Non-crop host plants of *Tetranychus* spider mites (Acari: Tetranychidae) in the field in Okinawa, Japan: Determination of possible sources of pest species and inference on the cause of peculiar mite fauna on crops

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Abstract

The species composition of spider mites on crops in Okinawa is peculiar in that *Tetranychus okinawanus* and *T. piercei* are dominant on most islands, whereas *T. urticae* (green form) and *T. kanzawai* are not. To determine the source plants of *Tetranychus* species infesting crops, as well as to contribute to our understanding of the cause of this peculiar mite fauna, we collected *Tetranychus* mites on non-crop plants throughout Okinawa (more than 450 sites on 15 islands) and identified them. Except in the case of *T. parakanzawai*, the species frequently found on crops tended to occur frequently on non-crop plants, suggesting that the peculiar species composition on crops reflects that also on non-crop plants. *T. parakanzawai* has been rarely found on crops but frequently found on particular non-crop plants, possibly due to the narrower host range of this species. The type of host plants varied among mite species; for example, *T. okinawanus* was frequently found on indigenous plants inhabiting the seashore and invasive weeds, *T. piercei* and *T. parakanzawai* on inland indigenous plants, *T. urticae* (green form) on invasive weeds, and *T. neocaledonicus* on introduced trees. These results are of great significance when considering vegetation control as a tactic for the integrated management of spider mites.

Key words: Beach; host range; invasive species; *Tetranychus ludeni*; *T. pueraricola*

INTRODUCTION

The spider mite genus *Tetranychus* (Acari: Tetranychidae) contains many species injurious to agricultural crops, among which *T. urticae* Koch (green form and red form) and *T. kanzawai* Kishida have been considered the major pest species in East Asia, including Taiwan and the main islands of Japan (e.g., Ehara and Shinkaji, 1996; Ho, 2000). *T. truncatus* Ehara is regarded as another major pest in Taiwan (Ho, 2000). However, we recently clarified that this is not the case on vegetable crops in Okinawa, which is composed of many small is-

lands lying between Taiwan and the main islands of Japan (Ohno et al., 2009). Eight *Tetranychus* species were found infesting crops but *T. urticae* (red form) and *T. truncatus* were not found in Okinawa. Among the eight species, *T. okinawanus* Ehara and *T. piercei* McGregor were the most dominant and second most dominant species, respectively, even though they have not been considered major pests in Taiwan or on the main islands of Japan (Ehara and Shinkaji, 1996; Ho, 2000; Takafuji and Ohashi, 2004). In contrast, *T. urticae* (green form) and *T. kanzawai* were not necessarily common in Okinawa. They were comparable in

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their frequency of occurrence to *T. piercei* in the northern part of Okinawa (the Okinawa Islands), while scarce in the southern part (the Sakishima Islands). Instead, *T. neocaledonicus* André, which occurs on Taiwan but is not common on crops there (Ho, 2000; Takafuji and Ohashi, 2004), was the third-most dominant species in the Sakishima Islands, while this species was the fifth most dominant in the Okinawa Islands. As other minor pest species, *T. ludeni* Zacher, *T. parakanzawai* Ehara and *T. pueraricola* Ehara & Gotoh occurred on crops at lower frequencies in Okinawa. This peculiar distribution of *Tetranychus* spider mites on crops in Okinawa needs to be explained.

Elucidation of non-crop plants utilized by pest spider mites is of great significance to integrative management in terms of the determination of possible source plants/environments (e.g., Morishita, 1992; Morishita and Takafuji, 1999). Further, knowledge of the distribution of *Tetranychus* spp. on non-crop hosts may aid our understanding of the peculiar fauna of this genus on crops in Okinawa; however, only a few preliminary surveys have reported non-crop hosts of *Tetranychus* in Okinawa (Ehara, 1966; Gotoh et al., 1996; Takafuji and Ohashi, 2004). To further understand the spider mite fauna of Okinawa, we extensively collected *Tetranychus* mites infesting non-crop plants throughout the area and identified them to the species level. Based on the data, we discuss the possible source of each of the eight *Tetranychus* species as well as the possible cause of the peculiar

fauna of *Tetranychus* in Okinawa.

