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Testing biocontrol potential of an indigenous predator against an invasive pest in New Zealand: *Buchananiella whitei* (Hemiptera: Anthocoridae) and the tomato red spider mite *Tetranychus evansi* (Acari: Tetranychidae)

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Abstract

The tomato red spider mite, *Tetranychus evansi* Baker & Pritchard (Acari: Tetranychidae) is an invasive pest that causes severe damage to solanaceous crops and has proven difficult to control using conventional acaricides or predatory mites. The minute pirate bug, *Buchananiella whitei* Reuter (Hemiptera: Anthocoridae), is a common but poorly studied anthocorid predator native to Australasia. This study investigated the development, survival, and reproduction (oviposition) of *B. whitei* when feeding on *T. evansi* under laboratory conditions, with *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs as a control diet. Results showed that *B. whitei* successfully completed development and achieved high survival (83%) on *T. evansi*, with developmental durations not significantly different from those developed on *E. kuehniella* eggs. Predation capacity increased with age of instar. We also documented for the first time that *B. whitei* exhibits a variable number of immature instars (five or six) during development, even under controlled environmental conditions. In our oviposition experiment, adult females fed on *T. evansi* produced a significantly higher number of eggs (4.2 ± 1.0 per male-female pair) in 7 days. These findings provide the first evidence that *B. whitei* can develop and reproduce on *T. evansi*, suggesting its potential as a biological control agent against this invasive mite. Further work should assess its performance under greenhouse and field conditions, and its integration with other natural enemies within pest management programmes.

Key words: Minute pirate bugs; biological control; predation; oviposition; developmental biology; Solanaceae

Introduction

The tomato red spider mite, *Tetranychus evansi* Baker & Pritchard, 1960 (Acari: Tetranychidae), is one of the most destructive pests of solanaceous crops worldwide. Native to South America, it has successfully invaded Africa, Europe, and Asia, and has more recently been reported from Oceania, including Australia and New Zealand (Navajas *et al.* 2013; Fan *et al.* 2021). The rapid global spread of *T. evansi* is attributed to its high dispersal ability, short generation time, and ability to thrive under warm and dry conditions (Migeon *et al.* 2009; Boubou *et al.* 2011). Although *T. evansi* prefers warm climates and has shorter generation time under higher temperature (Yeh 2025), recent studies in Australia revealed that *T. evansi* has developed a tolerance of cold, and has become invasive in cold regions outside its preferred distribution (Knihinicki *et al.* 2025).

Heavy infestations of *T. evansi* have been reported to cause up to 65% yield loss in African eggplant, 56% in tomato, and 25% in purple amaranth (Azandémè-Hounmalon *et al.* 2015, 2022). Management of this pest remains highly challenging. Chemical control using acaricides has been the mainstay in many regions, but resistance has evolved rapidly (Azandéme-Hounmalon *et al.* 2015). In addition, excessive pesticide use threatens beneficial arthropods, disrupts natural enemy communities, and poses environmental and food safety risks (Sánchez-Bayo 2021). As a result, sustainable and environment-friendly alternatives such as biological control are needed urgently.

The biological control of *T. evansi* remains challenging due to multiple barriers. While predatory mites of the family Phytoseiidae have been widely used for spider-mite control (Gerlach & Şengonca 1985), their performance

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against *T. evansi* appears limited (Navajas *et al. 2013)*. Many generalist predators perform poorly on tomato and other solanaceous plants, as these hosts possess glandular trichomes and defensive compounds that reduce predator mobility and survival (Koller *et al.* 2007; De Vasconcelos *et al.* 2008). Furthermore, *T. evansi* produces dense silk webs that physically hinder predator movement and limit access to eggs and juveniles, significantly lowering predation efficiency (Lemos *et al.* 2010; Sarmento *et al.* 2011). Even highly efficient predators, such as *Phytoseiulus persimilis* Athias-Henriot, 1957 and *Neoseiulus californicus* McGregor, 1954, exhibit reduced oviposition and population growth when preying on *T. evansi*, reflecting its low nutritional suitability and the ability to accumulate toxic secondary metabolites from plants (De Moraes & McMurtry 1986, Shirvani *et al.* 2023; Wang *et al.* 2024). Collectively, these limitations contribute to the poor establishment and efficacy of predatory mites against *T. evansi*, underscoring the need for alternative or complementary biological control approaches.

