pISSN: 0259-9996 – eISSN: 2783-3968

Journal of Entomological Society of Iran

2025, 45 (1), 107–119

Research Article

Impact of potassium and salicylic acid on predator performance: Life table analysis of *Typhlodromips caspiansis* Denmark & Daneshvar (Acari: Phytoseiidae)

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Abstract. The citrus red mite, *Panonychus citri* (McGregor), can cause severe damage to citrus trees. *Typhlodromips caspiansis* Denmark & Daneshvar is an indigenous predatory mite that was recently reported in association with *P. citri* in the Northern provinces of Iran. This study aimed to investigate the bottom-up effect of potassium and salicylic acid on the development and life table parameters of *T. caspiansis* on *P. citri* reared under host-plant treatment. Two-year-old citrus seedlings were sprayed with a solution containing potassium fertilizer (0.02 g/L) plus salicylic acid (1 mM). The survival rate and duration of the immature stages of the predator, as well as the longevity of adults and fecundity, were recorded. There was no significant difference in the egg and larval duration of *T. caspiansis* fed on *P. citri* reared on potassium+salicylic acid-treated and untreated (control) citrus seedlings. In comparison to the control, the duration of deutonymph was prolonged by the application of this treatment. Also, the longevity of females that came from immatures under host-plant treatment. The net reproductive rate (R_0), intrinsic rate of increase (r), and finite rate of increase (λ) of *T. caspiansis* did not show significant differences between potassium+salicylic acid-treated and untreated citrus seedlings; while the mean generation time (T) differed significantly. It can be concluded from the previous study and the present study that the positive effects of potassium+salicylic acid on *P. citri* control entail no negative outcomes regarding predator fitness. However, further field-based studies are needed for more realistic conclusions.

Keywords: Tri-trophic interactions, *Panonychuscitri*, Two-sex life-table, Citrus, Bottom-up effect

Article history
Received: 08 June 2024
Accepted: 21 November 2024
Published: 12 January 2025

Subject Editor: Hossein Madadi

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DOI: https://doi.org/10.61186/jesi.45.1.10

Introduction

Citrus, originally from southwestern China, northeastern India, Malay Archipelago, and Burma, has spread to tropical and subtropical regions worldwide (Langgut, 2017). Since the late 1930s, the citrus red mite, *Panonychuscitri* (McGregor) (Acari: Tetranychidae), has become increasingly abundant and is now recognized as a significant citrus pest in many countries (Childers &Fasulo, 2009; Zhang *et al.*, 2020). The escalation of *P. citri* from a minor to a major pest is linked to the frequent use of broad-spectrum pesticides, which disrupt the natural predator-prey balance and lead to outbreaks of secondary pests (Hill *et al.*, 2017; Qayyoum *et al.*, 2021). Therefore, it is crucial to reduce pesticide application by exploring alternative methods to promote sustainable agricultural production.

The significance of synthetic fertilizers and the role of natural enemies in regulating pest populations in citrus orchards have recently brought integrated management into the spotlight of public research aimed at safeguarding this crop (Ullah *et al.*, 2019; Urbaneja *et al.*, 2020). Among the natural enemies, predatory mites from the family Phytoseiidae (Acari) have gained considerable attention due to their potential as biological control agents for phytophagous mites and thrips on various crops (Novljan *et al.*, 2023). Based on field observations in the northern

provinces of Iran, *Typhlodromipscaspiansis*Denmark &Daneshvar is one of the most common predator species (Hajizadeh&Nazari, 2012; Omidi *et al*., 2016; Cokendolpher *et al*., 2019). This species is capable of controlling *P. citri* in citrus orchards if conserved through eco-friendly practices (Rahmani *et al*., 2004; Rahmani *et al*., 2010).

Fertilization is a common practice in agricultural landscapes to enhance pest resistance in plants (Singh & Sarkar, 2021; Mwangangi *et al*., 2021). In tri-trophic systems involving plants, herbivores, and natural enemies, fertilization and salicylic acid (SA) application can affect the morphological and biochemical characteristics of plants, which in turn can influence natural enemy performance through changes in the quality of prey (Filgueiras *et al*., 2019; Erb *et al*., 2021). Additionally, fertilizer and SA may improve the quality of host plants, leading to an increase in the abundance or quality of the herbivore population, which could impact the performance of natural enemies (Turlings&Wackers, 2004; Horgan *et al*., 2019).

These observations are supported by existing evidence. For instance, fertilizers were found to have a negative impact on the predation and larval development of *Aphidoletesaphidimyza* (Rondani) (Diptera: Cecidomyiidae) on canola plants (Fallahpour *et al*., 2013). On the other hand, copper and zinc fertilizers did not influence the population growth of *A. aphidimyza* on *Myzuspersicae* (Sulzer) (Hemiptera: Aphididae) (Mirab-balou & Alizamani, 2022), and salicylic acid (SA) did not affect the development time, consumption, and weight of *Chrysoperlacarnea* (Stephens) (Neuroptera: Chrysopidae) on melon plants (Moreno-Delafuente *et al*., 2020). Additionally, the presence of predators increased in eggplant (Moursy *et al*., 2021) and rice (Indhumathi *et al*., 2019) yields following the application of fertilizer and SA, respectively. However, there has been relatively less focus on investigating the positive or negative effects of fertilizing citrus trees on the natural enemies of *P. citri*.

In plants, Potassium (K) plays a crucial role in various physiological pathways (Zörb *et al*., 2014), activating a diverse range of K-dependent metabolic enzymes, regulating photosynthesis, facilitating nitrogen uptake, and aiding in protein synthesis (Wang *et al*., 2013; Hasanuzzaman *et al*., 2018). Additionally, it is widely believed that the application of potash fertilizer can decrease the prevalence of numerous invertebrate pests (Vieira *et al*., 2016; Mamunur Rashid *et al*., 2016; Jeer *et al*., 2021). Numerous studies have demonstrated that treating plants with exogenous salicylic acid (SA) enhances resistance against various herbivores, as well as fungal, bacterial, and viral pathogens, while also triggering the expression of systemic acquired resistance genes across a broad spectrum of plant species (War *et al*., 2013; Filgueiras *et al*., 2019; Jafarbeigi *et al*., 2020; Feng *et al*., 2021). Furthermore, in citrus plants, SA treatment has been found to effectively reduce pest incidence (Patt *et al*., 2018; Ibanez *et al*., 2022).

We previously found that Potassium+Salicylic acid treatment activated the highest level of resistance against *P. citri* in citrus seedlings (Mahpuya *et al*., 2024). However, the effects of induced resistance on *T. caspiensis*, a predator of *P. citri*, remain unknown. Therefore, the aim of this study was to explore the effect of foliar exposure of citrus plants to potassium+salicylic acid on some fitness parameters of *T. caspiansis*. We applied this elicitor to the aboveground parts of citrus seedlings, and then *P. citri* larvae (< 12 h) were fed on these treated plants until the deutonymphal stage (within 24-48 h). These specimens were introduced into *T. caspiansis*, and their developmental time, survival, and fecundity were monitored.

Materials and methods

Plant material and treatment

In July 2022, citrus seedlings of the Thomson Novel cultivar were cultivated in garden soil (pot size: 14 × 14 cm) within the research greenhouse at the Citrus and Subtropical Fruits Research Center in Ramsar, Iran. The greenhouse maintained a temperature of 25°C and a relative humidity of 60 ± 5%, with artificial lighting provided. Two-year-old citrus seedlings were utilized for the experiments. They were treated with a solution containing potassium fertilizer (27% EDTA-chelated potassium; Khazra, SodoorAhrarShargh Co., KhorasanRazavi, Iran, at a dosage of 0.02 g/L) along with salicylic acid (Merck Co., Germany, dissolved in acetone at a concentration of 1 g/ml and diluted in water to achieve a 1 mM solution). The untreated (control) group of seedlings received sprays of distilled water. The experimental setup followed a randomized block design, with 20 seedlings divided into two groups: those treated with potassium+salicylic acid and the untreated (10 seedlings in each group). To prevent insect infestation, the pots were covered with 50-mesh muslin and watered once a week with 1 L of distilled water.