MATERIALS AND METHODS

From June 2007 to November 2009, leaves of weeds and trees with spider mite damage recognizable by the naked eye were collected from more than 450 sites on 15 inhabited islands (Fig. 1): Okinawa Island, Iheya Island, Izena Island, Ie Island, Minna Island, Kume Island and Kudaka Island (belonging to the Okinawa Islands); Miyako Island, Irabu Island, Tarama Island, Ishigaki Island, Taketomi Island, Kuro Island, Iriomote Island and Yonaguni Island (belonging to the Sakishima Islands). Collections were made at least three times in different seasons for the majority of the islands, while Izena Island, Minna Island, Kudaka Island, Tarama Island, Taketomi Island and Kuro Island were only surveyed once. If samples were collected from a small island connected to one of the above islands by a bridge (e.g., Yagaji Island and Miyagi Island connected to Okinawa Island, and Ikema Island and Kurima Island connected to Miyako Island), the data were included among those of the larger island. The majority of plant samples were collected in cultivated areas and surrounding areas, such as forest edges, settlements, roadsides and vacant lots, while indigenous weeds and trees inhabiting the seashore (mostly sandy beach) were additionally examined. Any vegetable or ornamental plants infested by spider mites were also collected to examine whether the same mite species occurred on

Fig. 1. Location of the 15 islands of Okinawa surveyed in the present study. Is, Island.

both crop and non-crop plants at the same site and to present additional host records to Ohno et al. (2009).

Mites were identified first as a member of the genus *Tetranychus* based on the key provided by Ehara and Gotoh (2007), and then to the species level based on observations (and if necessary, measurements) of male aedeagi. If the mites in a sample did not include adult males, they were allowed to reproduce on leaf discs of Aino mulberry (*Morus australis* Poir.), kidney bean (*Phaseolus vulgaris* L.), or the collected plant, and were identified when male offspring were obtained. When the co-occurrence of different species in one sample was suspected based on observations of the body coloration of adults (see description by Ehara and Gotoh, 2007), the male aedeagi of multiple (up to 20) individuals were checked for confirmation. Voucher specimens were preserved separately by S. Ohno of Okinawa Prefectural Agricultural Research Center (OPARC), A. Miyagi of Miyakojima Branch of OPARC, and T. Gotoh of Ibaraki University, as slide-mounted specimens using Hoyer's medium. Raw collection and species identification data used in the present study are available from the first author.

Our extensive survey produced much new information on the geographic distribution and host plants of spider mite species. Since data on *Tetranychus takafujii* Ehara & Ohashi (= *T. evansi* Baker and Pritchard; see Gotoh et al., 2009) and *T. phaseolus* Ehara, which have been found only on non-crop plants in Okinawa, are presented elsewhere (Ikeshima et al., 2009; Ohno et al., 2010), the present study treated the data for *Tetranychus* species other than these two species. New distribution records of mite species were determined by referring to Ohno et al. (2009) and references therein. New host records were determined by referring to the worldwide host list provided by Migeon and Dorkeld (2006).

We regarded the number of collection sites for each mite species as an indicator of the frequency of occurrence of the species, as in Ohno et al. (2009). Non-crop plants collected were classified into the following seven categories: (I) indigenous weeds inhabiting the seashore, (II) indigenous trees inhabiting the seashore, (III) indigenous weeds inhabiting non-seashore environments, (IV) indigenous trees inhabiting non-seashore environments,

(V) invasive weeds including those considered archaeophytes, (VI) non-native herbal plants planted for ornamental purposes and/or as green manure, and (VII) non-native introduced trees. In the present study, a plant species which was not mentioned as an introduced species in several colored guides and checklists (e.g., Osada, 1976; Hatusima and Amano, 1994; Yonekura and Kajita, 2006) was considered to be indigenous to Okinawa. Data on the frequency of occurrence of mite species were summarized within each of the plant categories and compared among categories. Data for plants whose category was unclear were excluded from the comparison.

RESULTS

A total of 579 samples were taken, of which 553 from 431 sites were identified to the species level. The remaining samples were not identified due to a failure either to obtain male offspring or in the preparation of slide-mounted specimens. All eight *Tetranychus* species known to infest crops in Okinawa were found, but not *T. truncatus* and *T. urticae* (red form). The frequencies of occurrence of the eight *Tetranychus* species on 15 islands are summarized in Table 1. *T. okinawanus* was found on all islands examined, with a higher frequency than other congeners on a majority of islands. *T. piercei* occurred second most frequently in Okinawa, and in a few islands of the Sakishima Islands it was more dominant than *T. okinawanus*. *T. kanzawai* and *T. urticae* (green form) were as common as *T. piercei* in the Okinawa Islands, while they were relatively scarce in the Sakishima Islands. *T. neocaledonicus* was found at a similar frequency to *T. kanzawai* and *T. urticae* (green form) in the Okinawa Islands, but was more frequent than the two species in the Sakishima Islands. *T. ludeni* was newly found in the western part of the Sakishima Islands, resulting in a broad distribution in Okinawa, but was not common throughout the area. *T. pueraricola* was recorded only on two islands of the Okinawa Islands but not on the Sakishima Islands. *T. parakanzawai* was found to commonly occur throughout Okinawa, being the second and third most frequent species in the Okinawa Islands and the Sakishima Islands, respectively.