Anthocorid bugs (Hemiptera: Anthocoridae), also known as 'pirate bugs', are promising candidates for this role. These generalist predators are widely distributed in agricultural habitats and feed on a range of small arthropods including thrips, aphids, whiteflies, lepidopteran, and mites (Lattin 2000). Their predatory versatility, high searching ability for prey, and ease of rearing on factitious prey have made species such as *Anthocoris spp.*, *Montandoniola moraguesi*, *Orius insidiosus,* and *Tetraphleps spp.* commercially available and widely applied in greenhouse biological control programs (Lattin 1999).

Buchananiella whitei Reuter is a lesser-known anthocorid species native to Australasia and is widely recorded across New Zealand and Australia. It has been documented on various native trees (e.g., *Melicytus ramiflorus*, *Metrosideros excelsa*), as well as on *Vitis vinifera*, *Auricularia polytricha*, and onion crops (Lattin 2000; Liebherr 2006). This species has also been found in leaf litter, particularly during winter (Liebherr 2006). Although less studied than *Orius* species, *B. whitei* has been reported as part of arthropod predator assemblages in unsprayed or low-pesticide onion plots (Workman & Martin 2002) and more recently included in thrips assessments in strawberry crops (Li & Zhang 2026). These observations indicate that *B. whitei* may play a role as a generalist predator in agricultural ecosystems. However, only a few researchers have reported its life history and noted its ability to prey on thrips (Gong *et al*. 2026; Li & Zhang 2026). Information on *B. whitei* fecundity and impact on major crop pests such as *T. evansi* is still lacking.

In this study, we examined the development and survival of *B. whitei* when fed on *T. evansi*, and used *Ephestia kuehniella* (Mediterranean flour moth) eggs as a control diet. By comparing developmental time and survival across the two diets, we sought to clarify whether *T. evansi* is a suitable food source for *B. whitei*. This study provides the first experimental evaluation of *B. whitei* as a biological control agent against *T. evansi*, and contributes to the broader search for effective natural enemies of this invasive spider mite in solanaceous cropping systems.

Material and methods

Mites and plants

Tetranychus evansi were obtained from a regularly regenerated colony reared on black nightshade (*Solanum nigrum*) leaves. The initial mite cultures were collected from naturally infested black nightshade leaves at the Bioeconomy Science Institute, St Johns, Auckland, New Zealand, in 2025. (Note: Manaaki Whenua – Landcare Research [MWLR] became an internal group of the Institute in July 2025). A small branch of black nightshade with leaves was cut and inserted into a small water-filled bottle. The bottle was placed on a 10 × 10 × 2 cm sponge in a 22 × 22 × 4 cm plastic tray filled with water to prevent mite from escaping.

The initial *B. whitei* cultures and *E. kuehniella* eggs were obtained from Bioforce Limited, Auckland, New Zealand, in 2025. *Buchananiella whitei* were obtained from a 22 × 16 × 8 cm plastic box that also contained abundant frozen *E. kuehniella* eggs as food resources. The box was covered with fine gauze to allow gas exchange and prevent insects from escaping. There were vermiculite granules and rough paper in the box to provide cover and space for oviposition by predatory bugs. All cultures and units were maintained in room temperatures between 10°C and 25°C. The experiments used newly laid *B. whitei* eggs within one week of purchase.

Experimental arenas

Experiments were carried out using modified Munger cells (Zhang & Zhang 2021). Each cell unit was constructed using two clear plexiglass plates measuring 3.8 × 2.5 cm with a thickness of 0.2 cm. The upper plate contained a conical opening (1 cm wide at the top and 0.6 cm at the base). This opening was sealed on the upper side with a layer

of plastic film pierced with five small holes for ventilation, while the lower side was covered with a tomato leaf disc (1.5 cm in diameter). A piece of filter paper, moistened with water to maintain humidity, was placed beneath the leaf disc. The lower plexiglass plate supported the entire structure, and the two plates were held together using a pair of metal clips.