The colony of prey and predator

A population of *P. citri*, originally collected from a citrus orchard in Ramsar (Mazandaran, Iran), was reared on citrus seedlings (Thomson Novel cultivar) in a growth chamber under controlled conditions (25 ± 2°C, 16L: 8D, RH 65 ± 5%) without exposure to pesticides. After two generations, they were then exposed to both untreated and treated citrus seedlings for one generation. *Typhlodromips caspiansis* adults, also collected from a citrus orchard in Ramsar, were introduced to potted citrus seedlings covered with 50-mesh muslin. Each day, 20 *P. citri* deutonymphs were placed inside the cage for feeding. Monthly, the *T. caspiansis* adults were moved to a new caged seedling, and prey was provided.

Life history experiments

Each pot was individually covered with 50-mesh muslin. One hundred mated females of *T. caspiansis* were introduced into each cage and allowed to oviposit for 24 hours. Subsequently, 100 newly hatched *T. caspiansis* larvae were individually placed in each Petri dish (10 cm in diameter, 1 cm in depth) along with citrus leaves and twenty *P. citri* deutonymphs from the same treatment group. To maintain a consistent prey density for *T. caspiansis*, the *P. citri* deutonymphs were replenished every 24 hours.

The development of all *T. caspiansis* immature stages was monitored daily under a stereomicroscope, and the duration of eggs, larvae, and nymphs, as well as their survivorship, were individually recorded. To assess *T. caspiansis* longevity and fecundity, newly molted male and female adults (less than 12 hours old) from both the treatment and control groups were paired individually in Petri dishes with citrus leaves and twenty *P. citri* deutonymphs from the same treatment group. Again, to maintain a consistent prey density, the *P. citri* deutonymphs were replenished every 24 hours. All newly laid eggs of *T. caspiansis* were counted under a stereomicroscope and removed daily until the *T. caspiansis* adults had perished. This experiment was conducted in a growth chamber set at 25 ± 2°C, with a light-dark cycle of 16 hours light and 8 hours dark, and a relative humidity of 65 ± 5%.

Data analysis

The mean developmental periods, survival rates, and reproduction data of *T. caspiansis* were analyzed using the TWO-SEX-MSChart program (Chi & Liu, 1985; Chi, 1988; Chi, 2022). Age-specific fecundity curves (m_x) and age-specific survival rates (l_x) were calculated following the methodology outlined by Chi (2022). Life table parameters such as net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), and mean generation time (T) were derived from the software output using the age-stage, two-sex life table approach (Chi & Su 2006; Tuan *et al.*, 2014; Yang *et al.*, 2014). Standard errors for developmental periods, survival rates, adult longevity, fecundity, and life table parameters (R_0, r, λ, T) were obtained using the bootstrap technique with 100,000 resamplings, as described by Efron and Tibshirani (1994) and Huang & Chi (2012).

Results

Duration of immature stages

In the first year of the study, a notable difference was observed in the duration of immature stages of *T. caspiansis* (excluding egg and larvae) when fed *P. citri* from citrus seedlings treated with potassium+salicylic acid compared to the control group (Table 1). Specifically, the protonymphal stage lasted longer in the control group (1.90 days) compared to potassium+salicylic acid treatment group (1.77 days) ($P < 0.05$).

Conversely, the deutonymphal stage duration was longer in potassium+salicylic acid treatment group (2.29 days) than in the control group (2.09 days) ($P < 0.05$). Additionally, the total development time was significantly longer in potassium+salicylic acid treatment group (7.29 days) compared to the control group (6.97 days) ($P < 0.05$).

In the second year of the study, there was no significant difference in the duration of the egg, larval, and protonymphal stages of *T. caspiansis* when fed *P. citri* from citrus seedlings treated with potassium+salicylic acid compared to the control group (Table 1). However, the deutonymphal stage duration was significantly longer in potassium+salicylic acid treatment group (2.42 days) than in the control group (2.16 days) ($P < 0.05$). Similarly,

the total development time was significantly longer in potassium+salicylic acid treatment group (7.52 days) compared to the control group (7.05 days) ($P < 0.05$).

Adult longevity and reproduction

In both years, there was no significant difference in the male longevity of *T. caspiansis* when fed on *P. citri* reared on potassium+salicylic acid-treated citrus seedlings compared to control seedlings (Table 2). However, the female longevity of *T. caspiansis* was notably longer when fed *P. citri* from control seedlings (27.25 days in the first year and 28.39 days in the second year) than when fed *P. citri* from potassium+salicylic acid-treated seedlings (26.62 days in the first year and 27.37 days in the second year). Additionally, in both years, both the adult pre-oviposition period and the total pre-oviposition period of *T. caspiansis* were extended when fed *P. citri* from potassium+salicylic acid-treated seedlings (4.06 and 11.52 days in the first year, 3.85 and 11.40 days in the second year) compared to feeding on *P. citri* from control seedlings (3.26 and 10.25 days in the first year, 3.17 and 10.24 days in the second year) (Table 2). Furthermore, the oviposition period was longer when fed on control seedlings (9.99 and 10.72 days, respectively) compared to potassium+salicylic acid-treated seedlings (9.02 and 9.26 days, respectively), while fecundity remained unaffected (Table 2).

Life table parameters

The age-specific survival rate (l_x)of *T. caspiansis*, when fed on *P. citri* reared on potassium+salicylic acid-treated and control citrus seedlings is illustrated in Fig. 1. Our findings indicate that, over two years, this predator completed its development when feeding on both types of *P. citri*. Specifically, the age-specific survival rate (l_x) at the time of adult emergence for *T. caspiansis* was 0.98 and 0.91 in the first year (Fig. 1-A and B) and 0.97 and 0.89 in the second year (Fig. 1-C and D).

when fed on potassium+salicylic acid-treated and control seedlings, respectively. The last female adult (maximum age) mortality occurred on days 32 and 31 in the first year (Fig. 1-A and B) and 31 in the second year (Fig. 1-C and D) for both potassium+salicylic acid-treated and control seedlings. The age-specific fecundity (m_x) of *T. caspiansis*, when fed on *P. citri* reared on potassium+salicylic acid-treated and control citrus seedlings is illustrated in Figure 1. In both years, oviposition of the first female commences on the 9th day under potassium+salicylic acid treatment (Fig. 1-A and C) and the 7th day in the control group (Fig. 1-B and D).

Table 1. The mean (±SE) duration of immature stages of *Typhlodromips caspiansis* fed on *Panonychus citri* reared on untreated and potassium+salicylic acid-treated citrus seedlings.

Developmental stage (day)	First year		Second year	
	Control	Potassium+ Salicylic acid	Control	Potassium+ Salicylic acid
Egg	1.90 ± 0.03 a	1.94 ± 0.02 a	1.89 ± 0.03 a	1.91 ± 0.03 a
Larva	1.17 ± 0.03 a	1.29 ± 0.05 a	1.16 ± 0.04 a	1.25 ± 0.05 a
Protonymph	1.90 ± 0.03 a	1.77 ± 0.04 b	1.85 ± 0.04 a	1.85 ± 0.04 a
Deutonymph	2.09 ± 0.03 b	2.29 ± 0.06 a	2.16 ± 0.04 b	2.42 ± 0.05 a
Total immature stages	6.97 ± 0.06 b	7.29 ± 0.08 a	7.05 ± 0.07 b	7.52 ± 0.09 a

In each year, means in a row followed by different letters are significantly different at $P< 0.05$ by using a paired bootstrap test.