Host records in the present study are listed in the Appendix. *T. okinawanus* had the broadest host

Table 1. Geographic distribution and frequency of occurrence of eight *Tetranychus* spp.

Locality	No. sampling sites ^a	No. sites at which each mite species was found ^b							
		<i>T.o.</i>	<i>T.pi.</i>	<i>T.k.</i>	<i>T.u.g.</i>	<i>T.n.</i>	<i>T.l.</i>	<i>T.pu.</i>	<i>T.pa.</i>
Okinawa Islands									
Okinawa Island	180	72	23	21	16	23	2	13	33
Iheya Island	26	16	1*	1*		3	5		3*
Izena Island	1	1*							
Ie Island	6	2*	1*	2*	2*				1*
Minna Island	1	1*							
Kume Island	32	16	5	1	6	3*		1*	4*
Kudaka Island	1	1*							
Total	247	106	30	25	24	29	7	14	41
Sakishima Islands									
Miyako Island	70	25	32	2	5	4*	1		7*
Irabu Island	20	10	7				1		5*
Tarama Island	6	4*					3*		
Ishigaki Island	45	23	11	1		6			9*
Taketomi Island	4	3*							1*
Kuro Island	6	6*	1*				1*		
Iriomote Island	18	3	4				1*		10*
Yonaguni Island	14	6	10*						
Total	183	80	65	3	5	10	7		32

^aData from different plant species were pooled within each island. Collections from different plant species at the same site were considered to be a single sampling. When multiple samplings were made at the same site on different dates, they were treated as a single sampling.

^bSpecies abbreviations are as follows: *T.o.*, *T. okinawanus*; *T.pi.*, *T. piercei*; *T.k.*, *T. kanzawai*; *T.u.g.*, *T. urticae* (green form); *T.n.*, *T. neocaledonicus*; *T.l.*, *T. ludeni*; *T.pu.*, *T. pueraricola*; *T.pa.*, *T. parakanzawai*. The sum of the numbers of sites across different species usually exceeds the total number of sampling sites due to the co-occurrence of multiple species at single sites. A newly recorded distribution at the island level is denoted with an asterisk.

range in the field; this species was found on at least 51 non-crop plant species from 23 families, most of which were newly recorded host plants. The host range of *T. piercei* was the second broadest with at least 34 species from 15 families, again most of them new hosts. The numbers of recorded host species (families) of *T. kanzawai*, *T. urticae* (green form), *T. neocaledonicus* and *T. ludeni* were similar, being at least 13 (10), 16 (12), 20 (15) and 13 (10), respectively. *T. parakanzawai* showed a narrower host range than the above six species, occurring on at least 12 species from seven families, among which all the identified plants were newly recorded hosts. *T. pueraricola* was found on only one fabaceous species, the Taiwan kudzu vine *Pueraria montana*.

Table 2 shows the frequency of occurrence of each mite species summarized by the type of host plant. On indigenous plants inhabiting the seashore (categories I and II), *T. okinawanus* was clearly dominant and other species were scarce. Species

composition on indigenous plants inhabiting non-seashore environments (categories III and IV) showed different characteristics: *T. piercei* and *T. parakanzawai* were dominant, followed by other species. The relative frequency of the occurrence of *T. piercei* and *T. parakanzawai* varied between weeds and trees for both seashore and non-seashore indigenous plants; the former species occurred frequently on weeds, while the latter species were found rarely on weeds but frequently on trees. The dominance of *T. okinawanus* was also observed on invasive weeds (category V), while the second most dominant species in this category was *T. urticae* (green form). The characteristics of species composition on ornamental and green-manure herbal plants (category VI) were similar to those of invasive weeds but were unclear due to their smaller sample sizes. On introduced trees (category VII), *T. neocaledonicus* was clearly dominant.

Table 3 indicates the results of species identifica-

Table 2. Frequency of occurrence of eight *Tetranychus* spp. in relation to the type of host plants

Type of plant	Category ^a	No. sampling sites ^b	No. sites at which each mite species was found ^c							
			<i>T.o.</i>	<i>T.pi.</i>	<i>T.k.</i>	<i>T.u.g.</i>	<i>T.n.</i>	<i>T.l.</i>	<i>T.pu.</i>	<i>T.pa.</i>
Indigenous	I	61	56	8				3		1
	II	27	20							8
	III	69	19	29	3	2	4		14	3
	IV	107	14	25	11	1	6	1		61
Non-indigenous	V	109	66	18	3	22	4	5		2
	VI	19	11	4	1	2	1	1		
	VII	53	11	11	8	1	26			

^a I, weeds inhabiting the seashore; II, trees inhabiting the seashore; III, weeds inhabiting non-seashore environments; IV, trees inhabiting non-seashore environments; V, invasive weeds (including those regarded as archaeophytes); VI, herbal plants grown for ornamental purposes and/or as green manure; VII, introduced trees. See Appendix for species composition of the plants in each category.

