

# Could phytoseiid mites impair biological control of the invasive plant, *Ailanthus altissima*?

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## Original research

### ABSTRACT

*Aculus taihangensis* is a potential biological control agent of *Ailanthus altissima* (Miller) Swingle. However, predatory mites found in Europe may affect the action of this eriophyid agent. The aim of the present study was to evaluate the biology of two predatory mites, *Euseius stipulatus* and *Typhlodromus* (*Typhlodromus*) *exhilaratus*, feeding on *A. taihangensis*. Rearing stocks were maintained in germination chambers at  $25 \pm 1$  °C, with 12 hours of photophase and relative humidity  $70 \pm 5\%$ . Of 40 individualized *T. (T.) exhilaratus* eggs, only 37.5% achieved adulthood, while viability of *E. stipulatus* was 87.5%. The mean fecundity was 18 eggs/ female. Both predatory mites evaluated in this study feed on *A. taihangensis*. However, only *E. stipulatus* seems to be an efficient predator, capable of controlling *A. taihangensis*.

**Keywords** *Aculus taihangensis*; IPM; *Euseius stipulatus*; *Typhlodromus* (*Typhlodromus*) *exhilaratus*

## Introduction

*Ailanthus altissima* (Miller) Swingle (Simaroubaceae), commonly known as tree of Heaven, is a native tree to China and North Vietnam, thanks to its rapid global spread has become invasive in several places (Kowarik and Säumel 2007). With rapid growth, it invades natural areas establishing populations with high density, thus shading native species. It exhibits root allelopathy that inhibits growth and development of other plant species occupying the same environment (Heisey 1996). It is considered invasive in Europe and in all continents, except for Antarctica (Kowarik and Säumel 2007).

The introduction of herbivorous insects, mites and pathogens for the management of pests, weeds (or plants) and diseases that affect ecosystems, has been intensified over the years in order to decrease environmental impacts by controlling the density of invasive plants like tree of Heaven. Therefore, the biological control of weeds is aimed at reducing the population of some species with either ecological or economic importance (Seastedt 2015).

*Aculus taihangensis* Hong & Xue (Eriophyidae) described from Hebei Province, China (Hong and Xue 2005) as vagrant on *Ailanthus altissima*, has recently been reported also in Italy, Croatia, Greece, Serbia, Hungary, Romania, Bulgaria, Austria, Slovenia, and France on the same host (de Lillo *et al.* 2022). It seems to be an interesting candidate for the biological control of this exotic plant (de Lillo *et al.* 2017). Eriophyoidea generally causes damage to countless agricultural crops, foresting, and ornamental plants (Lindquist *et al.* 1996). The severity of the symptoms they induce consists of reduction of biomass production and

Received 22 August 2021  
Accepted 23 August 2022  
Published 06 September 2022

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Academic editor  
Kreiter, Serge

<https://doi.org/10.24349/2o0d-2ri4>

ISSN 0044-586X (print)  
ISSN 2107-7207 (electronic)



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**How to cite this article** Toldi M. *et al.* (2022), Could phytoseiid mites impair biological control of the invasive plant, *Ailanthus altissima*?. *Acarologia* 62(4): 892-897. <https://doi.org/10.24349/2o0d-2ri4>

reproductive performance of the host plant, and they depend on mite population density and on the morphology of the plant attacked (Oldfield 1996; Smith *et al.* 2010; de Lillo and Skoracka 2010). Approximately 80% of Eriophyoidea are exclusively associated to unique host plant species (Skoracka *et al.* 2010), which means they are a possible candidate for the control of invasive plants (Smith *et al.* 2010), ensuring the protection of the native plants in places of introduction.

