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ORIGINAL ARTICLE

Species composition of thrips (Thysanoptera: Thripidae) and spider mites (Acari: Tetranychidae) on cultivated chrysanthemum (Asteraceae) in Okinawa, southwestern Japan

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Abstract

We investigated the species composition of phytophagous thrips and spider mites on cultivated chrysanthemum in Okinawa, southwestern Japan. Eight thrips species belonging to the genera *Frankliniella*, *Microcephalothrips*, *Scirtothrips* and *Thrips* were found on chrysanthemum leaves. Among them, *Thrips nigropilosus* was the predominant species irrespective of season, island or cultivation environment (meshed greenhouse or open field), with its infestation frequency being 89% of the fields in which thrips occurred. This high frequency of occurrence suggests that *T. nigropilosus* is a major pest of chrysanthemum in Okinawa, even though this species has rarely been regarded as an important pest of chrysanthemum or other crops in any other areas. *Thrips palmi* was the second most dominant (infestation frequency 36%) and other species were scarce (<14%). *Tetranychus urticae* (green form) was the only tetranychid species on chrysanthemum in our survey. This lack of diversity among spider mites on chrysanthemum is peculiar considering that eight *Tetranychus* species have been found on vegetables in the same area. Since *T. urticae* (green form) has been shown to be resistant to a number of pesticides, severe pesticide applications might have simplified the spider mite fauna on chrysanthemum in Okinawa.

Key words: *Chrysanthemum morifolium*, *Frankliniella occidentalis*, *Scirtothrips dorsalis*, *Thrips palmi*, *Thrips tabaci*.

INTRODUCTION

Species identification of pests on crops is essential for adequate control of the targeted pests. In Okinawa, a subtropical area, the pest fauna is less well resolved than that in temperate areas of Japan, especially for tiny arthropod pests such as thrips and spider mites. This situation has long been an obstacle to establishing pest management practices in the area.

Due to its warm climate in winter, Okinawa is one of the main production areas of ornamental chrysanthemum *Chrysanthemum morifolium* Ramat. in Japan. However, the decolorization and deformation of chrysanthemum leaves, which drastically decrease the quality of the plants, have been problematic. The damage is possibly caused by thrips and spider mites, but the species composition of these taxa on chrysanthemum in Okinawa has remained unclear. Nagamine (1994) noted that *Thrips palmi* Karny (Thysanoptera: Thripidae) and *Tetranychus urticae* Koch (Acari: Tetranychidae) are two key pests of chrysanthemum in Okinawa without referring to methods used for field surveys and species identification. Thus, whether his results are reliable or not is unclear. In this study, we collected thrips and spider mites from cultivated chrysanthemum in Okinawa and identified them to the species level to obtain fundamental information for their management.

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MATERIALS AND METHODS

In Okinawa, chrysanthemum seedlings are usually prepared from April to November and planted in fields from August to December. The fields are lit up for one to three and a half hours after sunset every day to postpone the timing of flowering except one month before harvest (Department of Agriculture, Forestry and Fishers, Okinawa Prefectural Government 2009). The plants are harvested from November to April.

In 2009, we surveyed 34 chrysanthemum fields from March to May (spring) and 39 fields from September to November (autumn) on Okinawa Island, Ie Island and Kume Island, among which 16 fields were shared between the two collection periods. In Okinawa, chrysanthemum is cultivated in either an open field or a greenhouse with a meshed roof and walls (meshed greenhouse, hereafter); therefore, our surveys were conducted on both. To find thrips and spider mites on leaves, each field was investigated for a total of 40 min by two to four people (e.g. 20 min when two people were involved, 10 min when four people were involved). When adult thrips were found, they were collected and placed in 70% ethanol using a fine brush. If only larvae were found, infested leaves were collected and kept at 25°C under conditions of 14 h light : 10 h dark (LD 14:10) until adults emerged. When spider mites were found, several infested leaves were collected. If the mites in a sample did not contain males, they were allowed to reproduce on leaf discs of the collected chrysanthemum or mulberry *Morus australis* Poir. (Moraceae) at 25°C under conditions of LD 14:10. To examine the species composition of thrips in flowers, we also collected up to ten fully opened flowers of chrysanthemum per field in the spring survey. The color of flowers surveyed was red, white or yellow. Adult thrips that escaped from the flowers were placed in 70% ethanol.