Table 2. The mean (±SE) duration of adults' longevity and reproductive parameters of *Typhlodromips caspiansis* fed on *Panonychus citri* reared on untreated and potassium+salicylic acid-treated citrus seedlings.

Parameters	First year		Second year	
	Control	Potassium+ Salicylic acid	Control	Potassium+ Salicylic acid
Male longevity (day)	26.9 ± 0.5 a	27.6 ± 0.6 a	26.6 ± 0.5 a	27.7 ± 0.5 a
Female longevity (day)	27.2 ± 0.2 a	26.6 ± 0.3 b	28.4 ± 0.3 a	27.4 ± 0.3 b
Adult pre-oviposition period (APOP; day)	3.26 ± 0.10 b	4.06 ± 0.09 a	3.17 ± 0.08 b	3.85 ± 0.09 a
Total pre-oviposition period (TPOP; day)	10.2 ± 0.1 b	11.5 ± 0.1 a	10.2 ± 0.1 b	11.4 ± 0.1 a
Oviposition period (day)	9.99 ± 0.18 a	9.02 ± 0.15 b	10.7 ± 0.2 a	9.26 ± 0.18 b
Fecundity (eggs/female)	21.0 ± 0.4 a	21.8 ± 0.4 a	21.8 ± 0.3 a	21.2 ± 0.4 a

In each year, means in a row followed by different letters are significantly different at $P< 0.05$ by using a paired bootstrap test.

In the first year, the peaks of female progeny (highest daily fecundity) were 1.38 (at the age of 18 days) and 1.43 (at 13 days) females/female/day in potassium+salicylic acid treatment and control, respectively (Fig. 1-A and B). In the second year, the peaks of female progeny were 1.37 (at the age of 17 days) and 1.38 (at age 16 days) females/female/day in potassium+salicylic acid treatment and control, respectively (Fig. 1-C and D). The age-stage specific survival rate (S_{xj}) of *T. caspiansis* expresses the survival potential of newly hatched immatures in age *x* and stage *j*. The results showed that potassium+salicylic acid treatment did not affect relative numbers of alive larvae/nymphs compared with controls in both years (Fig. 2). The female age-specific fecundity (f_{xj}) of *T. caspiansis*, when fed on *P. citri* reared on potassium+salicylic acid-treated and control citrus seedlings, is illustrated in (Fig. 3). A similar trend with m_x was observed in f_{xj} changes of predators fed on control and treatment.

Analysis of the life table parameters of *T. caspiansis* for both years revealed no significant differences between potassium+salicylic acid-treated and control citrus seedlings in terms of net reproductive rate (R_0), intrinsic rate of increase (r), and finite rate of increase (λ). However, there was a significant difference in mean generation time (T) between the two groups (first year: 16.42 vs. 15.49 days, respectively; second year: 15.82 vs. 16.27 days, respectively) as shown in Table 3.

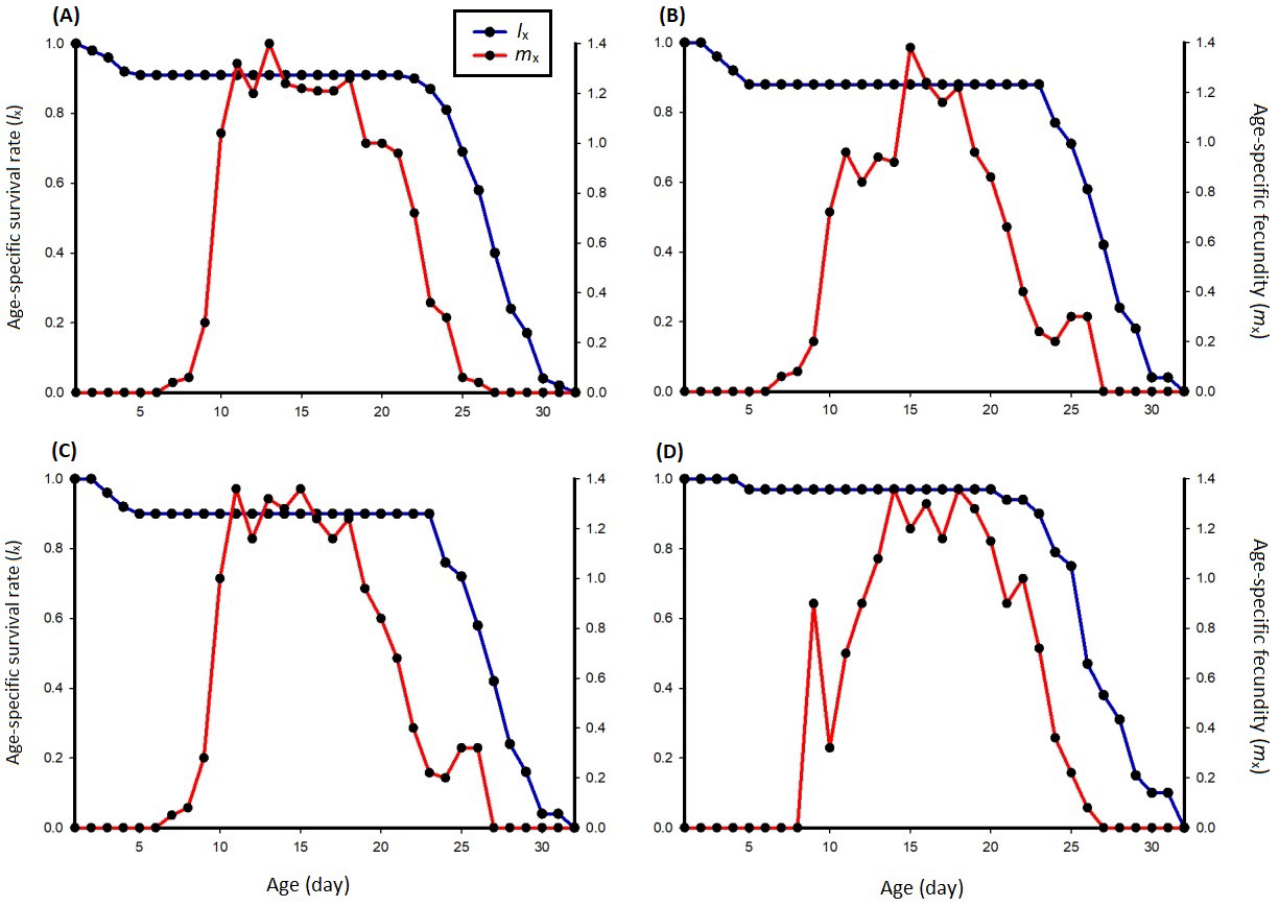

Fig. 1. Age-specific survival rate (l_x) and fecundity (m_x) of *Typhlodromips caspiansis* fed on *Panonychus citri* reared on untreated (B: first year, D: second year) and potassium+salicylic acid-treated (A: first year, C: second year) citrus seedlings.