Among the predatory mites that might be associated with eriophyid mites, phytoseiid mites are the most common and abundant on plants (Tixier 2018). Several species are important control agents in greenhouses (Zhang 2003) and orchards (Parra *et al.* 2002). They feed on mites, insects, nematodes, fungi, pollen, and plant exudates (McMurtry *et al.* 2013). *Amblyseius swirskii* Athias-Henriot, for example, fed efficiently on *Aculops lycopersici* (Tryon) on tomato leaves in laboratory trials (Park *et al.* 2010). *Typhlodromus (T.) exhilaratus* was reported to be a type III generalist predator (McMurtry *et al.* 2013), feeding on tetranychids, eriophyids, and pollen (Ragusa 1981). *Typhlodromus (T.) exhilaratus* has already been reported associated with *Aceria caulobia* (Nalepa) inside the stem galls induced by this mite in Apulia (de Lillo 1987; de Lillo and Monfreda 2004), and it is a quite common species in Southern Italy. Mites of *Euseius* are commonly found associated with plants with smooth leaves or little pubescent surface (Seelmann *et al.* 2007, McMurtry *et al.* 2013). They have been reported on eucalyptus, coffee, and forest fragments (Queiroz and Flechtmann 2011), and have also been associated with grapevines (Tixier *et al.* 2013). *Euseius stipulatus* (Athias-Henriot) is a generalist species, capable of developing when feeding on pollen as alternative food (McMurtry *et al.* 2013). This species has already been reported in Italy (Ragusa and Swirski 1976), Spain (Ferragut *et al.* 1988), and Portugal (Silva *et al.* 2019) in environments with temperate climate environments, where it provides a significant level of control of *Panonychus ulmi* (Koch) (Rodrigues 2005).

To date, nothing has been found about predatory mites controlling *A. taihangensis*. The present study hypothesizes that predatory mites found in European natural environments could reduce the level of biological control of this weed by eriophyoid. Therefore, the aim is to evaluate the predation capacity of *E. stipulatus* and *T. (T.) exhilaratus* feeding on *A. taihangensis*.

## MATERIAL AND METHODS

The experiments were carried out in the Acarology Laboratory of Università degli Studi di Bari Aldo Moro, Bari, Italy. *Euseius stipulatus* and *Aculus taihangensis* were collected from *Ailanthus altissima* in the city of Bari, Italy (41°06'33.3"N 16°53'04.3"E), while *Typhlodromus (T.) exhilaratus* was collected from *Suaeda vermiculata* Forsskål ex J. F. Gmelin (Amaranthaceae) in the city of Margherita di Savóia, Italy (41°22'23.5"N 16°07'38.6"E), where it was found inside the stem galls induced by *A. caulobia*. Rearing stocks of the predatory mites were maintained on *A. altissima* contaminated with *A. taihangensis* and *A. caulobia* populations. Rearing stocks were maintained in the laboratory throughout the period in a climate chamber at  $25 \pm 1$  °C, 12 hours of photophase, and  $70 \pm 5\%$  relative humidity.

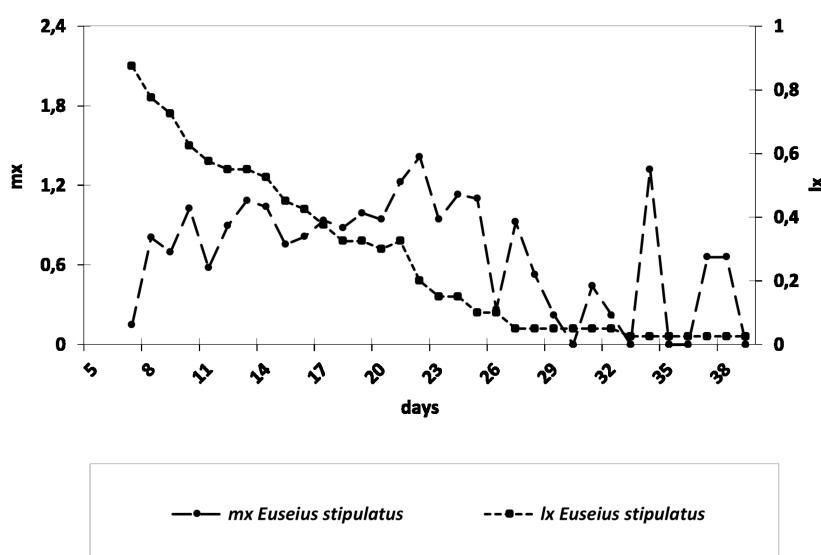
The study of predator development was initiated with 40 eggs of each species, obtained from isolated females for a period of 6 hours, which were isolated in arenas on Petri dishes with 6 cm containing 4 cm diameter leaf disks of *A. altissima*, contaminated with more than 20 individuals of *A. taihangensis* per day. Each leaf disk was attached to a pin, surrounded by distilled water, and replaced daily. Three daily observations were conducted at 8 AM, 1 PM, and 6 PM, using a stereo microscope Zeiss Stemi 305, during immature period to determine the duration of each of the immature stages. During adulthood, females were paired with males obtained from the stock colonies and evaluations were conducted once a day at 1 PM, checking the number of eggs laid and mite survival. Eggs were collected and transferred to other arenas to determine sex ratio. The males were kept isolated in the arenas until death.

