HERBIVOROUS AND PREDACIOUS MITES ON PERSIMMON TREES, *DIOSPYROS KAKI* THUNB., IN KOREA

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ABSTRACT - Oriental persimmon, *Diospyros kaki* Thunb., endemic to East Asia is one of the major fruit crops in Korea. Recently, spider mite problems on persimmon trees have increased in Korea. Although spider mites are ranked among the most serious pests on fruit trees, little is known about spider mite and predacious mite faunas on persimmon trees. We conducted a faunal survey of mites on persimmon trees in Korea from June to September 2006, especially focusing on herbivorous and predacious mites. Mites of Tetranychidae and Tenuipalpidae were predominantly collected as herbivores, while Phytoseiidae and Stigmaeidae were predominant predators. All identified tenuipalpid mites were *Tenuipalpus zhizhilashviliae* Reck. Most of the collected tetranychid mites were found to belong to the genus *Tetranychus*. To clarify the species identity, additional collections of tetranychid mites during summer 2007 on sweet persimmon were made. The mites were identified as *Tetranychus urticae* Koch. Four phytoseiid species, *Neoseiulus womersleyi* (Schicha), *Amblyseius eharai* Amitai and Swirski, *Phytoseius* (*Dubininellus*) *rubii* Xin, Liang and Ke and *Typhlodromus* (*Anthoseius*) *vulgaris* Ehara were collected. Among them, *A. eharai* was the most dominant species. Two predacious species of Stigmaeidae, *Agistemus terminalis* (Quayle) and *Agistemus lobatus* Ehara, also were collected.

Key words - Acari, Phytoseiidae, Stigmaeidae, Tenuipalpidae, Tetranychidae, persimmon, Korea.

INTRODUCTION

Oriental persimmon, *Diospyros kaki* Thunb., is endemic to East Asia. China, Japan and Korea account for a large portion of the total persimmon production in the world (FAOSTAT, 2005). In Korea, persimmon production rapidly have increased since 1990 (FAOSTAT, 2005). Now, persimmon is one of the most widely grown fruit crops as well as apple, pear, grape, citrus and peach in Korea (MAF, 2005). Although spider mites are ranked among the most serious pests on fruit trees all over the world, outbreaks of the mites on persimmon trees are generally rare, resulting in few reports of spider mite species and their biology on persimmon trees (Yamada and Tsutsumi, 1990). Recently, there has been an increase of spider mite problems on persimmon trees in Korea. This is an urgent issue which needs immediate attention.

Frequent use of pesticides including insecticides and acaricides has caused serious outbreaks of spider mites in various agricultural crops. This has caused increased pesticide resistance of mites (Cranham and Helle, 1985, Herron *et al.*, 1993; Campos *et al.*, 1996; Herron *et al.*, 1998) or has repelled and reduced the population of natural enemies (Huffaker *et al.*, 1970; McMurtry *et al.*, 1970). Therefore, it is important to develop other control methods, such as cultural control or biological control, to prevent damage by spider mites. Predacious mites are known as promising biological control agents of spider mites (McMurtry *et al.*, 1970). However, there is little information about predacious mite species on persimmon trees (Hiehata and Izumi, 2001).

The knowledge of the faunal structure of not only herbivorous but also predacious mites is basic and important to developing pest management strategies on persimmon orchards. With this objective in mind, we conducted a faunal survey of mites on persimmon trees in Korea, focusing on herbivorous and predacious mites.

MATERIALS AND METHODS

Mites were collected in persimmon orchards in Korea from early June to late September 2006. Sampling sites were selected from major cultivation areas of sweet and astringent persimmons in several environments.

