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SCIENTIFIC NOTE

Impact of occurrence of *Amblyseius andersoni* (Acari: Phytoseiidae) on two native phytoseiid (Mesostigmata) mites in a Japanese apple (Rosacaea) orchard

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Abstract

In 2014, *Amblyseius andersoni* (Acari: Phytoseiidae), was newly discovered in apple (Rosacaea) orchards in central Japan. In 2022, I found *A. andersoni* on leaves in an apple orchard in northern Japan. *Amblyseius andersoni* had been not observed in the orchard until at least 2018; only *Neoseiulus womersleyi* and *Typhlodromus vulgaris* (Mesostigmata: Phytoseiidae), both of which are native to Japan, had been observed on apple leaves. To understand the impact of *A. andersoni* on the two phytoseiid mite species, I compared the seasonal occurrences of the phytoseiid species and of *Tetranychus urticae* (Trombidiformes: Tetranychidae) in the orchard in 2018 and 2022. In both years, *T. urticae* numbers increased from mid-July to early August and then rapidly decreased with increasing *N. womersleyi* numbers. Mean total occurrence numbers of *N. womersleyi* and of *T. urticae* did not differ significantly between the two years. *Amblyseius andersoni* occurrence therefore likely had little impact on seasonal *N. womersleyi* occurrence. In contrast, in 2018, many *T. vulgaris* individuals were observed from August onwards, when *T. urticae* numbers had decreased, but *T. vulgaris* was seldom observed in 2022, although many *A. andersoni* were, suggesting that *A. andersoni* likely displaced *T. vulgaris* in the apple orchard.

Spider mites (Acari: Tetranychidae) are important pests in apple (Rosaceae) orchards in Japan, and they cause damage to leaves each year. The two-spotted spider mite, *Tetranychus urticae* Koch, is the dominant spider mite species in many apple orchards in Japan. *Tetranychus urticae* is difficult to control in apple orchards because it develops resistance to acaricides easily (Funayama 2018). Biological control of *T. urticae* by conserving native phytoseiid (Mesostigmata) mites in Japanese apple orchards therefore has been the subject of keen research interest in recent years (Funayama 2018). Three dominant native phytoseiid mite species, *Neoseiulus womersleyi* Schicha (Acari: Phytoseiidae), *Typhlodromus vulgaris* Ehara (Acari: Phytoseiidae), and *Amblyseius tsugawai* Ehara (Acari: Phytoseiidae), have been observed in apple orchards in northern Japan (Funayama *et al.* 2015). Phytoseiid mites are classified into four types (I–IV), based on food habits, biological traits, and morphological traits (McMurtry and Croft 1997; McMurtry *et al.* 2013). *Typhlodromus vulgaris* and *A. tsugawai* are Type III, which are generalist predators that feed on various food resources, including tetranychids, eriophyids, and pollen. In contrast, *N. womersleyi* is Type II, a specialist predator of tetranychid mites (McMurtry and Croft 1997). These three native phytoseiid mite species differ in their habitats in apple orchards: most *T. vulgaris* live on apple leaves, whereas most *A. tsugawai* inhabit the undergrowth (Funayama *et al.* 2015).

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Neoseiulus womersleyi occurs not only on apple leaves but also in the undergrowth, where *T. urticae* also occurs (Funayama *et al.* 2015).

In an earlier study (Funayama 2016), I described how each of the three phytoseiid mite species contributes to *T. urticae* control in apple orchards in northern Japan. First, when *T. urticae* females that have diapaused under rough bark on trees or in ground litter move to the undergrowth in the spring to reproduce (Gotoh 1997), *A. tsugawai* predation suppresses increases in *T. urticae* numbers in the undergrowth, thereby helping to reduce the numbers of *T. urticae* that later climb into the trees' canopies. Second, *T. vulgaris* on the apple leaves protect the canopy from *T. urticae* after the latter leaves the undergrowth. Finally, *N. womersleyi* in the undergrowth rapidly climb the trees to prey upon the increasing *T. urticae* populations on the apple leaves. In this way, the functions of each of the three native phytoseiid mite species can combine to control *T. urticae* in Japanese apple orchards.

