. Positions of the arrows relative to Axes 1 and 2 indicate how strongly independent variables are correlated with each axis, and therefore how related variables are to the pattern of preys consumption by *Balaustium* sp.

DISCUSSION

This is the first study that provides a description of immature and adult stages of this Argentinean unidentified *Balaustium*, as well as some data about their life cycle.

The expansion of preys range along predator life cycle is representative of increases in behavioral and morphological capability to capture and consume large preys. We observed that *Balaustium* sp. larvae did not feed on nymphs and adults of thrips which exhibit a defensive behavior by lifting the abdomen and releasing a drop of liquid through the anus. This behavior discouraged larvae from attacking them. Larvae preferred immobile stages such as *T. urticae* and whitefly eggs. Carrel and Tanner (2002) reported that high content of proteins and carbohydrates in arthropod eggs influences the maturation of oocytes and the fecundity of the adult stage. In addition to the nutritional contribution that prey may offer to the predators, consumer preferences are also related to the ease with which prey is caught (Dyer and Floyd 1993; Lang and Gsödl 2001; Reitz *et al.* 2006).

Deutonymphs seem to cope with thrips behaviour. Their larger size and agility may facilitate the capture of adults of thrips and spider mites, although they showed preference over the nymph of thrips and whiteflies. Adults were the most generalist since they exhibited an aggressive behavior, showed no preference for any type of prey and displayed compulsive predation behavior. It should be noted that aphids were not consumed by any active form of *Balaustium* sp. but the predator nevertheless attacked them. We observed that *Balaustium* sp. climbed up the aphids and pierced

them without causing their death. However, in the field, all mobile forms of this predator are frequently associated with aphids. Childer and Rock (1981) reported aphids as prey for *B. putmani*. This association could be a result of the aphids consumption of honeydew which is known to be rich in amino acids and sugars (Douglas 2008; Leroy *et al.* 2011) and aphids could be also a source of water for *Balaustium* sp. As a semelparous species, *Balaustium* sp. adults concentrated all their reproductive efforts in a few days, laying two or three eggs masses and dying soon. The short time that this predator has to complete the maturation of oocytes seems to be the reason for accepting all kinds of prey.

Contrary to Cadogan and Laing (1977), who reared *Balaustium putmani* Smiley with *Panonychus ulmi* Koch as the only prey, this unidentified *Balaustium* sp. needs different kinds of prey to complete its life cycle because they cannot finish their development by consuming only *T. urticae*. Something similar occurs with the native *Balaustium* of Bogota Savanna that complete their life cycle with mixed diet (Muñoz Cárdenas *et al.* 2014). Dietary breadth and feeding behaviour define the feeding strategy of a predator (Jaksic and Marone 2006).

The natural populations of this predator should be conserved and enhanced through the reduction or elimination of non-selective pesticides, along with other habitat management practices, such as the conservation of environment diversity. *Balaustium* sp. seems to be a promissory natural enemy of a complex of pests in horticultural farms in the surroundings of La Plata.

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گستره زیست‌خون غذایی، ترجیح طعمه و مدت رشد *Balaustium* sp. (Acari: Erythraeidae) از آرژانتین

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چکیده

گستره زیست‌خون غذایی، ترجیح طعمه و مدت رشد *Balaustium* sp. (Acari: Erythraeidae) در شرایط آزمایشگاهی مطالعه شد. طعمه‌های مورد استفاده عبارت بودند از مراحل نابالغ و کامل *Tetranychus urticae* Koch، *Bemisia tabaci* (Gennadius)، *Frankliniella occidentalis* (Pergande) و *Macrosiphum euphorbiae* (Thomas). گستره زیست‌خون غذایی با رشد کنه‌ها افزایش یافت. همه مراحل فعال *Balaustium* sp. بیش از یک نوع شکار را مصرف کردند. کنه‌های کامل شکارگر عمومی بودند و لاروها به عنوان چندخوار می‌توانند در نظر گرفته شوند. مرحله لاروی به طور معنی‌داری تخم‌های کنه تارتن دو لکه‌ای، پوره‌های سن دوم به مقدار زیادی سفیدبالک‌ها و پوره‌های تریپس را انتخاب کردند و کنه‌های کامل غیر انتخابی عمل کرده و از هر نوع طعمه‌ای که می‌توانستند شکار کنند تغذیه کردند. جزئیات رشد مراحل مختلف ارایه شده است.

واژگان کلیدی: مراحل رشدی؛ گیاهان باغی؛ شرایط آزمایشگاهی؛ انتخاب شکار؛ کنه سرخ مخملی.

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