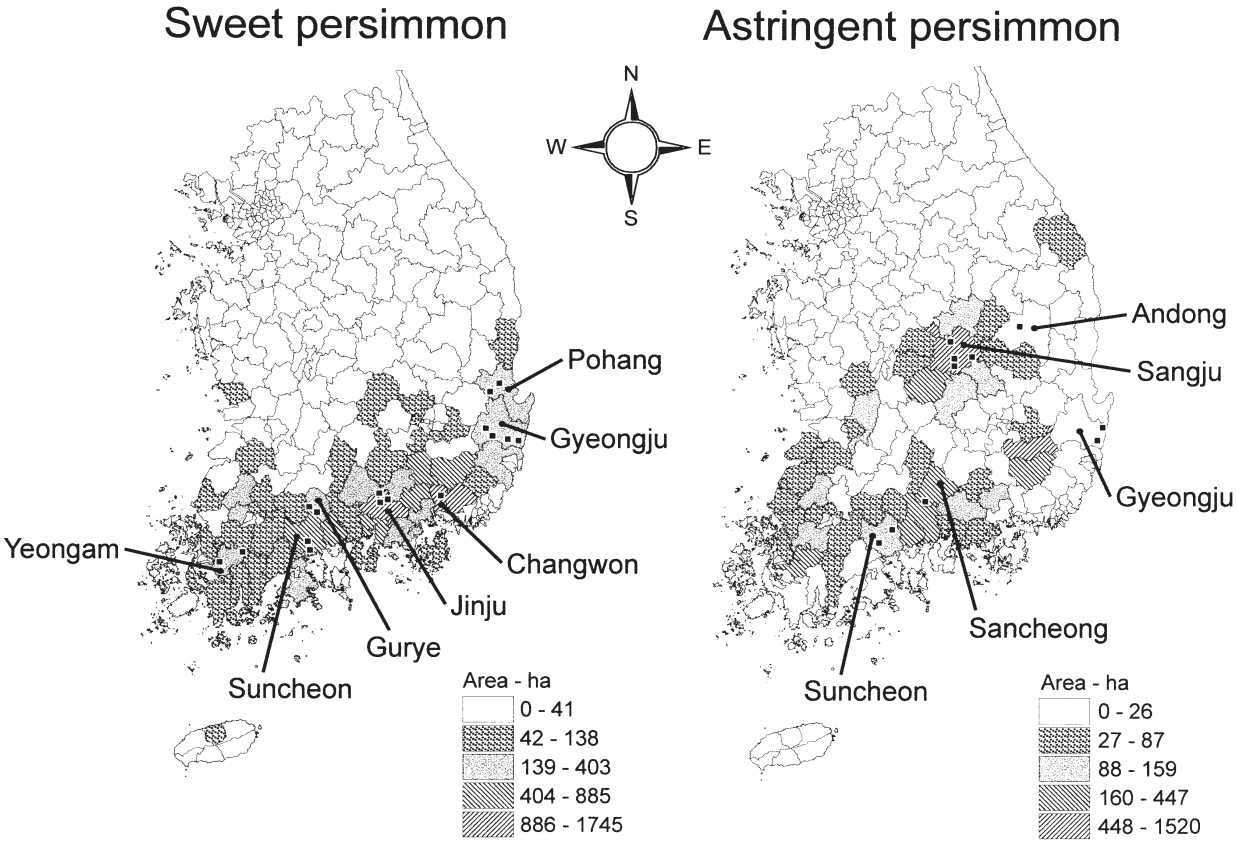

Fig. 1. Distributions of persimmon cultivation areas in Korea and sampling sites of mites. Squares indicate sampling sites. Solid lines indicate the names of cities or counties. The distribution maps were made based on the statistical databases in KOSIS (2005).

Samplings were conducted in the following regional representatives of three provinces, Gyeongsangnam-do, Gyeongsangbuk-do and Jeollanam-do in Korea (Table 1, Fig. 1). In Gyeongsangnam-do, a southern province, cities of Jinju and Changwon were selected because these are the areas of major production of sweet persimmon 'Fuyu'. County of Sancheong, where astringent persimmon is predominantly cultivated, is located in the foothills of Mt. Jiri, which has a mountain climate. In Gyeongsangbuk-do, an eastern province, cities of Andong and Sangju were selected because the latter is a major production area of astringent persimmon and both cities are enclosed by mountains. In contrast, cities of Pohang and Gyeongju, where sweet persimmon 'Fuyu' is dominantly cultivated, are exposed to the sea. In Jeollanam-do, a southwestern province, the city of Suncheon and the county of Yeongam have seaports of Kwangyang and Mokpo which had large volume of trade from China. The county of Gurye is another foothill region north of Mt. Jiri. Jeollanam-do is also a major production area of sweet persimmon.

Persimmon leaves with mites were collected and kept in ice boxes. After transporting these to the laboratory, mites were mounted in Hoyer's medium on glass slides and identified mainly based on the keys in Ehara (1977), Lee and Lee (1992), Ryu (1993, 1996), Ehara and Amano (1998), Ehara (1999) and Ehara and Amano (2004).