The data were compared using an ANOVA test and *post-hoc* Tukey's test at a significance level of 5% using R Studio (R Development Core Team 2010). Life-table calculations were performed according to Silveira-Neto *et al.* (1976).

Net reproductive rate ( $Ro = \sum mx.lx$ , where  $mx$ : the number of offsprings/ female x sex ratio;  $lx$ : specimens alive/total specimens), mean generation time ( $T = \sum mx.lx.x / \sum mx.lx$ ), innate ability to increase ( $r_m = \log Ro / T.0.4343$ ), and finite growth rate ( $\lambda = e^{r_m}$ ) were calculated.

## Results

Only 37.5% of *Typhlodromus* (*T.*) *exhilaratus* reached adulthood, while 87.5% of *E. stipulatus* did (Table 1). In most stages, *E. stipulatus* had a shorter duration of stages than *T. (T.) exhilaratus*, except for the larval stage. The duration of the immature period of *Euseius stipulatus* was about 5.6 days. The deutonymph stage being the shortest of the stages. The duration of the immature period of *T. (T.) exhilaratus* was about 7.6 days with the larval stage being the shortest of the stages.



**Figure 1** Specific fertility ( $mx$ ) and survival of *Euseius stipulatus* feeding on *Aculus taihangensis* at  $25 \pm 1$  °C, 12 hours of photophase, and  $70 \pm 5\%$  relative humidity.

Life table parameters were calculated only for *E. stipulatus* since, as only 4 females of *T. exhilaratus* laid 14 eggs. The mean fecundity of *E. stipulatus* was 18 eggs/female (Table 2). The sex ratio was 0.66 and the number of the males was 17. The results showed that *E. stipulatus* feed on *A. taihangensis*, reaches adulthood and lays eggs.

## Discussion

The study of the interactions of native predators with native introduced organisms is required when planning weed control programs using the introduced organisms as biological control agent. In our case we supposed the potential biological control of *A. altissima* using *A. taihangensis*. The present study showed that both *E. stipulatus* and *T. (T.) exhilaratus* fed on *A. taihangensis*, this one being a more suitable prey for *E. stipulatus*. *Aculus taihangensis* populations were not suitable to keep *T. (T.) exhilaratus* populations.

**Table 1** Mean duration, in days ( $\pm$ SE), of immature stages of *Euseius stipulatus* and *Typhlodromus (Typhlodromus) exhilaratus* feeding on *Aculus taihangensis*, at  $25 \pm 1^\circ\text{C}$ , 12 hours of photophase, and relative humidity  $70 \pm 5\%$ .

|                                      | Immature stages          |                        |                         |                         |                       |
|--------------------------------------|--------------------------|------------------------|-------------------------|-------------------------|-----------------------|
|                                      | Egg                      | Larva                  | Protonymph              | Deutonymph              | Egg-adult             |
| <i>Euseius stipulatus</i>            | $1.6 \pm 0.3\text{Ba}^*$ | $1.8 \pm 0.3\text{Aa}$ | $1.4 \pm 0.6\text{Bab}$ | $1.1 \pm 0.5\text{Bb}$  | $5.6 \pm 1.0\text{B}$ |
| Survival (%)                         | 100                      | 97.50                  | 97.44                   | 94.6                    | 87.5                  |
| N                                    | 40                       | 39                     | 38                      | 37                      | 35                    |
| <i>Typhlodromus (T.) exhilaratus</i> | $2.7 \pm 0.9\text{Aa}$   | $1.2 \pm 0.4\text{Bc}$ | $2.7 \pm 1.2\text{Aab}$ | $1.7 \pm 1.0\text{Abc}$ | $7.6 \pm 1.2\text{A}$ |
| Survival (%)                         | 77.50                    | 100                    | 75                      | 83.33                   | 37.5                  |
| N                                    | 31                       | 31                     | 24                      | 18                      | 15                    |

\*Same lowercase letters in the rows represent no significant difference; same uppercase letters in the column represent no significant differences; both according to Tukey's test at a significance level of 5%.