***Development and predation of* B. whitei *feeding on* T. evansi**

Buchananiella whitei eggs were collected from the rough paper in the stock culture. In the experimental group, each egg was transferred individually into a 1.8 mL empty tube. After hatching, each first instar was then transferred into a new experimental unit containing 30 *T. evansi* eggs. Once they developed into the second instar, each of these was individually transferred into a new experimental unit containing 20 *T. evansi* adults, where it remained through the subsequent instar stages and for seven days after reaching adulthood (i.e., after completing the final instar). In the control group, abundant *E. kuehniella* eggs (c. 50 per unit) were used instead of *T. evansi*. *B. whitei* individuals were moved into new experimental units with the same amount of prey daily to ensure the consistency of food availability for both treatments. The remaining prey items from the previous day were counted, and dead individuals were examined to determine whether they had been sucked dry in order to assess the predation rate. Each treatment was replicated 30 times. All experimental units were placed in plexiglass cabinets which were maintained at 25°C ± 1°C, 80% ± 5% relative humidity, and a 16:8 h (L:D) photoperiod.

Oviposition of B. whitei feeding on T. evansi

After adult emergence, the sex of each *B. whitei* individual was determined using morphological differences on terminal abdominal sternites: the presence in males but the absence in females of an asymmetrical pygophore (Gong *et al.* 2026). Then, adults were paired (one male and one female). Each treatment was replicated 10 times. Each pair from the *T. evansi* treatment was transferred into a 79.89 mL bottle containing a leaf from a tomato infested with abundant *T. evansi* adults (*c.* 50 per bottle). Similarly, 10 pairs in the control group (*i.e.* feeding on *E. kuehniella*) were placed in bottles of the same size containing an ample supply of *E. kuehniella* eggs (*c.* 50 per bottle). Tomato leaves and *E. kuehniella* eggs were replaced or replenished daily. A small piece of rough paper (3 x 3 cm) was provided as substrate for laying eggs. All experimental units were maintained at room temperature (10°C–25°C) under a 16:8 h (L:D) photoperiod for a 14-day observation period.

Statistical analysis

Survival data were evaluated using the Kaplan-Meier method, and differences between treatments were tested with the Log-Rank (Mantel-Cox) test. The corresponding χ^2 values, degrees of freedom (df), and *P* values are reported. Developmental duration and oviposition data did not satisfy the assumption of normality (Shapiro-Wilk test, $P<0.05$), thus nonparametric tests were applied. The Wilcoxon rank-sum test was used for comparisons between two groups (reporting *W* and *P* values). Statistical significance was defined at $P < 0.05$. Each replicate represented one (development and predation experiment) or one pair (oviposition experiment) predators maintained under controlled laboratory conditions. Results are presented as mean ± SEM values. All statistical analyses were performed using SPSS version 27.0 (SPSS Inc., Chicago, IL, USA).

Results

Development

When fed exclusively on *T. evansi*, the survival rate of *B. whitei* remained high, sustaining 100% individuals from day 0 to day 4 (Fig. 1). Between days 4 and 7, a slight decline in survival rate was observed, with survival decreasing to 83% and remaining stable thereafter. Individuals fed on *E. kuehniella* eggs maintained a 100% survival rate throughout the observation period. However, Kaplan-Meier analysis indicated that the survival of *B. whitei* was not significantly affected by the different diet ($\chi^2 = 3.163$; $df = 1$; $P = 0.075$).

When comparing the developmental durations of different life stages (Table 1), no statistically significant differences were observed between the two prey treatments. A few individuals from both treatments underwent the sixth nymphal instar before reaching adulthood. When comparing developmental durations across instars, those individuals were suspected to have undergone one additional molt between the second and fourth instars compared with others in the same treatment.