The collections and slides of the mites were made by B.-K. Chung. In general, the mite species treated in this study were primarily determined by M. Kawashima, and the determination was confirmed by Dr. S. Ehara, Tottori, Japan. All mite specimens are retained in the Insect Ecology Laboratory, School of Bioresource Sciences, Andong National University, Andong, Korea.

RESULTS AND DISCUSSION

A total of 1085 mites collected on sweet and astringent persimmon trees were examined under the microscope. The largest collection was the mites belonging to the family Phytoseiidae, followed by the family Tetranychidae (Fig. 2). In addition, fewer numbers of mites belonging to the families Tydeidae, Stigmaeidae and Tenuipalpidae were collected. Mites belonging to Astigmata and Oribatida, which are not considered to damage persimmon trees, also were collected. In this study, we focused on two important herbivorous mite

Table 1. Sampling sites of mites on sweet and astringent persimmon trees.

(a) Sweet persimmon (total: 14,239 ha)

Province	City or county	District
Jeollanam-do (3,311)*	Gurye-gun (190)*	Gurye-eup
		Muncheok-myeon
	Suncheon-si (609)	Byeollyang-myeon
		Sangsa-myeon
	Yeongam-gun (171)	Geumjeong-myeon
		Seoho-myeon
Gyeongsangbuk-do (873)	Gyeongju-si (241)	Geoncheon-eup
		Naenam-myeon
		Oedong-eup
		Yangnam-myeon
	Pohang-si (248)	Gigye-myeon
		Singwang-myeon
Gyeongsangnam-do (8,429)	Changwon-si (1,748)	Dong-eup
	Jinju-si (1,094)	Daegok-myeon
		Jiphyeon-myeon
		Micheon-myeon

(b) Astringent persimmon (total: 7,744 ha)

Province	City or county	District
Jeollanam-do (1,584)	Suncheon-si (101)	Nagan-myeon
		Seo-myeon
Gyeongsangbuk-do (3,233)	Andong-si (15)	Icheon-dong
	Gyeongju-si (8)	Gampo-eup
		Yangnam-myeon
	Sangju-si (1,084)	Gongseong-myeon
		Nakdong-myeon
		Oenam-myeon
		Oeseo-myeon
Gyeongsangnam-do (1,448)	Sancheong-gun (414)	Sicheon-myeon

* The numbers in parentheses indicate the hectares (ha) of persimmon cultivations of the regions (KOSIS, 2005).

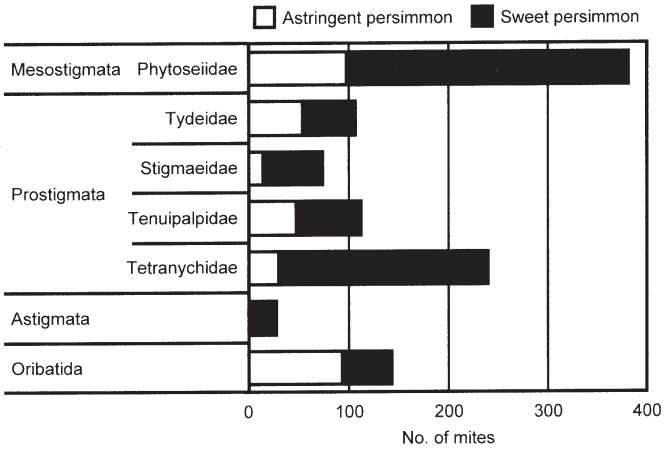

Fig. 2. Total numbers of mites collected on persimmon leaves.

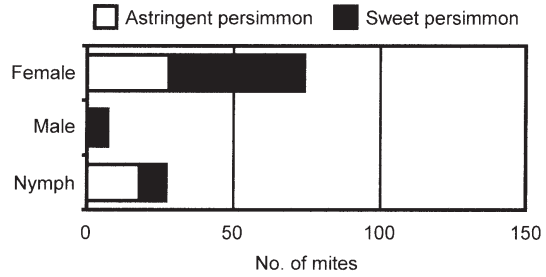

Fig. 3. Total numbers of *Tunuipalpus zhizhilashviliae* collected on persimmon leaves. In addition to these individuals, there were four specimens whose developmental stages were indeterminable. No other tenuipalpid mites were found.