In 2022, however, I found many *Amblyseius andersoni* (Chant) (Acari: Phytoseiidae) in an apple orchard (39.23° N, 140.56° E) at the Akita Fruit Tree Experiment Station, in Yokote, Akita Prefecture, northern Japan. The specimens were identified from their external and internal morphology by Dr. Hidenari Kishimoto of the National Agriculture and Food Research Organisation's Institute for Plant Protection. In the orchard, *A. andersoni* had not been observed until at least 2018 – before then, only the three above-mentioned native phytoseiid mite species had been observed. *Amblyseius andersoni* was found for the first time in Japan in 2014, in apple and apricot orchards in Nagano Prefecture in central Japan (Toyoshima *et al.* 2016).

Amblyseius andersoni is the dominant phytoseiid species in European apple orchards (Tixier *et al.* 2014) and is classified as a Type III generalist predator (Koveos and Broufas 2000; McMurtry *et al.* 2013). It is an important predator of tetranychid mites in European vineyards (Lorenzon *et al.* 2012) and is commercially available. There is concern about the potential for interaction and food competition between *A. andersoni* and native phytoseiid species – especially the generalists – in Japanese apple orchards. In the present study, I compared the seasonal occurrences of *N. womersleyi*, *T. vulgaris, A. andersoni,* and *T. urticae* on leaves in the apple orchard (2000 m^2) at the Akita Fruit Tree Experimental Station in 2018 and 2022.

In the orchard, "Fuji" apple trees (older than 20 years; approximately 4 m high) are grown at a spacing of 4 × 3 m. As described in Funayama *et al.* (2015), the orchard is managed by spraying with insect growth regulator, the narrow spectrum insecticides, and fungicides; no acaricides are applied. In 2018 and 2022, 20 leaves were sampled from each of six apple trees at 7-day intervals from June to September (340 leaves per tree). A brushing machine (DKI-7200, Daiki Co. Inc., Tokyo, Japan) was used to collect material from both surfaces of the leaves into glass Petri dishes (120 mm diameter). *Tetranychus urticae* adults, nymphs, and larvae were counted under a binocular microscope. Phytoseiid mites were mounted in Hoyer's medium, after which a binocular microscope was used to count only the adult females, which were identified to species level from their external and internal shapes, per Toyoshima *et al.* (2013). This investigation was not performed in 2019–2021.

I plotted the seasonal occurrences of the three phytoseiid mites and *T. urticae* on apple leaves in the apple orchard in 2018 and 2022 (Fig. 1). The relationship between the seasonal occurrences of *T. urticae* and *N. womersleyi* was similar in both years: the number of *T. urticae* increased rapidly and peaked in mid-August in 2018 and in late July in 2022. The population then rapidly decreased, and the species was seldom observed in September in both years.

Neoseiulus womersleyi occurred and rapidly increased in numbers in mid-August in 2018 and late July to early August in 2022 – slightly after the population increase of *T. urticae* – and rapidly decreased thereafter. The mean numbers of *N. womersleyi* and of *T. urticae* per tree did not differ significantly between the two years (*N. womersleyi*, $P = 0.090$ and *T. urticae*, $P = 0.469$ by Mann–Whitney *U*-test; JMP 8, SAS Institute, Cary, North Carolina, United States of America; Table 1). Generally, the density of specialist phytoseiid mites in orchards, including *N. womersleyi*, increases continuously during the summer in a time-lagged response to increases in the density of *T. urticae* (*e.g.*, Kishimoto 2002). Therefore, the seasonal occurrences of *N. womersleyi* and *T. urticae* in the

Table 1. Numbers of mites of each species collected on leaves in apple orchards in 2018 and 2022

Year	No. trees	Mean total number ± standard error*			
		Tetranychus urticae†	*Neoseiulus womersleyi*‡	*Typhlodromus vulgaris*‡	*Amblyseius andersoni*‡
2018	6	290.2 ± 33.5	3.5 ± 1.6	16.3 ± 5.3	0
2022	6	252.5 ± 42.0	7.5 ± 2.1	0.5 ± 0.3**	22.7 ± 3.0**

Note: Significance: ** $P < 0.01$ (Mann–Whitney *U*-test).
*Twenty leaves were collected from each tree every week from June to September (340 leaves per tree).
†Total number of adults, nymphs, and larvae.
‡Number of adult females.

