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Article

Effects of starvation and humidity on the development and survival of *Amblyseius swirskii*, *Agistemus exsertus* and *Amblyseius eharai*

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Abstract

The ability of predatory mites to endure starvation or low humidity is very important for them to maintain their populations in unfavorable environments. The effects of starvation and humidity on the development and survival of *Amblyseius* (*Typhlodromips*) *swirskii*, *Amblyseius eharai* and *Agistemus exsertus* were studied in the laboratory. The results showed that most eggs of *A. eharai* and *A. exsertus* could not hatch at relative humidities (RH) lower than 60%. Only *A. swirskii* larvae could develop into protonymph stage without prey at 60–100%RH among three species. When the prey was absent, protonymphs or gravid females of *A. swirskii* survived significantly longer than those of *A. eharai* at 60–100%RH, respectively. Furthermore, at lower humidities (60–70%RH) similar case was observed in the virgin female stage. In addition, nymphs and females of the two phytoseiid mites survived significantly longer than those of *A. exsertus* at 60–100%RH. It indicated that *A. swirskii* might be a stronger competitor relative to *A. eharai* or *A. exsertus* under starvation and low humidity conditions.

Key words: Invasion risk, tolerance for starvation, Phytoseiidae, Stigmaeiidae, biological control, competition

Introduction

Amblyseius eharai Amitai & Swirski and *Agistemus exsertus* Gonzalez are indigenous and dominant natural enemies of *Panonychus citri* (McGregor) and *Phyllocoptruta oleivora* (Ashmead) which are the primary pest mites in citrus orchards in China (Yang *et al*. 1986; Cao *et al.*1998; Jiang *et al*. 1988; Ji *et al*. 2006, 2012). But these two predators can not control the populations of those pest mites, presumably because of their low density in citrus orchards early in the season or the continued use of pesticides (Ji *et al*. 2006, 2012).

Neoseiulus (*Amblyseius*) *cucumeris* Oudemans, a commercialized predatory mite, had been widely used in citrus orchards to control those pest mites in China (Zhang *et al*. 2003). But *N. cucumeris* could not colonize the citrus orchards in China (Ji *et al*. 2012), presumably because of interspecific competition and/or its lower ability to adapt to citrus ecosystem (Ji *et al*. 2012). So, the predatory mites must be released every year. Then other predators with stronger ability to adapt to citrus ecosystem might be better alternatives.

We conjectured that *Amblyseius* (*Typhlodromips*) *swirskii* Athias–Henriot is a preferable candidate for the above purpose, because it is a dominant natural enemy in its original area, the coastal plain citrus orchards in Israel (Palevsky *et al*. 2003; Ali *et al*. 2005). Phytoseiid mites are commonly used as introduced biocontrol agents, however, some negative effects of the exotic phytoseiid mites on indigenous phytoseiid mites occupying similar habitats were reported (Sato *et al*. 2012; Palevsky *et al*. 2013), for example, *Euseius stipulatus* (Athias- Henriot) displaced *Euseius*

cucumeris could survive for 8–10 days (Williams, 2004). Whereas, if without prey and water, the female *N. californicus* survived for only 4.3 days at 20°C and 85% RH (Toyoshima *et al.* 2009). In addition, feeding is obligatory for larval *A. eharai* and *Galendromus* (*Typhlodromus*) *occidentalis* (Nesbitt) (Zhang & Croft 1994; Chittenden & Saito 2001; Ji *et al.* 2013). Unfed larvae of *A. eharai* could survive for 1.9–3.2 days in range of 60–100%RH and 25°C (Table 2), and unfed larvae of *G. occidentalis* died within 2–3 days at 95%RH and 20°C (Croft & Croft 1993).

In this study, the effects of starvation and humidity on the development and survival of *A. swirskii*, *A. eharai* and *A. exsertus* were studied in the laboratory. The results showed that all protonymphs, deutonymphs and females of *A. swirskii*, *A. eharai* and *A. exsertus* were gradually fainting with starvation and died, but some significant differences were observed among them. When the prey was absent, in protonymph or gravid female stage, the survival duration of *A. swirskii* was significantly longer than that of *A. eharai* under all humidity conditions (Table 3, 6). In the lower humidity range (60–70%RH), a similar case was observed between the virgin females of the two phytoseiid mites (Table 5). It is important to note that the survival durations of nymphs or females of the two phytoseiid mites were significantly longer than those of *A. exsertus* in all tests (Table 3, 4, 5, 6). Those indicated that the ability to endure starvation or low humidity of *A. swirskii* was stronger than those of *A. eharai* or *A. exsertus*.

In conclusion, *A. swirskii* might be a better competitor relative to *A. eharai* and *A. exsertus* when the prey was absent. In addition, all eggs of *A. exsertus* and most eggs of *A. eharai* could not develop at low humidity (60%RH), whereas, *A. swirskii* could do (Table 1). Furthermore, larval *A. eharai* or *A. exsertus* could not develop into protonymph stage without prey, but *A. swirskii* could do. Therefore, because of the high abilities of eggs and larvae to adapt to low humidity, *A. swirskii* might be also a strong competitor.

But the result of competition should be influenced by a series of factors, for example, alternative prey in the ecosystem, intraguild predation, intrinsic rate of increase (r_m), and so on. In fact, we showed a contrary result in our previous studies: when the prey was sufficient, *A. eharai* might be a better competitor relative to *A. swirskii*, because that the immatures of *A. eharai* just needed fewer prey to develop into adults, and that its intrinsic rate of increase (r_m) was higher relative to *A. swirskii* (Ji *et al.* 2013). So the results of this study were just as a part of the invasion risk evaluation, and more studies should be conducted in the future.

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