We examined an average of 12 (at most 30) individuals from leaves per field and an average of six individuals from flowers (at most 50) per field. Because the thrips collected in a field frequently included individuals differing in body coloration, we included individuals varying in color in the sample so as to detect multiple species from single fields as much as possible. These specimens were macerated with 10% KOH and mounted in Hoyer's medium or Canada balsam after dehydration in ethanol and clearing in clove oil. Species identification was based on Mound and Kibby (1998), Masumoto and Okajima (2004) and Palmer (1992). For spider mites, at least one adult for each sex from a field was mounted in Hoyer's medium after observation of body coloration of living females and identified by referring to Ehara and Gotoh (2009). Voucher specimens were preserved in the Okinawa Prefectural Agricultural Research Center, Itoman City, Okinawa, Japan.

We regarded the number of collection fields for each thrips and mite species as an indicator of the frequency of occurrence of the species for calculation of infestation frequency and statistical comparisons. Data on the frequency of occurrence of thrips and mite species were summarized by collection period (spring and autumn), area (island) and cultivation environment (meshed greenhouse and open field). Infestation frequency of a given thrips species was defined as the ratio of the total number of collection fields to the total number of fields in which thrips were found. We used Fisher's exact test with Bonferroni correction to compare the species composition of thrips between groups varying in collection period, island or cultivation environment. In this test, each of the multiple species found from a single field was treated as an independent data point.

RESULTS

Table 1 shows the species composition of thrips and spider mites on chrysanthemum leaves in Okinawa in 2009. In spring, six thrips species belonging to three genera were found in 21 (61.8%) of the 34 chrysanthemum fields surveyed: *Thrips nigropilosus* Uzel, *Thrips palmi*, *Thrips tabaci* Lindeman, *Thrips hawaiiensis* (Morgan), *Scirtothrips dorsalis* Hood and *Frankliniella intonsa* (Trybom). In autumn, two other thrips, *Frankliniella cephalica* (Crawford) and *Microcephalothrips abdominalis* (Crawford), were found in addition to the six species in 26 (66.7%) of the 39 fields surveyed. There were no significant differences in the species composition of thrips in any combinations of the 12 groups ($P>0.05$). Of the eight species collected from leaves, *T. nigropilosus* was the most predominant irrespective of season, island and cultivation environment, its infestation frequency being 88.9%. *Thrips palmi* was the second most predominant with an infestation frequency of 35.6%. Infestation frequencies of the other six species were low, ranging 2.2–13.3%. Multiple species were simultaneously found in 23 of the 45 fields while the remaining 22 fields contained only one species, either *T. nigropilosus* (19 fields), *T. palmi* (two fields) or *S. dorsalis* (one field). The other five species always co-occurred with other species. *Thrips nigropilosus* and *T. palmi* frequently co-occurred: they were found in 13 fields at the same time.

Flowers from 26 of the 29 fields surveyed contained thrips (Table 2). These thrips comprised seven species of three genera. No significant differences in species composition were observed in any combinations of six

Table 1 Species composition of thrips and spider mites on chrysanthemum leaves in Okinawa in 2009