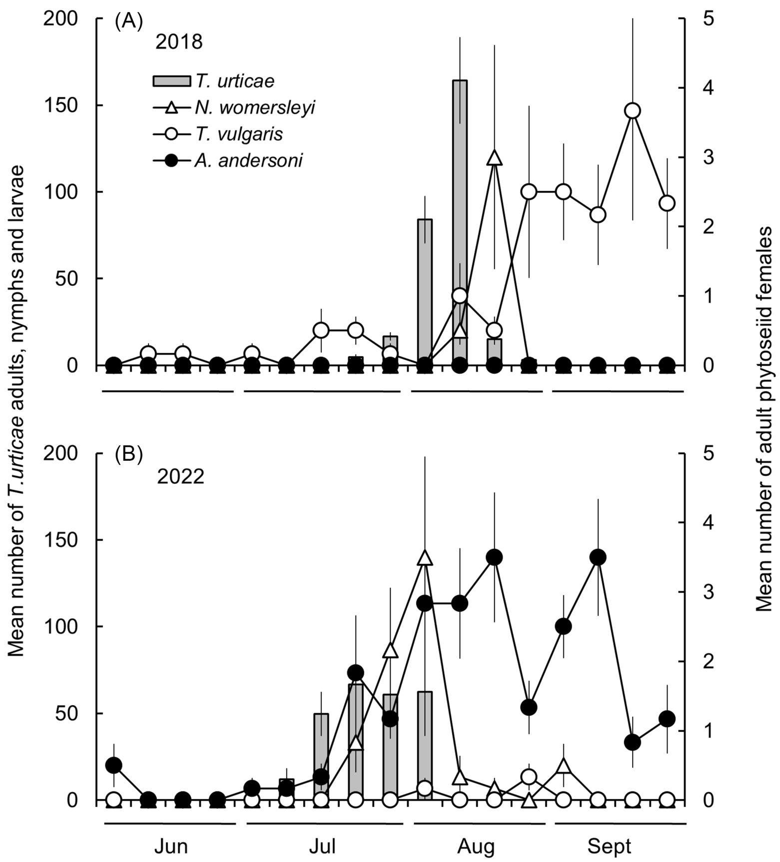

Figure 1. Seasonal occurrences of the three phytoseiid mites (*Neoseiulus womersleyi, Typhlodromus vulgaris, Amblyseius andersoni*) and *Tetranychus urticae* on apple leaves in a Japanese apple orchard in **A**) 2018 and **B**) 2022. The orchard was managed by selective chemical spraying in both years. Leaves were collected from six trees in each year. Numbers for each tree are means ± standard error (vertical line) on 20 leaves.

two years (Fig. 1) appeared to follow the normal pattern, suggesting that the occurrence of *A. andersoni* would have little impact on the predatory activity of *N. womersleyi* against *T. urticae*.

However, in 2022, as occurred with *N. womersleyi*, the increase in the numbers of *A. andersoni* was synchronised with the increase in the population of *T. urticae* (Fig. 1). Moreover, the mean

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maximum density of *T. urticae* in 2022 (mean ± standard error 66.7 ± 12.8 per tree) was significantly lower than it was in 2018 (mean ± standard error 164.2 ± 24.9 per tree; $P = 0.008$ by Mann–Whitney *U*-test). Although *A. andersoni* is a generalist predator, this finding suggests that the nonnative phytoseiid was actively targeting *T. urticae* as prey. Fu *et al.* (2021) reported that *A. andersoni* shows a Type II response to *Aceria pallida* Keifer (Acari: Eriophyoidae), an important pest of goji berry, *Lycium baebarum* (Solanaceae). *Amblyseius andersoni* therefore might come to supplant *N. womersleyi* in helping to suppress increases in the *T. urticae* population. If this is the case, a detailed investigation will be required to determine whether *A. andersoni* influences the availability of food for *N. womersleyi*.