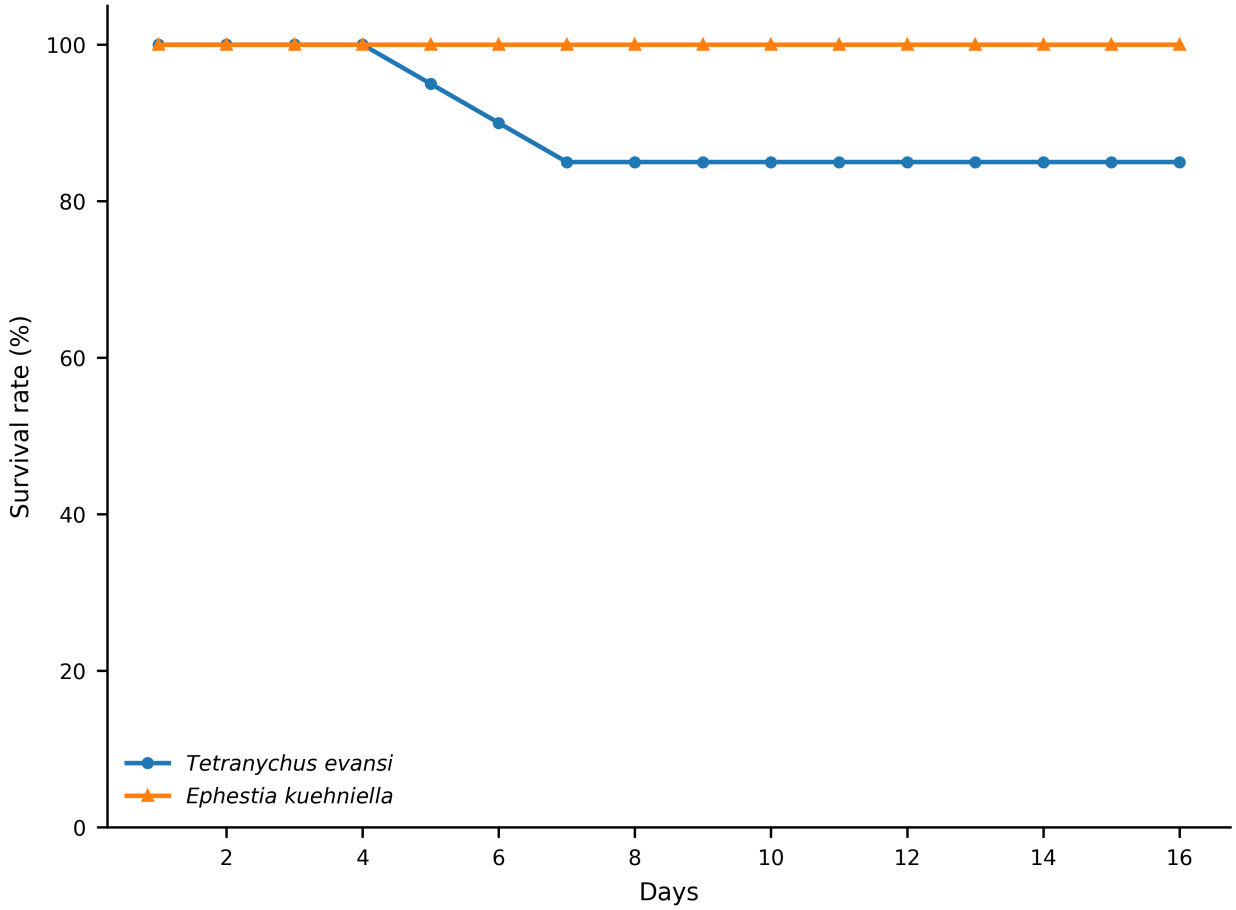

Figure 1. Age-specific survivorship of *Buchananiella whitei* feeding on either *Tetranychus evansi* or *Ephestia kuehniella (control)* (n = 30 per treatment). The x-axis represents days since egg hatching. Differences between treatments were not statistically significant using Log-Rank (Mantel–Cox) test from Kaplan–Meier analysis ($\chi^2 = 3.163$; df=1; $P = 0.075$).

Table 1. Biological parameters of *Buchananiella whitei* feeding on either *Tetranychus evansi* (treatment) or *Ephestia kuehniella (control)* (n = 30 per treatment, *B. whitei* individuals with six instars were not counted as valid replicates). The last two rows show data for *B. whitei* individuals exhibiting six instars (i.e. they underwent one additional molt during the second to fourth instars).

		Duration of each nymphal stage, 1st to 6th instar (days)						
Treatment	*n*	1st	2nd	3rd	4th	5th	6th	Total pre-adult (days)
E. kuehniella (Control)	30	2.1±0.3	2.2±0.5	2.5±0.7	3.0±0.3	5.9±0.3		15.7±0.8
T. evansi (Treatment)	30	2.2±0.4	2.3±0.4	2.6±0.7	3.1±0.3	5.9±0.2		16.1±0.9
W value		390	408	374.5	361	373		350.5
P value		0.382	0.943	0.853	0.282	0.652		0.334
E. kuehniella	5	2.2±0.4	1±0	2±0	1.8±0.4	2.2±0.4	5.6±1.1	15.8±1.2
T. evansi	4	2.4±0.5	1.2±0.4	2±0	1.6±0.5	2±0	5.4±1.0	14.6±0.5

Predation

The predation rate of *B. whitei* varied across developmental (instar) stages (Fig. 2). Predation rate gradually increased as the nymphs developed (from 3.2 to 10.5 *T. evansi* adult/ *B. whitei* individuals/day), reflecting enhanced feeding ability associated with growth and increasing body size. First instar nymphs were unable to prey on *T. evansi* adults within the confined experimental arena, as they were easily trapped by the dense webbing produced by adult mites. *T. evansi* adults were provided to the later instars of *B. whitei*, as these stages were no longer trapped by the webbing.