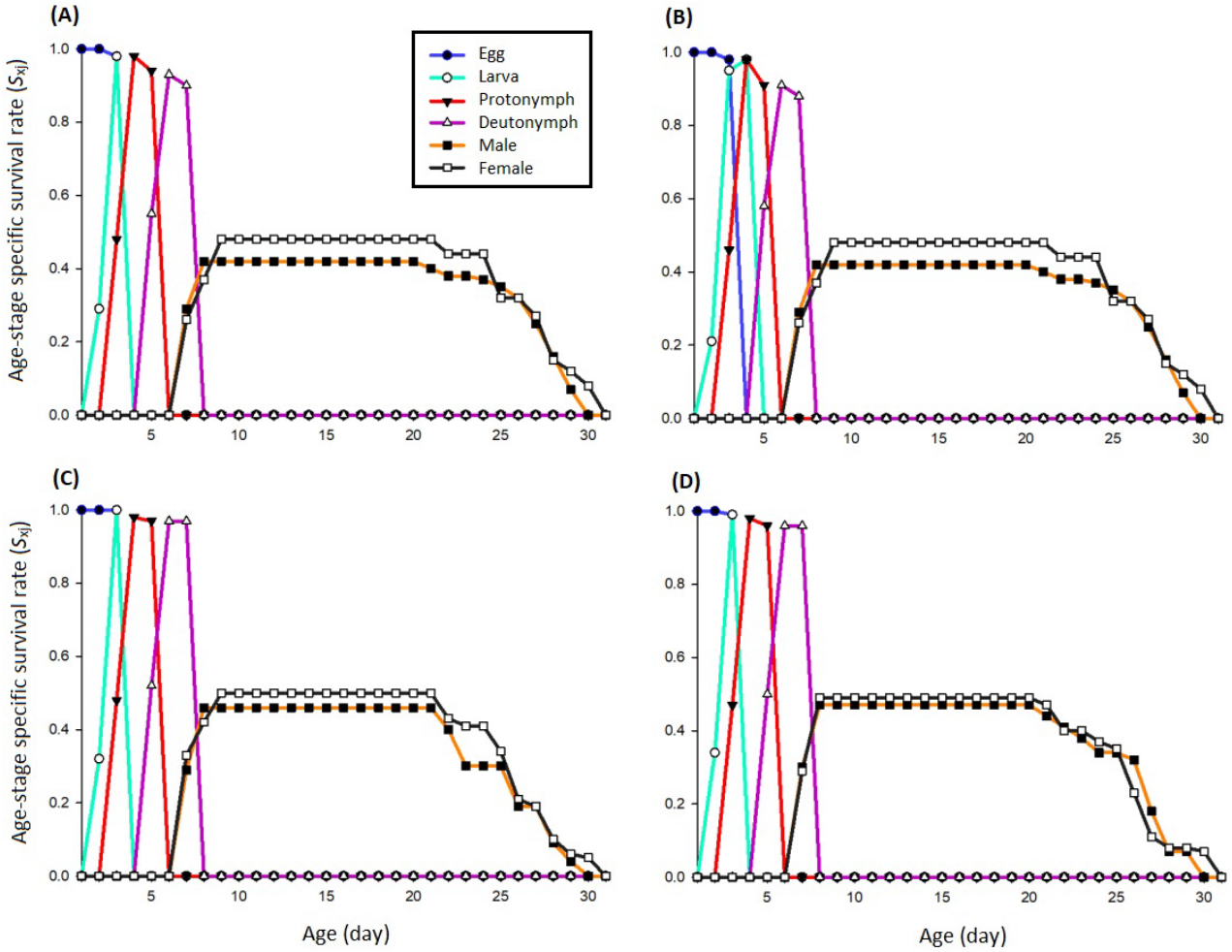

Fig. 2. Age-stage specific survival rate (S_{xj}) of *Typhlodromips caspiansis* fed on *Panonychus citri* reared on untreated (B: first year, D: second year) and potassium+salicylic acid-treated (A: first year, C: second year) citrus seedlings.

Discussion

Natural enemies, such as predators, play a crucial role in community assembly and ecosystem function. Their success is dependent on the quantity and quality of their prey, which are greatly influenced by the quality and availability of the host plant (Garratt *et al.*, 2011).

Previous literature supports the idea of bottom-up cascades in plant-host-predator food webs (Borer *et al.*, 2006; Daugherty *et al.*, 2007; Chen *et al.*, 2010; Riggi & Bommarco, 2019), suggesting that host resources indirectly impact predator efficacy. Our study revealed that variations in the quality of *P. citri* affected the developmental time of immature stages and reduced the female longevity of *T. caspiansis*. However, it did not have an impact on fecundity and life-table parameters, except for the mean generation time of the predatory mite.

In our study, the similar duration of *T. caspiansis* larvae on potassium+salicylic acid-treated and control citrus seedlings can be attributed to the species' facultative feeding habits during this stage (Rafatifard *et al.*, 2004). The developmental period of deutonymphs and the overall immature stages of *T. caspiansis* were prolonged when they were fed *P. citri* from citrus seedlings treated with potassium+salicylic acid. Treatment of seedlings may offer low-quality nutrients to insect herbivores, diminishing their fitness and weight. Consequently, the immature stages of *T. caspiansis* develop at a slower pace to acquire the necessary food and mitigate the adverse effects of a subpar diet. Our findings align with a study on a Bell pepper–aphid–predator system by Mirab-balou and Alizamani (2022), where the larval development time of *A. aphidimyza* was extended by the application of Fe, Mn, Cu, and Zn fertilizers. Conversely, in a separate study, the application of salicylic acid did not impact the developmental rate of *C. carnea* immatures, predators of *Aphis gossypii* Glover (Hemiptera: Aphididae) (Moreno-Delafuente *et al.*, 2020).

The extended lifespan of predators can effectively reduce populations of herbivorous insects (Barclay, 1982) as predators have the potential to consume more prey, leading to stronger adults with higher reproductive success. In our study, the adult longevity of female *T. caspiansis* was reduced by the application of potassium+salicylic acid. We hypothesized that *P. citri* may transfer harmful effects from plants, such as secondary metabolites, to its predators. This decrease in longevity could have a negative impact on the control of *P. citri*. Interestingly, the treatment did not affect the longevity of male *T. caspiansis* in our experiment, possibly because males allocate their energy towards detoxification rather than egg production, thereby neutralizing the negative effects of the treated prey. The difference in the results of the two studies may be due to differences in the nutritional characteristics of the studied species. Because both nymphs and adults of *P. citri* have feeding activity (Rafati-Fard *et al.*, 2004), poor-quality food probably has greater negative effects on this species.

In contrast to our results, Mirab-balou and Alizamani (2022) demonstrated that the adult longevity and fecundity of *A. aphidimyza* increased when feeding on hosts reared on fertilized treated plants. Additionally, consistent with Soltaniyan *et al.* (2020), we observed that low food quality only delays oviposition by *T. caspiansis* without reducing or increasing it. The l_x and m_x curves demonstrate the bottom-up effects of fertilization on the third level of the food chain (Fig. 1). A decrease in nutrition quality may lead to lower survival rates and delayed reproduction (Razmjou *et al.*, 2006; Gharekhani *et al.*, 2020).