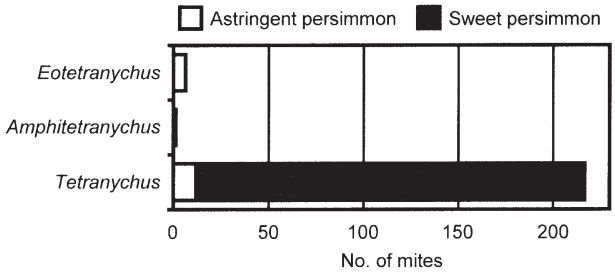

Fig. 4. Total numbers of mites belonging to Tetranychidae collected on persimmon leaves. Data include all developmental stages except the egg stage. In addition to these individuals, there were 16 indeterminable specimens.

families, Tenuipalpidae and Tetranychidae, and two important predacious mite families, Phytoseiidae and Stigmaeidae.

Herbivorous mites - All of the identified tenuipalpid mites were the persimmon false spider mite, *Tenuipalpus zhizhilashviliae* Reck (Fig. 3). The host range of *T. zhizhilashviliae* is extremely limited as this mite is known only to infest persimmon and grape (Ghai and Shenhmar, 1984). Detailed information about the biology of *T. zhizhilashviliae* and its damage on persimmon are scant. It is uncertain even with this high incidence, how much damage it causes to persimmon trees. This mite has been identified on persimmon trees in Korea (Lee and Lee, 1992) and Japan (Jpn. Soc. Appl. Entomol. Zool., 2006).

Tetranychid mites belonging to three genera, *Eotetranychus*, *Amphitetranychus* and *Tetranychus*, were collected (Fig. 4). Although we could identify the mites only to genus level from the specimens collected in 2006, *Tetranychus* was an extremely predominant group. This genus includes some of the most important pest species such as the two-spotted spider mites, *Tetranychus urticae* Koch, or the Kanzawa spider mite, *Tetranychus kanzawai* Kishida. To clarify the species identity, we made additional collections of tetranychid mites in 2007 during summer in sweet persimmon orchards of one region from Gyeongsangnam-do and two regions from Jeollanam-do. All of the collected mites were identified as *T. urticae*. In Japan, *T. kanzawai*, at times infests and damages persimmon trees, especially astringent persimmons (cultivars 'Tonewase' and 'Hiratanenashi') growing in greenhouses (Tsutsumi and Yamada, 1993). The authors suggested that spider mites have a potential to cause serious damage to persimmon trees.

We did not try to collect mites belonging to the superfamily Eriophyoidea (most are less than 200 μm long). However, one mite species belonging to Eriophyidae, the persimmon bud mite, *Aceria diospyri* Keifer, has been reported as a persimmon pest causing blackening of fruit and fruit drop in Japan (Ashihara *et al.*, 2004),

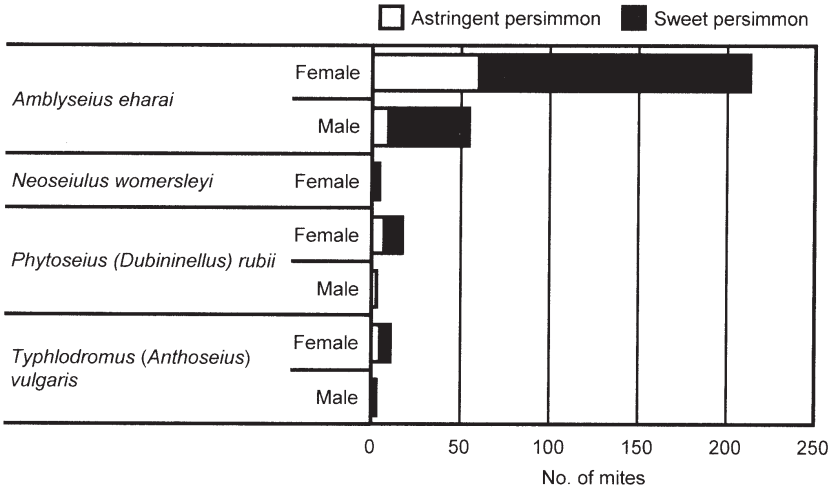

Fig. 5. Total numbers of adults belonging to Phytoseiidae collected on persimmon leaves. In addition to these individuals, 71 nymphs and five larvae of phytoseiid mites were also collected.