^b Collections from different plant species belonging to the same category at the same site were treated as a single sampling.

^c Species abbreviations are the same as in Table 1. The sum of the numbers of sites across different species exceeds the total number of sampling sites due to the co-occurrence of multiple species at single sites.

Table 3. Results of mite species identification when crop and non-crop plants were simultaneously collected at the same location

Island	Collection date	Crop plant (mite species ^a)	Non-crop plant (mite species ^a)
Okinawa	19 Aug. 2008	Water spinach (<i>T.o.</i>)	<i>Solanum americanum</i> (<i>T.o.</i>)
	9 Dec. 2008	Melon (<i>T.n.</i>)	<i>Mallotus japonicus</i> (<i>T.pa.</i>); <i>Morus australis</i> (<i>T.pi.</i>); <i>Tabebuia chrysotricha</i> (<i>T.n.</i>)
	26 Dec. 2008	Egyptian bean and water spinach (both <i>T.o.</i>); taro (<i>T.pi.</i>); winged bean (<i>T.k.</i> and <i>T.pi.</i>)	<i>Amaranthus</i> sp. (<i>T.o.</i>); <i>Morus australis</i> (<i>T.k.</i> , <i>T.o.</i> and <i>T.pi.</i>)
	5 Feb. 2009	Sweet potato (<i>T.n.</i>)	<i>Hibiscus rosa-sinensis</i> and <i>Youngia japonica</i> (both <i>T.n.</i>)
	23 Apr. 2009	Bell pepper (<i>T.u.g.</i>)	<i>Solanum americanum</i> (<i>T.u.g.</i>)
Kume Miyako	12 May 2009	Carrot (<i>T.o.</i>)	<i>Amaranthus</i> sp. and <i>Solanum americanum</i> (both <i>T.o.</i>)
	20 May 2008	Okra (<i>T.pi.</i>)	<i>Oxalis debilis</i> (<i>T.pi.</i>)
	18 Mar. 2009	Kidney bean (<i>T.pi.</i>)	<i>Amaranthus</i> sp. and <i>Oxalis debilis</i> (both <i>T.pi.</i>)
	30 Mar. 2009	Wax gourd (<i>T.u.g.</i>)	<i>Oxalis debilis</i> (<i>T.u.g.</i>)
	7 Apr. 2009	Wax gourd (<i>T.o.</i>)	<i>Amaranthus</i> sp., <i>Medicago lupulina</i> , <i>Setaria</i> sp. and <i>Solanum americanum</i> (all <i>T.o.</i>)
Irabu	30 Jul. 2009	Maize and melon (both <i>T.o.</i>)	<i>Ipomoea biflora</i> (<i>T.o.</i> and <i>T.pi.</i>)
	4 May 2008	Cucumber (<i>T.o.</i>)	<i>Diplocyclos palmatus</i> and <i>Solanum americanum</i> (both <i>T.o.</i>)
Tarama	16 Mar. 2009	Eggplant (<i>T.o.</i>); bell pepper (<i>T.l.</i>)	<i>Amaranthus</i> sp. and <i>Solanum americanum</i> (both <i>T.o.</i>)
Ishigaki	8 Nov. 2007	<i>Crepidiastrum lanceolatum</i> (<i>T.o.</i>)	<i>Pueraria montana</i> (<i>T.pi.</i>)
	13 Jun. 2008	Tomato (<i>T.o.</i>)	<i>Amaranthus</i> sp. (<i>T.o.</i>)
	22 Dec. 2008	Okra (<i>T.o.</i>)	<i>Acalypha australis</i> and <i>Bidens pilosa</i> (both <i>T.o.</i>)
Iriomote	11 Jun. 2008	Sponge gourd (<i>T.pi.</i>)	<i>Melanolepis multiglandulosa</i> (<i>T.pa.</i>)

^a Species abbreviations are the same as in Table 1. Data on crop plants from 2007 to 2008 were also used by Ohno et al. (2009).

tion when the mites were simultaneously collected on both crop and non-crop plants at single sites. In 15 (88%) out of the 17 cases, at least one mite species was shared between crop and non-crop plants.

DISCUSSION

The present study extensively examined non-crop hosts of *Tetranychus* species in Okinawa and determined major non-crop host plants as possible sources for the majority of the eight species found.