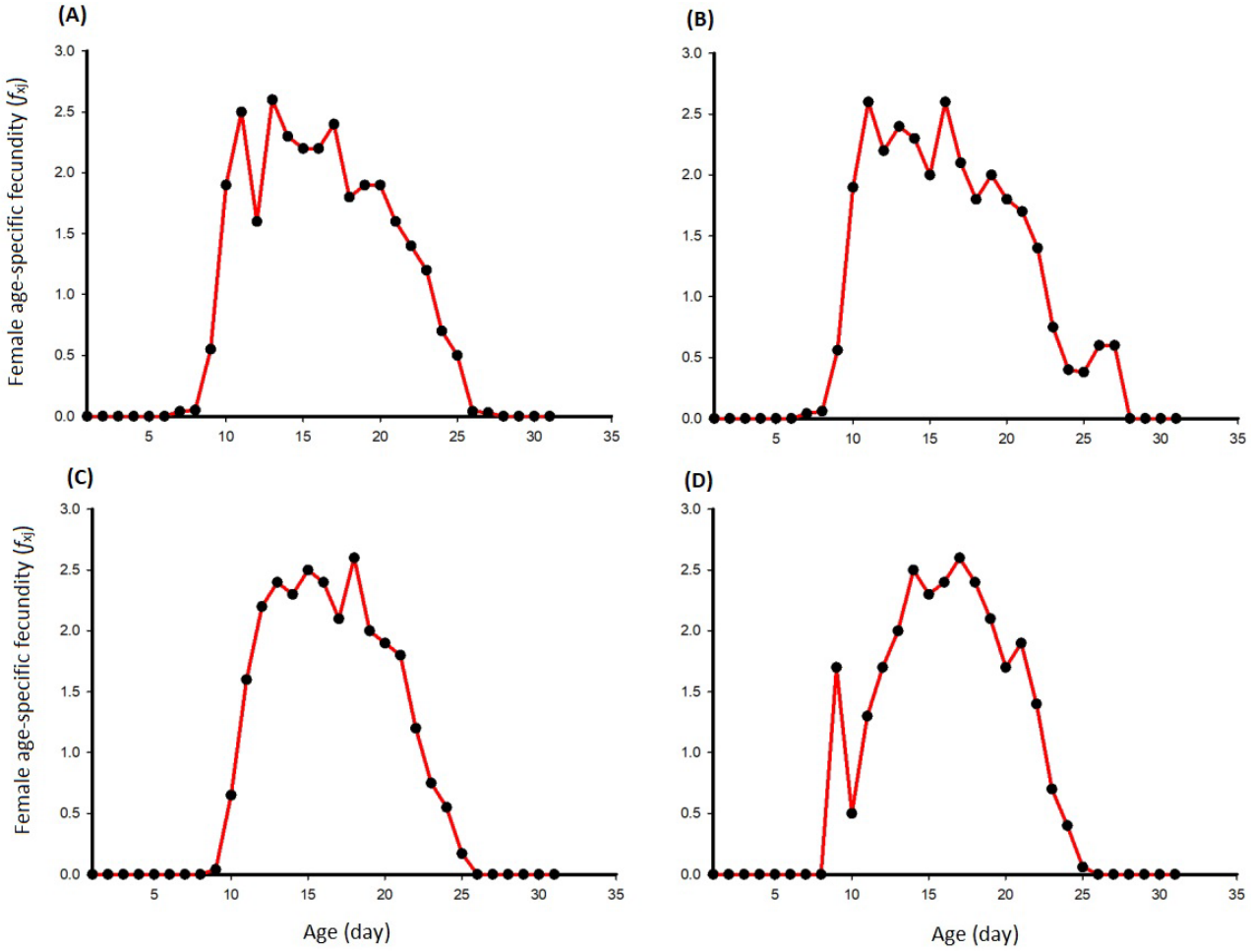

Fig. 3. Female age-specific fecundity (f_{xj}) of *Typhlodromips caspiansis* fed on *Panonychus citri* reared on untreated (B: first year, D: second year) and potassium+salicylic acid-treated (A: first year, C: second year) citrus seedlings.

Table 3. The mean (±SE) life table parameters of *Typhlodromips caspiansis* fed on *Panonychus citri* reared on untreated and potassium+salicylic acid-treated citrus seedlings.

Developmental stage (day)	First year		Second year	
	Control	Potassium+ Salicylic acid	Control	Potassium+ Salicylic acid
R_0 (offspring)	14.4±1.0 a	14.4±1.0 a	15.5±0.1 a	15.7±1.1 a
r_m(day^{-1})	0.172±0.005 a	0.162±0.005 a	0/171±0.006 a	0.160±0.005 a
λ(day^{-1})	1.19±0.01 a	1.18±0.01 a	1.19±0.00 a	1.17±0.01 a
T (day)	15.5±0.1 b	16.4±0.1 a	15.8±0.1 a	16.3±0.1 b

In each year, means in a row followed by different letters are significantly different at $P< 0.05$ by using a paired bootstrap test.

The similar or positive intrinsic rate of increase (r) and finite rate of increase (λ) values in potassium+salicylic acid treatment and control groups suggest higher birth rates compared to mortality rates (Santos *et al.*, 2014). Similarly, the identical R_0 parameter values for these treatments indicate similar numbers of offspring (Menezes *et al.*, 2014). *Typhlodromips caspiansis*, when fed on *P. citri* reared on potassium+salicylic acid-treated citrus seedlings, exhibited a longer mean generation time (T) compared to the control group. If does not impact the r value, a higher T value is desirable in biocontrol programs as it extends the predation period. Some studies suggest that fertilization or salicylic acid treatment triggers resistance mechanisms in plants, ultimately affecting predator performance (Walde, 1995; El-Doksh *et al.*, 2005; Mallinger *et al.*, 2011; Han *et al.*, 2015; Yali & Sattari-Nassab, 2020), while others indicate the absence of such cascading effects (Yang *et al.*, 2016; Alakhdar & Abou-Setta, 2021; Rowen & Tooker, 2021). We believe that this dichotomy may be linked to species' life history strategies and how host plants alter the quality of herbivorous hosts. In our study, the reduction in food quality forced immature stages to extend their growth period to obtain the nutritional requirements (Mahpoya *et al.*, 2023). However, the decrease in food quality probably did not have an important effect on the physiology of predatory mites and their energy reserves. Therefore, their vital factors, including the fecundity of female adults, were unaffected. Finally, the results showed that the reduction in food quality does not have a negative effect on the life table parameters of *T. caspiansis* population.

In summary, this study contributes an additional example to the existing research on interactions between plants, herbivorous mites, and predators. In our previous study (Mahpoya *et al.*, 2023), we observed that citrus seedlings treated with potassium+salicylic acid significantly reduced the fitness parameters of *P. citri*. In the present study, despite observing a decrease in survival rate, we found that the reproduction and population growth rates of the predator were not affected when *T. caspiansis* fed on *P. citri* reared on citrus seedlings treated with potassium+salicylic acid compared to the control group. These findings suggest that our study could offer valuable insights into the combined use of inducers, fertilizers, and natural enemies in managing *P. citri*. However, further research is necessary to assess the predatory performance of *T. caspiansis* on fertilized/induced citrus under field conditions.

Author's Contributions

Zahra Mahpoya: conceptualization, methodology, formal analysis, investigation, draft preparation, visualization**; JabraeilRazmjou:** conceptualization, methodology, final review and edit, supervision, project administration and funding acquisition**; Sirous Aghajanzadeh:** conceptualization, methodology, final review and edit, visualization**; Seyed Ali Asghar Fathi:** final review and edit, visualization**; Mahdi Hasanpour:** final review and edit.

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Funding

This work supported by the University of Mohaghegh Ardabili.

Data Availability Statement

All data supporting the findings of this study are available within the paper.

Acknowledgments

The work received financial support from the University of MohagheghArdabili (Ardabil, Iran) which is greatly appreciated.

Ethics Approval

Insects and plants were used in this study. All applicable international, national, and institutional guidelines for the care and use of animals were followed. This article does not contain any studies with human participants performed by the author.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

REFERENCES

Aguilera, G., Riggi, L., Miller, K., Roslin, T. & Bommarco, R. (2021) Organic fertilisation enhances generalist predators and suppresses aphid growth in the absence of specialist predators. *Journal of Applied Ecology* 58, 1455–1465. https://doi.org/10.1111/1365-2664.13862.

Alakhdar, H. H. & Abou-Setta, M. M. (2021) Efficacy of three elicitors on *Tetranychus urticae* Koch (Acari: Tetranychidae) infestation level and its associated natural enemies on *Phaseolus vulgaris* L. and their effects on plant parameters. *Phytoparasitica*. 49:935–942. https://doi.org/10.1007/s12600-021-00931-x.

Barclay, H. J. (1982) Models for pest control using predator release, habitat management and pesticide release in combination. *Journal of Applied Ecology* 19(2):337-348. https://doi.org/10.2307/2403471.

Borer, E. T., Halpern, B. S. & Seabloom, E. W. (2006) Asymmetry in community regulation: Effects of predators and productivity. *Ecology* 87(11), 2813-2820. https://doi.org/10.1890/0012-9658.