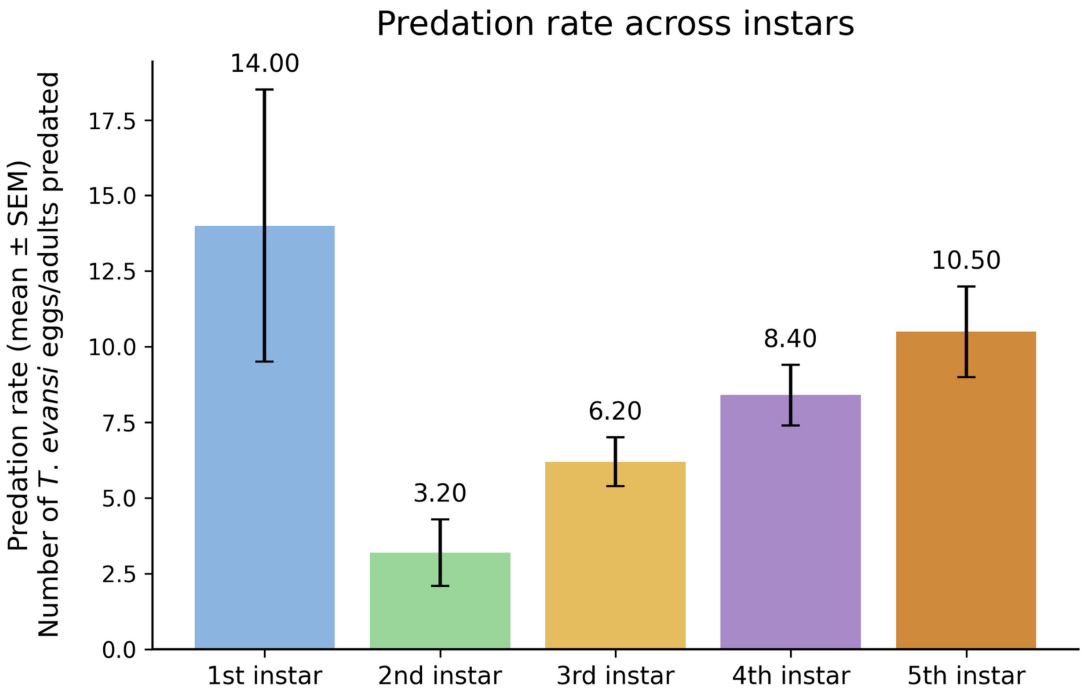

Figure 2. Daily predation rate (mean ± SEM; number of prey consumed per predator) of *Buchananiella whitei* feeding on *Tetranychus evansi*. First-instar nymphs were provided with *T. evansi* eggs, later instars and adults were provided with *T. evansi* adults (n = 30).

Oviposition

The oviposition rate of *B. whitei* varied significantly between prey types (W=55; P <0.01) (Table 2). Females provided with *T. evansi* produced an average of 4.2 ± 1.0 eggs per pair over the 14-day observation period, whereas those fed on *E. kuehniella* eggs almost stopped laying eggs (0.2 ± 0.4). *B. whitei* began oviposition approximately one week after adult emergence; therefore, all eggs laid during the 14-day observation period were produced in the latter half of the experiment.

Table 2. Oviposition rate (eggs per male: female pair) of *Buchananiella whitei* feeding on either *Tetranychus evansi* (treatment) or *Ephestia kuehniella* (control) during a 14-day observation period after adult emergence (n = 10 pairs per treatment).