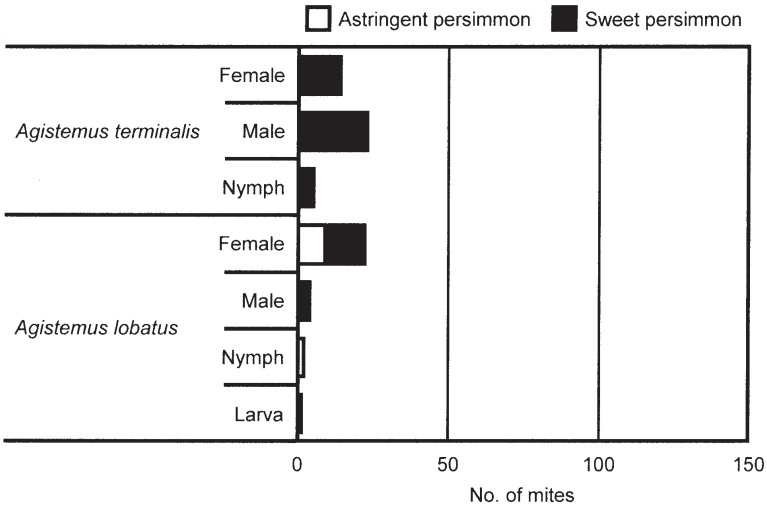

Fig. 6. Total numbers of mites belonging to Stigmaeidae collected on persimmon leaves. In addition to these, there were three unidentified specimens.

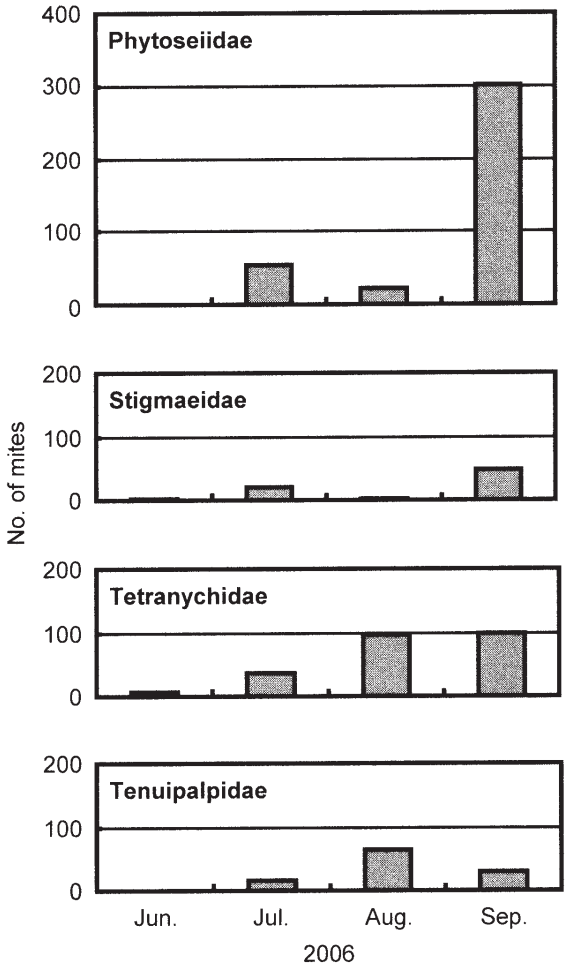

Fig. 7. Monthly numbers of mites belonging to four families collected on persimmon leaves in 2006. Data include all developmental stages except the egg stage.

Brazil (Morton, 1987) and New Zealand (Manson, 1989). Although this species has not been reported in Korea, further detailed research will be needed to confirm its absence.