Chen, Y., Olson, D. M. & Ruberson, J. R. (2010) Effects of nitrogen fertilization on tritrophic interactions. *Arthropod-Plant Interaction* 4, 81-94. https://doi.org/10.1007/s11829-010-9092-5.

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

Chi, H. (2022) TWOSEX-MSChart: A Computer Program for the Age-Stage, Two-Sex Life Table Analysis; National Chung Hsing University: Taichung, Taiwan, 2022; Available online: http://140.120.197.173/Ecology/ (accessed on 8 March 2021).

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

Childers, C. C. & Fasulo, T. R. (2009) Citrus red Mite, IFAS Extension, *ENY817 University of Florida*. (https://ufdcimages.uflib.ufl.edu/IR/00/00/46/19/00001/CH02100.pdf).

Cokendolpher, J. C., Zamani, A. & Snegovaya, N. Y. (2019) Overview of arachnids and arachnology in Iran. *Journal of Insect Biodiversity and Systematics* 5(4), 301–367. http://zoobank.org/References/25A30039-DA91-4E19-AD93-50098BB2BB61.

Daugherty, M. P., Briggs, C. J. & Welter, S. C. (2007) Bottom-up and top-down control of pear psylla (*Cacopsylla pyricola*): Fertilization, plant quality, and the efficacy of the predator *Anthocoris nemoralis*. *Biological Control* 43(3), 257-264. https://doi.org/10.1016/j.biocontrol.2007.09.001.

Efron, B. & Tibshirani, R. J. (1994) An Introduction to the Bootstrap; Chapman and Hall/CRC Press: New York, NY, USA.

El-Doksh, R. A. A., EI-Nagar, J. B. & Hegazy, W. H. (2005) Effect of potassium fertilizer on the population of certain sucking insects and their associated predators in cotton fields. *Journal of Plant Protection and Pathology* 30(9), 5607-5615. https://doi.org/10.21608/jppp.2005.239025.

Erb, M., Züst, T. & Robert, C. A. M. (2021) Using plant chemistry to improve interactions between plants, herbivores and their natural enemies: challenges and opportunities. *Current Opinion in Biotechnology* 70, 262-265. https://doi.org/10.1016/j.copbio.2021.05.011.

Fallahpour, F., Hosseini, M., Ghorbani, R. & NassiriMahallati, M. (2013) The effect of canola fertilization on predation and development of *Aphidoletes aphidomyza* on *Lipaphis erysimi*. *Conference of Biological Control in Agriculture and Natural Resources*, University of Tehran, 27-28.

Feng, J. L., Zhang, J., Yang, J., Zou, L. P., Fang, T. T., Xu, H. L. & CAI, Q. N. (2021) Exogenous salicylic acid improves resistance of aphid-susceptible wheat to the grain aphid, *Sitobion avenae* (F.) (Hemiptera: Aphididae). *Bulletin of Entomological Research*. https://doi.org/10.1017/S0007485321000237.

Filgueiras, C. C., Martins, A. D., Pereira, R. V. & Willett, D. S. (2019) The Ecology of salicylic acid signaling: primary, secondary and tertiary effects with applications in agriculture. *International Journal of Molecular Sciences* 20(23), 5851. https://doi.org/10.3390/ijms20235851.

Garratt, M. P. D., Wright, D. J. & Leather, S. R. (2011) the effects of farming system and fertilisers on pests and natural enemies: a synthesis of current research. *Agriculture, Ecosystems & Environment* 141(3-4), 261-270. https://doi.org/10.1016/j.agee.2011.03.014.

Gharekhani, G., Salehi, F., Shirazi, J. & Vaez, N. (2020) Tri-trophic interactions among nitrogen-fertilized tomato cultivars, the tomato fruit worm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) and the ectoparasitoid, *Habrobracon hebetor* (Say) (Hymenoptera: Braconidae). *Egyptian Journal of Biological Pest Control* 30, 6. https://doi.org/10.1186/s41938-019-0199-4.

Hajizadeh, J. &Nazari, M. (2012) A checklist and key for the Phytoseiid mites (Acari: Phytoseiidae) of citrus orchards in Iran, with a new record for Iranian Phytoseiid mites. *Systematic and Applied Acarology* 17(4), 388-396. https://doi.org/10.11158/saa.17.4.7.

Han, P., Bearez, P., Adamowicz, S., Lavoir, A. V., Amiens-Desneux, E. & Desneux, N. (2015) Nitrogen and water limitations in tomato plants trigger negative bottom-up effects on the omnivorous predator *Macrolophus pygmaeus*. *Journal of Pest Science* 88, 685–691. https://doi.org/10.1007/s10340-015-0662-2.

Han, P., Lavoir, A. V., Rodriguez-Saona, C. & Desneux, N. (2022) Bottom-up forces in agroecosystems and their potential impact on arthropod pest management. *Annual Review of Entomology* 67, 239–59. https://doi.org/10.1146/annurev-ento-060121-060505.

Hasanuzzaman, M., Bhuyan, M. H. M. B., Nahar, K., Hossain, M. S., Mahmud, J. A., Hossen, M. S., Masud, A. A. C. & Moumita, F. M. (2018) Potassium: A vital regulator of plant responses and tolerance to abiotic stresses. *Agronomy* 8, 31. https://doi.org/10.3390/agronomy8030031.

Hill, M. P., Macfadyen, S., Nash, M. A. (2017) Broad spectrum pesticide application alters natural enemy communities and may facilitate secondary pest outbreaks. *PeerJ* 5, e4179. https://doi.org/10.7717%2Fpeerj.4179.

Horgan, F. G., CrisolMartínez, E., Stuart, A. M., Bernal, C. C., de Cima Martín, E., Almazan, M. L. P., Ramal, A. F. (2019) Effects of vegetation strips, fertilizer levels and varietal resistance on the integrated management of arthropod biodiversity in a tropical rice ecosystem. *Insects* 10 (10), 328. https://doi.org/10.3390/insects10100328.

Huang, Y. B. & Chi, H. (2012) Age-stage, two-sex life tables of *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) with a discussion on the problem of applying female age-specific life tables to insect populations. *Insect Science* 19, 263–273. https://doi.org/10.1111/j.1744-7917.2011.01424.x.

Ibanez, F., Suh, J. H., Wang. Y., Rivera, M., Setamou, M. & Stelinski, L. L. (2022) Salicylic acid mediated immune response of Citrus sinensis to varying frequencies of herbivory and pathogen inoculation. *BMC Plant Biology* 22, 7. https://doi.org/10.1186/s12870-021-03389-5.

Indhumathi, J., Muthukrishnan, N., Durairaj, C., Thavaprakaash, N. & Soundararajan, R. P. (2019) Effect of methyl salicylate on rice leaffolder *Cnaphalocrocis medinalis* (Guenee), parasitoid *Xanthopimpla flavolineata* (Cameron) and predator *Micraspis sp*. *Madras Agricultural Journal* 106 (1-3), 1. https://doi.org/10.1007/s13744-020-00771-0.

Jafarbeigi, F., Samih, M. A., Alaei, H. & Shirani, H. (2020) Induced tomato resistance against *Bemisia tabaci* triggered by salicylic acid, β-aminobutyric acid, and *Trichoderma*. *Neotropical Entomology* 49, 456–467. https://doi.org/10.1007/s13744-020-00771-0.

Jeer, M., Yele, Y., Sharma, K. C. & Prakash, N. B. (2021) Exogenous application of different silicon sources and potassium reduces pink stem borer damage and improves photosynthesis, yield and related parameters in wheat. *Silicon* 13, 901–910. https://doi.org/10.1007/s12633-020-00481-7.

Langgut, D. (2017) The citrus route revealed: From Southeast Asia into the Mediterranean. *HortScience* 52(6), 814–822. http://dx.doi.org/10.21273/HORTSCI11023-16.