The development time of *E. stipulatus* feeding on *A. taihangensis* was similar to that of the same predator feeding on *Carpobrotus edulis* (L.) N. E. Brown (Aizoaceae) pollen (Ferragut *et al.* 1987). However, it was longer when feeding on apple, almond, pear, apricot, plum, walnuts and cherry pollen (Bouras and Papadoulis 2005). The same was the case when feeding on *Aleurothrixus floccosus* Maskell (Aleyrodidae), *Panonychus citri* (McGregor), *Tetranychus urticae* Koch (Tetranychidae), *Lorryia formosa* Cooreman (Tydeidae), and *Planococcus citri* Risso (Pseudococcidae) (Ferragut *et al.* 1987). However, this time was longer than when the same mite feeds on alternatives presented above. These pollen diets could be considered, in the future, as complementary diets that have been shown in other cases to increase predator fitness and, at the end, the control. To date, there has only been one study on the biology of *T. (T.) exhilaratus* (Ragusa 1981) feeding on different diet types: *Borago officinalis* (L.) (Boraginaceae), *Salvia rosmarinus* Spenser (Lamiaceae), *Bougainvillea* spp. (Nyctaginaceae), *Jasminum* spp. (Oleaceae), *Oxalis* spp. (Oxalidaceae), and *Duranta ellisia* Jacquemin (Verbenaceae) pollen, and on *P. citri* and *T. urticae* in which the duration of the egg-adult period was between 5.5-8 days. The development time of this mite in this study is within this range reported above, suggesting that this predator is a generalist, surviving on a wide range of food sources. These results suggest that this predator is a generalist, surviving on a broad range of food.

The intrinsic rate, oviposition period and fecundity of *E. stipulatus* were higher when feeding on *C. edulis* pollen (0.19; Ferragut 1987), indicating that it is a suitable diet, while *A. taihangensis* could be considered as a complementary food.

The predator *T. (T.) exhilaratus* was expected to be an efficient biological control agent of *A. taihangensis*, since, according to Ragusa (1981), the diet of this predator includes tetranychids,

**Table 2** Mean duration, in days ( $\pm$  SE), pre-oviposition, oviposition, longevity, and mean fecundity and eggs per female ( $\pm$  SE) of *Euseius stipulatus* feeding on *Aculus taihangensis* at  $25 \pm 1^\circ\text{C}$ , 12 hours of photophase and  $70 \pm 5\%$  relative humidity.

|                  | N  | <i>Euseius stipulatus</i> |
|------------------|----|---------------------------|
| Pre-oviposition  | 18 | $2.17 \pm 0.20$           |
| Oviposition      | 18 | $10.56 \pm 1.75$          |
| Post-oviposition | 18 | $2.8 \pm 1.10$            |
| ♀ Longevity      | 18 | $16.78 \pm 1.88$          |
| ♂ Longevity      | 17 | $11.53 \pm 1.69$          |
| Fecundity        | 18 | $18 \pm 2.77$             |

N = number of mites evaluated

eriphyids, and pollen. However, the results obtained did not corroborate the initial hypothesis.

The potential of *E. stipulatus* for biological control increases in more humid environments and milder temperatures (Thurman *et al.* 2017). This mite is considered tolerant to pesticides compared to other species usually found in the same environment, such as *Neoseiulus californicus* (McGregor) and *Phytoseiulus persimilis* Athias-Henriot (Argolo *et al.* 2014). Nonetheless, *E. stipulatus* has only been found in preserved vineyards environments (Silva *et al.* 2019). Several studies provided information on the occurrence of predatory mites on plants. However, little is known about the parameters that explain this occurrence (Tixer 2018). The biological control of *A. taihangensis* on *A. altissima* will be more efficient only under unfavorable conditions for *E. stipulatus*.

In conclusion, *A. taihangensis* was not a suitable prey for *T. (T.) exhilaratus*, suggesting that there is no risk of impairing the action of this eriophyid in the control of *A. altissima* in the field. On the other hand, *A. taihangensis* is a suitable prey for *E. stipulatus*, so it should be considered that this predatory mite may be a factor impeding the success of a biological control program using the eriophyid for biological control of *A. altissima*. However, further studies are needed to know the real risk in the field as this also depends on environmental conditions, and the ability of the predator to search for prey.

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