These results are of great significance when considering vegetation control as a tactic for the integrated management of pest spider mites in Okinawa. *T. truncatus* and *T. urticae* (red form), which have not been found on crops in Okinawa, were not found on non-crop plants either, suggesting that they do not seem to occur in Okinawa. Overall, the mite species which occurred frequently on crops tended to occur frequently on non-crop plants. Dominant species on crops in the Sakishima Islands (*T. okinawanus*, *T. piercei* and *T. neocaledonicus*) and the Okinawa Islands [these three species plus *T. kanzawai* and *T. urticae* (green form)] (Ohno et al., 2009) were also dominant on non-crop plants in the respective areas (Table 1). This finding provides an explanation for the peculiar *Tetranychus* fauna on crops in Okinawa: it reflects the abundance of each species on non-crop plants in the field. This idea is also supported by the fact that the same mite species were found on both crop and non-crop plants occurring at the same location in most cases (Table 3) which suggests the movement of mites from non-crop to crop plants. However, *T. parakanzawai* was a clear exception. Although this species was found only once on crops despite more than 200 samplings (Ohno et al., 2009), the present results showed that the species commonly occurs throughout Okinawa (Table 1).

We further clarified that mite species composition varied markedly among different types of non-crop plants (Table 2). This result allows us to further discuss the source and habitat of each mite species. For example, *T. okinawanus* was dominant on indigenous plants inhabiting the seashore, mainly the perennial weeds *Vigna marina* and *Ipomoea pes-caprae*, and the tree *Scaevola taccada* (see Appendix), all of which are common on sandy beaches in Okinawa. This result suggests not only that these plants are major sources of *T. okinawanus*, but also the possibility that one of the natural habitats of this mite is the seashore; therefore, cultivation fields located near the sea may be exposed to a higher risk of invasion by *T. okinawanus*. This interpretation matches the fact that *T. okinawanus* is dominant in Okinawa but not on neighboring larger islands, such as Taiwan. Since a smaller island has a longer coastline relative to its area, the chance of incursion of the species from the seashore to inland would be higher on smaller

islands. At present, however, it is unclear whether *T. okinawanus* is also abundant on seashores in Taiwan and other Asian regions, which is of great interest. Other major hosts of *T. okinawanus* were invasive annual herbs, such as *Amaranthus* spp. and *Solanum americanum* (see Appendix). Some papers have regarded *T. okinawanus* as an invasive species which uses invasive weeds as major hosts (e.g., Ohashi et al., 2003; Takafuji and Ohashi, 2004).

On crop plants in Okinawa, *T. piercei* was one of the most common spider mite species, while *T. parakanzawai* was rarely found (Ohno et al., 2009). We showed that both species were similarly common on non-crop indigenous plants inhabiting non-seashore environments. Interestingly, *T. piercei* was found on both weed and tree species, whereas the occurrence of *T. parakanzawai* was extremely biased toward tree species (Table 2), suggesting species difference in the preference on plant species and/or habits. The former species was collected from many plant species, among which the perennial weeds *Puraria montata* and *Ipomoea indica*, and the trees *Morus australis* and *Melanolepis multiglandulosa*, were considered major source hosts (see Appendix). In contrast, more than 80% of *T. parakanzawai* samples were collected from the trees, *Mallotus japonicus*, *Melanolepis multiglandulosa* and *Clerodendrum trichotomum* (see Appendix). The supposed narrow host range of *T. parakanzawai* in the field compared to other major species is possibly one of the causes of the scarcity of this species on crops.

In most cases, *T. urticae* (green form) was found on invasive weeds, such as *Solanum americanum* and *Oxalis debilis* (see Appendix), showing the importance of this kind of plant as a source of the pest. This result matches the view that this species is non-native to Okinawa, and suggests that populations of this species are mainly maintained on introduced plants in artificially developed areas. *T. urticae* (green form) is considered a worldwide invasive species originating from the Mediterranean region and thus non-native to Japan (Navajas et al., 1998; Hinomoto et al., 2001). The reason why this invasive species has not expanded its range to indigenous plants in Okinawa is of interest but unclear at present. Irrespective of their similar distribution pattern in Okinawa, *T. kanzawai* and *T. urticae* (green form) somewhat varied in the host

usage pattern; the former species was found on both indigenous and non-indigenous plants at a similar frequency (Table 2). Among the recorded host plants of *T. kanzawai*, *Morus australis* was most frequently infested (see Appendix), suggesting that this plant is one of the most important source of this pest in Okinawa.

T. neocaledonicus had a unique host usage pattern. It was the species most frequently found on introduced trees, such as *Bauhinia* spp. and *Jatropha integerrima* (see Appendix), strongly suggesting that such trees are sources of this mite. Considering that most of the introduced trees examined were of tropical origin, *T. neocaledonicus* might have been introduced from tropical regions together with the trees. One of the minor species on crops, *T. ludeni*, was also less frequently found on non-crop plants with no clear characteristics in its host usage pattern. The scarcity of this species irrespective of its broad distribution and host ranges needs to be explained. Another minor species, *T. pueraricola*, showed a distinct pattern. It was found only on an indigenous perennial weed, *Pueraria montana*, in the Okinawa Islands. This suggests the strong host preference of *T. pueraricola* for the plant despite its potential to use a wide range of plant taxa as hosts (Gotoh et al., 2004). The narrow host range of *T. pueraricola* in the field is probably a cause of the rarity of this species on crops.