Liu, P., Ma, H., Zhu, Q. S., Chen, B. C., GAO, J. & Lin, X. Q. (2016) Research progress of insect adaptability to their host plants. *Biological Disaster Science* 39, 250–254. https://doi.org/10.16380/j.kcxb.2024.02.013.

Mahpuya, Z, Razmjou, J., Aghajanzadeh, S., Fathi, SA. A. & Hassanpour, M. (2023) Salicylic acid and fertilizers affect the performance of *Panonychuscitri* (McGregor) (Acari; Tetranychidae) on citrus seedlings. *International Journal of Acarology* 50(1), 1-9. https://doi.org/10.1080/01647954.2023.2287491.

Mallinger, R. E, Hogg, D. B. & Gratton, C. (2011) Methyl salicylate attracts natural enemies and reduces populations of Soybean aphids (Hemiptera: Aphididae) in soybean agroecosystems. *Journal of Economic Entomology*. 104(1), 115-124. https://doi.org/10.1603/ec10253.

Menezes, C. W. G., Camilo, S. S., Fonseca, A. J., AssisJúnior, S. L., Bispo, D. F. & Soares, M. A. (2014) A dietaalimentar da presa *Tenebrio molitor* (Coleoptera: Tenebrionidae) podeafetar o desenvolvimento do predador *Podisus nigrispinus* (Heteroptera: Pentatomidae)? *Arquivos do Instituto Biológico* 81, 250–256. https://doi.org/10.1590/1808-1657001212012.

Mirab-balou, M. & Alizamani, T. (2022) The effect of nutritional interaction between micronutrient fertilizers and *Capsicum annuum* L. on the population growth of *Aphidoletes aphidimyza* Rondani as predator of green peach aphid. *Journal of Iranian Plant Protection Research* 35(4), 481-494 (in Persian with English abstract). http://dx.doi.org/10.22067/JPP.2021.70745.1028.

Moreno-Delafuente, A., Garzo, E., Fereres, A., Viñuela, E. & Medina, P. (2020) Effects of a salicylic acid analog on *Aphis gossypii* and its predator *Chrysoperla carnea* on melon plants. *Agronomy* 10, 1830. https://doi.org/10.3390/agronomy10111830.

Moursy, F. S., Gad, D. A. M., Adly, D. & Sadek, I. I. (2021) Study the effect of two organic fertilizers, methods of fertilization on productivity, pests and predatory insects associated with eggplant under modified climatic condition. GSC *Biological and Pharmaceutical Sciences* 16(01), 170–185. https://doi.org/10.30574/gscbps.2021.16.1.0205.

Mwangangi, I. M., Büchi, L., Haefele, S. M., Bastiaans, L., Runo, S. & Rodenburg, J. (2021) Combining host plant defence with targeted nutrition: Key to durable control of hemiparasitic *Striga* in cereals in sub-Saharan Africa*? New Phytologist* 230(6), 2164-2178. https://doi.org/10.1111/nph.17271.

Novljan, M., Bohinc, T., Kreiter, S., Döker, I. & Trdan, S. (2023) The indigenous species of predatory mites (Acari: Phytoseiidae) as biological control agents of plant pests in Slovenia. *Acarologia* 63(4), 1048-1061. https://doi.org/10.24349/0p4s-gjtm.

Omidi, J., Hadizadeh, A. & MohammadiSharif, M. (2016) Species diversity of phytoseiid mites on different ecosystems in Sari district. *Journal of Agroecology* 7, 461-472. https://doi.org/10.22067/jag.v7i4.28579.

Patt, J. M., Robbins, P. S., Niedz, R. P., McCollum, T. G. & Alessandro, R. (2018) Exogenous application of the plant signalers methyl jasmonate and salicylic acid induces changes in volatile emissions from citrus foliage and influences the aggregation behavior of Asian citrus psyllid (*Diaphorina citri*), vector of Huanglongbing. *PLos One* 13(3). e0193724. https://doi.org/10.1371/journal.pone.0193724.

Qayyoum, M. A., Song, Z. W., Zhang, B. X., Li, D. S. (2021) Dispersal mechanism assessment for *Panonychus citri* (Acari: Tetranychidae) secondary outbreaks. *Annals of Entomological Society of America* 114(4), 501–510. https://doi.org/10.1093/aesa/saab008.

Rafati-Fard, M., Hajizadeh, J. & Arbabi, M. (2004) Biology of *Typhlodromips caspiansis* (Acari: Phytoseiidae) predator of some spider mites (Acari: Tetranychidae) under laboratory conditions. *Journal of Entomological Society of Iran* 24(1), 49-65. (in Persian with English abstract).

Rafatifard, M., Hajizadeh, J. & Arbabi, M. (2004) Biology of *Typhlodromips caspiansis* (Acari: Phytoseiidae) predator of some spider mites (Acari: Tetranychidae) under laboratory condition. *Journal of Entomological Society of Iran* 24(1), 49-65. (In Persian with English abstract).

Rahmani, H., Kamali, K. & Faraji, F. (2010) Predatory mite fauna of Phytoseiidae of Northwest Iran (Acari: Mesostigmata). *Turkish Journal of Zoology* 34, 8. https://doi.org/10.3906/zoo-0902-23.

Rashid, M. M., Jahan, M. & Islam, K. S. (2016) Impact of nitrogen, phosphorus and potassium on brown planthopper and tolerance of its host rice plants. *Rice Science* 23(3), 119-131. https://doi.org/10.1016/j.rsci.2016.04.001.

Razmjou, J., Moharramipour, S., Fathipour, Y. & Mirhoseini, S. Z. (2006) Effect of cotton cultivar on performance of *Aphis gossypii* (Hom. Aphididae) in Iran. *Journal of Economic Entomology*. 99(5), 1820-1825. https://doi.org/10.1603/0022-0493-99.5.1820.

Riggi, L. G. & Bommarco, R. (2019) Subsidy type and quality determine direction and strength of trophic cascades in arthropod food webs in agroecosystems. *Journal of Applied Ecology* 56(8), 1982-1991. https://doi.org/10.1111/1365-2664.13444.

Rowen, E. K. &Tooker, J. F. (2021) Ground predator activity-density and predation rates are weakly supported by dry-stack cow manure and wheat cover crops in no-till maize. *Environmental Entomology* 50(1), 46–57. https://doi.org/10.1093/ee/nvaa136.

Santos, A. A., Almeida, L. M., Castro-Guedes, C. F. & Penteado, S. R. C. (2014) Life table analysis and consumption capacity for *Harmonia axyridis* (Coleoptera: Coccinellidae), feeding on *Cinara atlantica* (Hemiptera: Aphididae). *Florida Entomology*. 97, 1702–1709. http://www.jstor.org/stable/24364132.

Singh, A. & Sarkar, S. (2021) Effect of excess use of fertilizers on insect/pest infestation in *Oryza sativa*: A review. *Journal of Entomology and Zoology Studies* 9(5), 246-252. https://doi.org/10.22271/j.ento.2021.v9.i5c.8834.

Soltaniyan, A., Kheradmand, K., Fathipour, Y. & Shirdel, D. (2020) Supplementation of natural prey with pollen grains exerts an influence on the life table parameters of *Neoseiulus californicus*. *Bulletin of Entomological Research*. 1–7. https://doi.org/10.1017/S000748532000005X.

Tuan, S. J., Lee, C. C. & Chi, H. (2014) Population and damage projection of *Spodoptera litura* (F.) on peanuts (*Arachis hypogaea* L.) under different conditions using the age-stage, two-sex life table. *Pest Management Science* 70, 805–13. https://doi.org/10.1002/ps.3618.

Turlings, T. C. J. & Wackers, F. (2004) Recruitment of predators and parasitoids by herbivore-injured plants. *Advances in Chemical Ecology* 2, 21-75. https://doi.org/10.1017/CBO9780511542664.003.