In 2018, *T. vulgaris* occurred from mid-June and increased rapidly in numbers after late August, when the *T. urticae* population decreased. Many *T. vulgaris* individuals were observed in September (Fig. 1). It is possible that the main food resource of *T. vulgaris* is pollen grains that are derived from various plants and that stick to the apple leaves (Funayama 2016); therefore, *T. vulgaris* populations can remain steady even if spider mites are not present (Funayama *et al.* 2015). Moreover, *T. vulgaris* has commonly been observed on apple trees, and this mite's numbers have been observed to increase after *T. urticae* numbers decrease due to predation by *N. womersleyi* (Funayama *et al.* 2015), a pattern also noted in 2018 in the present study. This pattern is likely caused by the fact that generalist phytoseiid mites, including *T. vulgaris*, are severely impeded by the complex webs of *T. urticae* (Shimoda *et al.* 2009). In addition, *T. urticae* is not a suitable food source for *T. vulgaris* (Toyoshima 2003). However, I found in the present study that the number of *T. vulgaris* per tree was significantly lower in 2022 than in 2018 ($P = 0.002$ by Mann–Whitney *U*-test; Table 1). In 2022, only a few *T. vulgaris* individuals were observed in early August and early September, whereas many *A. andersoni* were present at that time (Fig. 1). These data suggest that, in the four years between 2018 and 2022, *A. andersoni* had displaced *T. vulgaris*.

Displacement of phytoseiid mite species has occurred previously in Japanese fruit-tree orchards. *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae) was found for the first time in Tokyo in 1964, and in commercial orchards in the Kanto region, the dominant native species, *N. womersleyi*, was replaced by *N. californicus* in the 1990s (Kishimoto 2002; Gotoh *et al.* 2014). The possibility that *A. andersoni* distribution could expand widely in Japanese apple orchards, as had occurred with *N. californicus*, is a matter of concern.

Among potential factors that may have allowed the displacement of *T. vulgaris* by *A. andersoni*, weather conditions between 2018 and 2022 likely were not significant: according to weather data collected by the Japan Meteorological Agency (JMA) automated meteorological data acquisition system (AMeDAS) for Yokote city (39° 30′ N, 140° 55′ E; 6.6 km from the orchard), daily annual mean temperatures barely fluctuated during that time, ranging from 11.6 to 12.2 °C, and daily annual mean cumulative precipitation ranged from 52.5 to 85.0 mm. Orchard management practices, including agrochemical spraying and mowing, were also consistent through these years. Laboratory tests indicate that the two factors behind the 1990s displacement of *N. womersleyi* by *N. californicus* in the Kanto region were (1) different degrees of pesticide susceptibility (Ullah *et al.* 2016) and (2) asymmetrical intraguild predation (Gotoh *et al.* 2014). In contrast, it is unlikely that different degrees of pesticide susceptibility are behind the displacement of *T. vulgaris* by *A. andersoni*: in both years, the study orchard was managed by the same spraying regime, which involved narrow-spectrum insecticides and fungicides. Moreover, the susceptibility of *T. vulgaris* to broad-spectrum chemicals, including pyrethroids and organophosphates, has decreased considerably in commercial apple orchards (Ogasawara *et al.* 2022). It was also not clear in the present study whether *T. vulgaris* displacement by *A. andersoni* is occurring through asymmetrical intraguild predation. Detailed investigations are needed to determine the cause of this phenomenon and to assess whether the occurrence of *A. Andersoni* in Japanese apple orchards will change the control of pest *T. urticae* by the three native phytoseiid mite species, including *A. tsugawai* (Funayama 2016).

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