In conclusion, we have clarified a peculiar fauna of *Tetranychus* spider mites on both crop and non-crop plants in Okinawa (Ohno et al., 2009; present study), providing fundamental information on their integrated management in that area. One of the most marked peculiarities is that two serious pest species, *T. urticae* (green form) and *T. kanzawai*, are scarce or even not found in the southern part of Okinawa (Sakishima Islands) even though these species are common in adjacent areas (i.e., Taiwan, the Okinawa Islands and the main islands of Japan). There may be some abiotic or biotic factors (e.g., climatic condition, vegetation or specialist predators) specific to the Sakishima Islands that hamper population growth and range expansion by these species. Determination of such factors is important in that it is not only of biogeographical interest but also suggestive for controls of the two species in areas other than the Sakishima Islands.

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Appendix. Host plant records for eight *Tetranychus* spp. examined in the present study

Plant family: Species [Common name, if any]	Plant category ^a	No. sampling sites ^b	No. sites at which each mite species was found ^c							
			<i>T.o.</i>	<i>T.pi.</i>	<i>T.k.</i>	<i>T.u.g.</i>	<i>T.n.</i>	<i>T.l.</i>	<i>T.pu.</i>	<i>T.pa.</i>
Acanthaceae: <i>Thunbergia grandiflora</i> (Roxb. ex Rottl.) Roxb. [Bengal clock vine]	VI	1	1*							
<i>Thunbergia</i> sp. [Clock vine]	VI	1						1		
Agavaceae: <i>Cordylone terminalis</i> (L.) Kunth [Dwarf red dracaena]	Crop	1			1					
Amaranthaceae: <i>Amaranthus</i> spp. [Amaranth]	V	22	16*	3*		2		1		
Apiaceae: <i>Cenella asiatica</i> (L.) Urb. [Indian pennywort]	III	1	1*							
<i>Daucus carota</i> L. [Carrot]	Crop	1	1*							
<i>Peucedanum japonicum</i> Thunb.	Crop	1	1							
Apocynaceae: <i>Parsonia alboflavescens</i> (Dennst.) Mabb.	III	1					1*			
<i>Plumeria</i> sp. [Plumeria]	VII	1		1*						
Araceae: <i>Alocasia</i> sp. [Alocasia]	VI	1	1*							
Araliaceae: <i>Hedera</i> sp. [Ivy]	VI	2				2				
Aristolochiaceae: <i>Aristolochia lukuensis</i> Hatus.	III	1		1*						
Asclepiadaceae: <i>Asclepias curassavica</i> L. [Milk weed]	VI	1	1*							
Asteraceae: <i>Ageratum conyzoides</i> L. [Flossflower]	V	1	1*							
<i>Ageratum houstonianum</i> Mill. [Blue billy goatweed]	V	3	3*			1*				
<i>Aster subulatus</i> Michx. [Annual salt marsh aster]	V	1	1*							
<i>Bidens pilosa</i> L. [Spanish needle]	V	19	17		1*			2*		
<i>Conyza sumatrensis</i> (Retz.) E. Walker [Sumatran fleabane]	V	1	1*							
<i>Cosmos bipinnatus</i> Cav. [Cosmos]	IV	1	1*							
<i>Crassocephalum crepidioides</i> (Benth.) S. Moore [Fireweed]	V	3	1*			3*				
<i>Dahlia × hortensis</i> Guill. [Dahlia]	Crop	1	1*							
<i>Emilia sonchifolia</i> (L.) DC. [Cupid's shaving brush]	V	3	2*	1*						
<i>Lactuca indica</i> L. [Indian lettuce]	V	2	2*							
<i>Liatris spicata</i> (L.) Willd. [Blazing star]	Crop	1	1*							
<i>Sonchus oleraceus</i> L. [Common sowthistle]	V	3				2	1*			
<i>Tagetes</i> sp. [Marigold]	VI	1	1*							
<i>Youngia japonica</i> (L.) DC. [Oriental false hawksbeard]	III	3	1*		1*		1*			
<i>Wedelia biflora</i> (L.) DC.	I	3	2*					1*		
Unidentified weed species 1	Unknown	1				1				
Unidentified weed species 2	Unknown	1						1		
Bignoniaceae: <i>Tabebuia chrysotricha</i> (Mart. ex DC.) Standl. [Golden trumpet tree]	VII	2					2*			
Brassicaceae: <i>Brassica juncea</i> (L.) Czern. [Leaf mustard]	Crop	1			1					
Caprifoliaceae: <i>Sambucus chinensis</i> Lindl. [Chinese elderberry]	III	7	6*			1*				
Caryophyllaceae: <i>Stellaria aquatica</i> (L.) Scop. [Water chickweed]	VII	3				3*				
Convolvulaceae: <i>Ipomoea aquatica</i> Forssk. [Water spinach]	Crop	2	2			1				
<i>Ipomoea batatas</i> (L.) Poir. [Sweet potato]	Crop	4	3				1			
<i>Ipomoea biflora</i> (L.) Pers. [White woodrose]	VII	6	5*	2*						
<i>Ipomoea cairica</i> (L.) Sweet [Cairo morning glory]	VII	2	1*						1	
<i>Ipomoea indica</i> (Burm.) Merr. [Blue morning glory]	III	17	8*	7*		1*	1*			
<i>Ipomoea nil</i> (L.) Roth [Japanese morning glory]	VI	2	2*							