Ullah, M. I., Riaz, M., Arshad, M., Khan, A. H., Afzal, M., Khalid, S., Mehmood, N., Ali, S., Khan, A. M., Zahid, S. M. A. & Riaz, M. (2019) Application of organic fertilizers affect the Citrus leafminer, *Phyllocnistis citrella* (Lepidoptera: Gracillariidae) infestation and citrus canker disease in Nursery plantations. *International Journal of Insect Science*. https://doi.org/10.1177/1179543319858634.

Urbaneja, A., Grout, T. G., Gravena, S., Wu, F., Cen, Y. & Stansly, P. A. (2020) Citrus Pests in a Global World. The Genus Citrus. *Elsevier* Inc. https://doi.org/10.1016/B978-0-12-812163-4.00016-4.

Vieira, D. L., de Oliveira Barbosa, V., de Souza, W. C. O., da Silva, J. G., Malaquias, J. B. & de Luna Batista, J. (2016) Potassium silicate-induced resistance against blackfly in seedlings of *Citrus reticulata*. *Fruits* 71(1), 49-55. https://doi.org/10.1051/fruits/2015047.

Walde, S. J. (1995) How quality of host plant affects a predator-prey interaction in biological control. *Ecology* 76 (4), 1206–1219. https://doi.org/10.2307/1940927.

Wang, M., Zheng, Q., Shen, Q. & Guo, S. (2013) The critical role of potassium in plant stress response. *International Journal of Molecular Sciences*. 14, 7370-7390. https://doi.org/10.3390%2Fijms14047370.

War, A. R., Hussain, B. & Sharma, H. C. (2013) Induced resistance in groundnut by jasmonic acid and salicylic acid through alteration of trichome density and oviposition by *Helicoverpa armigera* (Lepidoptera: Noctuidae). *AOB Plants*. 5: plt 053. https://doi.org/10.1093%2Faobpla%2Fplt053.

Yali, M. P. & Sattari_Nassab, R. (2020) Evaluating the biological control capability of *Coccinella septempunctata* on canola plants treated with humic acid and salicylic acid via functional response experiments. *International Journal of Tropical Insect Science*. 40, 1031–1041. https://doi.org/10.1007/s42690-020-00162-3.

Yang, Y., Li, W., Xie, W., Wu, Q., Xu, B., Wang, S., Li, C. & Zhang, Y. (2014) Development of *Bradysia odoriphaga* (Diptera: Sciaridae) as affected by humidity: An age–stage, two-sex, life-table study. *Applied Entomoloy and Zoology*. 50, 3–10. https://doi.org/10.1007/s13355-014-0295-6.

Yang, Y., Liu, K., Han, H., Xu, H., Zhang, F., Zheng, X., Tian, J., Wang, G., Chen, G. & Lu, Z. (2016) Impacts of nitrogen fertilizer on major insect pests and their predators in transgenic BT rice lines T2A-1 and T1C-19. *Entomologia Experimentalis et Applicata*. 160, 281–291. https://doi.org/10.1111/eea.12479.

Zhang, Z. Y., Ali, M. W., Saqib, H. S. A., Liu, S. X., Yang, X., Li, Q. & Zhang, H. (2020) A shift pattern of bacterial communities across the life stages of the citrus red mite, *Panonychus citri*. *Frontiers in Microbiology*. 11:1620. https://doi.org/10.3389/fmicb.2020.01620.

Zörb, C., Senbayram, M. & Edgar, P. (2014) Potassium in agriculture – Status and perspectives. *Journal of Plant Physiology* 171(9), 656–669. https://doi.org/10.1016/j.jplph.2013.08.008.

Citation: Mahpoya, Z., Razmjou, J., Aghajanzadeh, S., Fathi, S. A. A. & Hasanpour, M. (2025) Impact of potassium and salicylic acid on predator performance: Life table analysis of *Typhlodromips caspiansis* Denmark &Daneshvar (Acari: Phytoseiidae) *J. Entomol. Soc. Iran* 45 (1), 107–119.

DOI: https://doi.org/10.61186/jesi.45.1.10

URL: https://jesi.areeo.ac.ir/article_131275.html

pISSN: 0259-9996 – eISSN: 2783-3968

Journal of Entomological Society of Iran

2025, 45 (1), 107–119

تاثیر پتاسیم و سالیسلیک اسید روی عملکرد شکارگر: تجزیه و تحلیل جدول زندگی *Typhlodromips caspiansis* Denmark & Daneshvar (Acari: Phytoseiidae)

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۲- مرکز تحقیقات مرکبات و میوه های نیمه گرمسیری ، رامسر، ایران

چکیده: کنه‌ی قرمز مرکبات، *Panonychus citri* (McGregor) می‌تواند آسیب شدیدی به درختان مرکبات وارد کند. *Typhlodromips caspiansis* کنه‌ی شکارگر بومی این آفت است که اخیراً همراه با کنه‌ی قرمز مرکبات در استان‌های شمالی ایران گزارش شده است. در مطالعه‌ی حاضر، القای مقاومت در نهال های مرکبات دو ساله پس از محلول‌پاشی با اسید سالیسیلیک+پتاسیم، در برابر *P. citri* انجام شد. همچنین اثر پایین به بالای اسید سالیسیلیک+پتاسیم بر پارامترهای رشد جمعیت *T. caspiansis* تغذیه شده روی *P. citri* پرورش‌یافته روی گیاهان تیمار شده بررسی شد. نهال‌های دو ساله‌ی مرکبات با محلول اسید سالیسیلیک (۱میلی مولار) +پتاسیم (۰.۰۲ گرم/لیتر) پاشش شدند و محلول‌پاشی با آب به‌عنوان شاهد بود. میزان بقا و مدت مراحل نابالغ، طول عمر و باروری بالغین *T. caspiansis* در تیمار پتاسیم+سالیسیلیک اسید در شرایط اتاقک رشد (۲ ± ۲۵ درجه‌ی سلسیوس، رطوبت نسبی ۵ ± ۶۵ درصدبا طول روز ۱۶ ساعت) ثبت شد. تفاوت معنی‌داری در طول دوره‌ی تخم و لارو *T. caspiansis* تغذیه شده با *P. citri* پرورش یافته با کود پتاسیم+سالیسیلیک اسید و شاهد مشاهده نشد. در مقایسه با شاهد، این تیمار طول دوره‌ی پوره‌ی سن دو را طولانی‌تر کرد. نرخ خالص تولیدمثلی (R_0)، نرخ ذاتی افزایش جمعیت (r) و نرخ متناهی افزایش جمعیت (λ) کنه‌ی *T. Caspiansis* تفاوت معنی‌داری بین تیمارپتاسیم+سالیسیلیکاسید و شاهد نشان نداد، در حالی‌که میانگین طول یک نسل (T) به‌طور قابل توجهی متفاوت بود. پیش‌بینی می‌شود که یافته‌های این مطالعه و مطالعات قبلی می‌تواند تاثیرات مثبت پتاسیم+سالیسیلیک اسید را در کنترل کنه‌ی قرمز مرکبات فراهم کند. با این حال، مطالعات مزرعه‌ای برای تعیین تأثیر تیمارهای مذکور روی کاهش خسارت این آفت مرکبات و عملکرد شکارگری *T. caspiansis* روی این آفت مورد نیاز است.

کلمات کلیدی: پارامترهای رشد جمعیت، کنه‌ی قرمز مرکبات، جدول زندگی دوجنسی، اثر پایین به بالا

تاریخچه مقاله

دریافت: ۱۴۰۳/۰۳/۰۹

پذیرش: ۱۴۰۳/۰۹/۰۱

انتشار: ۱۴۰۳/۱۰/۲۳

دبیر تخصصی: حسین مددی

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DOI: https://doi.org/10.61186/jesi.45.1.10