Predacious mites - Phytoseiid mites are the most important predators of spider mites (McMurtry and Croft, 1997). A total of 305 adults and 76 immature stages of Phytoseiidae were collected but only adults were identified. Among them, *Amblyseius eharai* Amitai and Swirski was predominantly collected and a few numbers of *Neoseiulus womersleyi* (Schicha), *Phytoseius* (*Dubininellus*) *rubii* Xin, Liang and Ke and *Typhlodromus* (*Anthoseius*) *vulgaris* Ehara also were collected (Fig. 5). *Amblyseius eharai* is common in diverse crop systems in Korea (Ryu *et al.*, 1997; Jung *et al.*, 2003; Jung and Lee 2004). This species has been known as a dominant species in agrochemical-reduced and free citrus orchards in southern Japan (Tanaka and Inoue, 1973; Kishimoto *et al*., 2007), and as a potentially important biological control agent of the citrus red mite, *Panonychus citri* (McGregor) (Tanaka and Kashio, 1977). *Phytoseius rubii,* identified by Dr. S. Ehara, was previously reported in Korea under the name *Phytoseius* (*Phytoseius*) *mori* Xin, Liang and Ke (Ryu and Ehara, 1992). However, *P.* (*P.*) *mori* was synonymized with *P.* (*Dubininellus*) *rubii* Xin, Liang and Ke by Wu (1997). *Phytoseius rubii* was collected on several plants including persimmon trees in Korea (Ryu and Ehara, 1992, cited as *P. mori*). However, the ecology of this species is uncertain. In Japan, *A. eharai* and *T. vulgaris* were reported to occur on persimmon trees with other phytoseiids such as *Phytoseius* (*Dubininellus*) *nipponicus* Ehara and *Phytoseius* (*Dubininellus*) *kishii* Ehara (Hiehata and Izumi, 2001). The authors speculated that these phytoseiid species were effective predators for control of *A. diospyri* populations.

Stigmaeid mites also have been known as important predators of spider mites and preferably prey on spider mite eggs (Santos and Laing, 1985). A total of 74 mites belonging to Stigmaeidae were collected and 71 individuals were identified. Two predacious species of Stigmaeidae, *Agistemus terminalis* (Quayle) and *Agistemus lobatus* Ehara, were found (Fig. 6). *Agistemus terminalis* was reported to occur in citrus orchards in Japan (Ehara, 1962; Tanaka and Inoue 1973; Ohnishi *et al.*, 2003) and found preying on eggs of the citrus red mite (Ehara, 1964; Inoue and Tanaka, 1983). On the other hand, *A. lobatus* has been found on apple trees in Aomori Prefecture of Japan (Ehara, 1964) and is known to prey on eggs of *T. urticae*, the European red mite, *Panonychus ulmi* (Koch), and the hawthorn spider mite, *Amphitetranychus viennensis* (Zacher) (Amano, 1996).

Possible interaction of herbivorous and predacious mites in persimmon - Although the densities of mites were not quantitatively comparable between sweet and astringent persimmons in this study, most of the spider mites were found on sweet persimmon rather than on astringent persimmon. And most of them seemed more likely to be *T. urticae*, confirmed from the 2007 collections. This suggests that *Tetranychus* species may have adapted or habituated to sweet persimmon than to the astringent persimmon in Korea. This is contradictory to the Japanese case where the outbreaks of *T. kanzawai* arise mainly on astringent persimmons (Tsutsumi and Yamada, 1993).

Figure 7 shows monthly numbers of herbivorous and predacious mites collected on persimmon trees. The herbivores, tetranychid and tenuipalpid mites were most abundant in August, although numbers did not increase from August to September. The numbers of predators, phytoseiid and stigmaeid mites, followed the herbivores. Thus, they were abundantly collected in September. The above results might suggest that there would be numerical interaction between spider mites and predacious mites in persimmon.

It appears that persimmon is not basically a suitable host for spider mites, because the reproduction rate was lower on persimmon, in case of *T. kanzawai*, than other fruit trees such as pear and apple, albeit there was no statistical analysis (Yamada and Tsutsumi, 1990). Recent increases of spider mites on persimmon trees in Korea might be related to some factors, such as enhanced nutritional value of persimmon, and suppression of natural enemy complex of mites from the intensified orchard management by pesticides. Pesticide spray has increased from 4-5 times per year in the 1970s to 10-11 times in the 2000s (interview of four farmers in Jinju by B-K. Chung, 2006). From the questionnaires to leading farmers of persimmon in 2000 and 2001, pesticide spray frequencies were 7.6 and 7.7 times per year (Lee *et al*., 2003).

If densities of natural enemies are low on persimmon trees, immigrating spider mites from the surrounding area may possibly survive and increase their numbers gradually. As spider mites have shown rapid development of resistance to many groups of acaricides, cultural or biological controls would be more effective methods to manage populations on persimmons. To prevent damage by spider mites on persimmon trees, it will be important to regulate immigration of spider mites to persimmon trees and maintain the abundance of natural enemies on the trees. Therefore, in future study, it will be necessary to elucidate the basic biology of the predacious mites collected in this study and their interactions with each spider mite species occurring on the persimmon trees.

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