Appendix. (Continued)

Plant family: Species [Common name, if any]	Plant category ^a	No. sampling sites ^b	No. sites at which each mite species was found ^c						
			<i>T.o.</i>	<i>T.pi.</i>	<i>T.k.</i>	<i>T.u.g.</i>	<i>T.n.</i>	<i>T.l.</i>	<i>T.pu.</i>
<i>Ipomoea pes-caprae</i> (L.) Sweet [Beach morning glory]	I	33	30*	4*				2*	
<i>Ipomoea triloba</i> L. [Three-lobed morning glory]	V	2	1*	1*					
Cucurbitaceae: <i>Benincasa hispida</i> (Thunb.) Cogn. [Wax gourd]	Crop	3	1*		1	1			
<i>Citrullus lanatus</i> (Thunb.) Matsum. et Nakai [Watermelon]	Crop	1				1			
<i>Cucumis melo</i> L. [Melon]	Crop	2		1	1				
<i>Cucumis sativus</i> L. [Cucumber]	Crop	1						1	
<i>Diplocyclos palmatus</i> (L.) C. Jeffrey	III	2	1*		1				
Euphorbiaceae: <i>Acalypha australis</i> L. [Three-seeded copperleaf]	V	8	2*	5*			1*		
<i>Chamaesyce prostrata</i> (Aiton) Small [Groundfig spurge]	V	1		1*					
<i>Jatropha curcas</i> L. [Barbados nut]	VII	1					1*		
<i>Jatropha integririma</i> Jacq. [Peregrina]	VII	13		5*	3*		5*		
<i>Mallotus japonicus</i> (L. f.) Müll. Arg. [Japanese mallotus]	IV	23	1*	1*					21*
<i>Melanolepis multiglandulosa</i> (Reinw. ex Blume) Rechb. f. et Zoll.	IV	35	1*	9*	1*		4*		24*
<i>Phyllanthus amarus</i> Schum. [Niruri]	V	4		3*		1*			1*
Fabaceae: <i>Bauhinia</i> spp. [Orchid tree]	VII	15	1*	2*		1	12		
<i>Canavalia</i> spp. [Jack bean]	III	4	1*	3					
<i>Clitoria ternatea</i> L. [Butterfly pea]	VI	1			1*				
<i>Crotalaria juncea</i> L. [Sunn-hemp]	VI	1	1*						
<i>Erythrina variegata</i> L. ex Stickman [Coral tree]	VII	12	6*	1*	3*		3*		
<i>Galactia tashiroi</i> Maxim.	I	1		1*					
<i>Glycine max</i> (L.) Merr. [Soybean]	Crop	1	1						
<i>Medicago lupulina</i> L. [Black medic]	V	2	1			1			
<i>Mucuna pruriens</i> (L.) DC. [Velvet bean]	VI	3		3*					
<i>Phaseolus vulgaris</i> L. [Kidney bean]	Crop	3	1	2					
<i>Psophocarpus tetragonolobus</i> (L.) DC. [Winged bean]	Crop	2	1			1			
<i>Pueraria montana</i> (Lour.) Merr. [Taiwan kudzu vine]	III	28	2	15				14	1*
<i>Vigna marina</i> (Burm.f.) Merr. [Beach bean]	I	39	37*	3*					1*
<i>Vigna reflexopilosa</i> Hayata	III	2		2*					
Geraniaceae: <i>Geranium carolinianum</i> L. [Carolina cranesbill]	V	2	22*	2*			1*		5*
Goodeniaceae: <i>Scaevola taccada</i> (Gaertn.) Roxb. [Fan flower]	II	26						1*	
Lamiaceae: <i>Salvia greggii</i> A. Gray [Cherry sage]	VI	1						1*	
<i>Salvia leucantha</i> Cav. [Mexican bush sage]	VI	1						1*	
<i>Perilla frutescens</i> (L.) Britton [Perilla]	Crop	1	1						
Unidentified weed species	Unknown	1	1						
Limnocaritaceae: <i>Hydrocleys nymphoides</i> (Willd.) Buchenau [Water poppy]	VI	1	1*						
Malvaceae: <i>Abelmoschus esculentus</i> (L.) Moench [Okra]	Crop	1		1*				1	
<i>Abutilon indicum</i> (L.) Sweet [India abutilon]	V	1							
<i>Hibiscus mutabilis</i> L. [Cotton rosemallow]	VII	2	1*	1*	1*				
<i>Hibiscus rosa-sinensis</i> L. [Chinese hibiscus]	VII	5	2*		1*		2		
<i>Hibiscus syriacus</i> L. [Rose of Sharon]	VII	1					1		
<i>Malva sylvestris</i> L. [Common mallow]	VI	1						1	