Treatment	*n*	Number of eggs
E. kuehniella	10	0.2±0.4
T. evansi	10	4.2±1.0
W value		55
P value		<0.01

Discussion

This study provides the first experimental evidence that *B. whitei* could complete its development and reproduce when feeding on *T. evansi*. The ability shown in our experiments by *B. whitei* to sustain high survival and normal developmental duration on this prey suggests that *T. evansi* is a suitable food source for it. The oviposition results further indicate that *T. evansi* can support not only survival but also reproduction, making *B. whitei* a promising candidate for biological control. We also observed that *B. whitei* almost stopped oviposition when fed on *E. kuehniella* eggs in the bottle oviposition experiment. However, regular reproductive activity was evident in our stock cultures maintained in boxes, where *E. kuehniella* eggs were the sole food resource and the population of *B. whitei* increased normally. When

comparing the *E. kuehniella* treatment in small bottles with that in the larger rearing box, we inferred that the small piece of rough paper provided in the bottles was not an adequate oviposition substrate, likely because it did not offer sufficient folded or sheltered space. Although rough paper was supplied in both treatments, we observed that in the *T. evansi* treatment *B. whitei* readily laid eggs on the leaf disc, whereas in the *E. kuehniella* treatment oviposition nearly ceased. This suggests that the limited oviposition in the bottles might have been due to the absence of enough suitable oviposition substrates. This observation is consistent with previous studies on *Orius laevigatus*, which demonstrated the need for plant materials or artificial substrates to stimulate egg-laying behavior (Bonte & Clercq 2010).

Few studies have examined the biology or predatory potential of *B. whitei*, and no published records exist of its interaction with spider mites. The present findings therefore extend the known prey range of *B. whitei* and suggest that it may play a broader ecological role in pest suppression than previously recognised.

Compared with other predators that have been tested against *T. evansi*, *B. whitei* exhibited stronger performance in several aspects. Predatory mites such as *Phytoseiulus persimilis*, *Neoseiulus californicus*, and *Amblyseius swirskii* often display low survival and fecundity when feeding on *T. evansi* (De Moraes & McMurtry 1986; Shirvani *et al.* 2023; Wang *et al.* 2024). These failures have been linked to several factors, including the dense silk web produced by *T. evansi*, and the toxic secondary metabolites that were sequestered from host plants such as tomato (Koller *et al.* 2007; Sarmento *et al.* 2011). Anthocorid bugs, however, are more mobile than these mite species and use piercing-sucking mouthparts that allow them to feed through the webs (Lattin 1999). The relatively high reproductive output of *B. whitei* on *T. evansi* in our experiment indicates that this predator is less affected by the toxic compounds accumulated by the mite. This may reflect a higher physiological tolerance to alkaloids and terpenoids commonly found in solanaceous plants. Similar resilience has been noted in other anthocorids, such as *Orius insidiosus*, which maintains normal feeding activity on prey reared on chemically defended host plants (Armer *et al.* 1998). Additionally, the species' generalist feeding behavior, previously documented in field crops such as onions in New Zealand (Workman & Martin 2002) may allow populations to persist on alternative prey in the absence of mites, and help establish stable biological control practices.

This study also provides some basic biological information about *B. whitei*. Its development proceeded mainly through five instars with consistent survival across stages, which is similar to those observed in related anthocorids (Ballal *et al.* 2016). However, in this study, several individuals underwent six instars. Our observations of variable instar number are the first reported in the family Anthocoridae. It has been reported that some factors may affect the number of instars, including temperature, photoperiod, diet, humidity, rearing density and so on (Esperk *et al.* 2007; Mo *et al.* 2013). However, variable instar number could also exist under standard rearing conditions and the mechanism is still unknown (Barraclough *et al.* 2014).

The efficiency of *B. whitei* in greenhouse and field environments still needs to be evaluated before its importance in agricultural practice can be fully determined. Further studies assessing its functional and numerical responses, potential intraguild interactions, and compatibility with other biological control agents—such as predatory mites or entomopathogenic fungi—would provide a clearer understanding of its role within integrated pest management (IPM) systems.

In conclusion, *B. whitei* successfully developed, survived, and reproduced when feeding on *T. evansi* under laboratory conditions. These findings expand current knowledge of its biology and provide the first evidence that this native anthocorid may contribute to the suppression of *T. evansi* populations in solanaceous cropping systems. Given its generalist feeding habit, high mobility, and apparent tolerance to mite webs and prey-associated toxins, *B. whitei* shows strong potential as a biological control agent within IPM programmes targeting *T. evansi*.

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