Appendix. (Continued)

Plant family: Species [Common name, if any]	Plant category ^a	No. sampling sites ^b	No. sites at which each mite species was found ^c						
			<i>T.o.</i>	<i>T.pi.</i>	<i>T.k.</i>	<i>T.u.g.</i>	<i>T.n.</i>	<i>T.l.</i>	<i>T.pa.</i>
Moraceae: <i>Broussonetia papyrifera</i> (L.) L'Hér. ex Vent. [Paper mulberry]	VII	1		1*					
<i>Morus australis</i> Poir. [Aino mulberry]	IV	33	11*	15*	9*	1*	2		2*
Oxalidaceae: <i>Oxalis corniculata</i> L. [Yellow wood sorrel]	III	2		1*	1*				
<i>Oxalis debilis</i> Kunth [Violet wood sorrel]	V	11		2*	1*	6*	1*		1*
Piperaceae: <i>Piper retrofractum</i> Vahl [Java long piper]	VI	2	2*						
Poaceae: <i>Setaria</i> sp. [Foxtail grass]	Unknown	1	1*						
<i>Zea mays</i> L. [Maize]	Crop	2	1*	1*		1			
Pontederiaceae: <i>Eichhornia crassipes</i> (Mart.) Solms-Laub. [Common water hyacinth]	V	3	2*				1		
Rosaceae: <i>Cerasus campanulata</i> (Maxim.) A. V. Vassil. [Taiwan cherry]	VII	1			1*				
<i>Rosa</i> sp. [Rose]	VI	1		1					
Rubiaceae: <i>Paederia scandens</i> (Lour.) Merr. [Skunk vine]	III	1	1*						
Rutaceae: <i>Murraya paniculata</i> (L.) Jack [Orange jasmine]	IV	1		1					
Solanaceae: <i>Brugmansia suaveolens</i> (Humb. et Bonpl. ex Willd.) Bercht et C. Presl [Angel's trumpet]	VII	3	1*				1*		
<i>Capsicum annuum</i> L. 'Grossum' [Bell pepper]	Crop	2		1				1*	
<i>Physalis pubescens</i> L. [Ground cherry]	V	2	1*					1*	
<i>Solanum americanum</i> Mill. [American black nightshade]	V	29	20*			10			
<i>Solanum melongena</i> L. [Eggplant]	Crop	3							
Sterculiaceae: <i>Melochia corchorifolia</i> L. [Chocolate weed]	V	1	1*						2*
Urticaceae: <i>Boehmeria nivea</i> (L.) Gaudich. [Ramie]	III	3					1*		
Violaceae: <i>Viola</i> sp. [Violet]	Unknown	1		1*				1*	
Verbenaceae: <i>Callicarpa japonica</i> Thunb. [Japanese beautyberry]	IV	2	1*						1*
<i>Clerodendrum inerme</i> (L.) Gaertn. [Seaside clerodendrum]	II	1							15*
<i>Clerodendrum trichotomum</i> Thunb. [Harlequin glory bower]	IV	15							
Zingiberaceae: <i>Alpinia zerumbet</i> (Pers.) B. L. Burtt et R. M. Sm. [Shell ginger]	IV	1		1*					
Family unknown: Unidentified tree species 1	Unknown	1	1						
Unidentified tree species 2	Unknown	1					1		
Unidentified tree species 3	Unknown	1							1
Unidentified weed species 1	Unknown	1		1					
Unidentified weed species 2	Unknown	1				1			

^a See footnote of Table 2 for explanation. Data for category 'Unknown' were included in Table 1 but not in Table 2.^b When multiple samplings were made at the same site on different dates, they were treated as a single sampling.^c Species abbreviations are the same as in Table 1. A newly recorded host is denoted with an asterisk. The sum of the numbers of sites across different species sometimes exceeds the total number of sampling sites due to the co-occurrence of multiple species at single sites.