					No. of fields in which each species was found (total no. of individuals examined)								
Collection period	Island	Cultivation environment[†]	No. of fields surveyed	No. of fields in which thrips were found[‡]	*T. nigropilosus*	*T. palmi*	*T. tabaci*	*T. hawaiiensis*	*S. dorsalis*	*F. intonsa*	*F. cephalica*	*M. abdominalis*	No. of fields in which *Tetranychus urticae* (green form) was found
March to May	Okinawa	M	3	2	2 (13)	1 (7)	0	0	0	0	0	0	2
		O	9	5	5 (60)	1 (1)	1 (2)	1 (3)	0	0	0	0	5
	Ie	M	4	4	4 (47)	1 (1)	0	1 (1)	0	0	0	0	0
		O	8	6	6 (30)	2 (8)	1 (5)	0	1 (4)	1 (1)	0	0	0
	Kume	M	4	2	2 (18)	1 (2)	0	0	0	0	0	0	3
		O	6	2	2 (21)	0	2 (6)	0	1 (1)	0	0	0	3
September to November	Okinawa	M	7	6	5 (50)	3 (7)	0	1 (1)	0	0	0	0	2
		O	10	9	9 (84)	3 (6)	0	2 (4)	1 (1)	0	0	1 (1)	2
	Ie	M	6	3	3 (40)	0	0	0	0	0	0	0	2
		O	5	3	3 (24)	0	0	1 (1)	0	0	0	0	1
	Kume	M	4	4	2 (19)	3 (12)	0	0	0	0	0	0	2
		O	7	6	4 (28)	2 (10)	0	0	1 (3)	0	1 (1)	1 (1)	0
Total[§]			57	45	40 (434)	16 (54)	4 (13)	6 (10)	5 (9)	1 (1)	1 (1)	2 (2)	19

[†]M, meshed greenhouse; O, open field. [‡]Sum of the numbers of fields across different thrips species exceeds the total number of fields due to the co-occurrences of multiple species in a single field.
[§]This number of fields is smaller than the sum of the numbers of fields across a row because several fields were shared between the two collection periods.

Table 2 Species composition of thrips on chrysanthemum flowers in Okinawa from March to May 2009

Island	Cultivation environment†	No. of fields surveyed	No. of fields in which thrips were found‡	No. of fields in which each species was found (total no. of individuals examined)						
				T. nigropilosus	*T. palmi*	*T. tabaci*	*T. hawaiiensis*	*F. intonsa*	*F. cephalica*	*M. abdominalis*
Okinawa	M	2	2	0	1 (1)	0	0	1 (3)	0	0
	O	8	8	2 (5)	1 (2)	1 (1)	8 (55)	5 (15)	0	0
Ie	M	3	3	1 (2)	0	1 (2)	3 (17)	0	0	0
	O	8	8	0	6 (8)	5 (12)	5 (11)	1 (1)	1 (1)	3 (5)
Kume	M	4	3	0	0	0	0	3 (9)	0	1 (1)
	O	4	4	0	2 (2)	0	4 (16)	0	0	1 (2)
Total		29	28	3 (7)	10 (13)	7 (14)	20 (99)	10 (28)	1 (1)	5 (8)

†M, meshed greenhouse; O, open field. ‡Sum of the numbers of fields across different thrips species usually exceeds the total number of fields due to the co-occurrences of multiple species in a single field.

groups (P>0.05). *Thrips hawaiiensis* was the most predominant species in flowers (infestation frequency 76.9%), followed by *T. palmi* and *F. intonsa* (both 38.5%). *Thrips nigropilosus* was found in only three fields (11.5%), but had the highest infestation frequency on leaves. The infestation frequency of *T. tabaci* on flowers (26.9%) was higher than that on leaves (8.9%). *Thrips palmi* was found on flowers (38.5%) and leaves (35.6%) to a similar extent.

Spider mites were found in 13 of the 34 fields (38.2%) in spring, and nine of the 39 fields (23.1%) in autumn (Table 1). All of them were identified as *Tetranychus urticae* (green form). This species was found in both meshed greenhouses and open fields of all the three islands surveyed (Table 1).

DISCUSSION

The present study clarified the species composition of thrips and spider mites on chrysanthemum in Okinawa, which is fundamental to controlling them. A total of eight thrips species belonging to four genera were found on leaves. Among them, *T. nigropilosus* had a remarkably higher infestation frequency than other thrips species irrespective of collection period, island and cultivation environment. This result suggests that *T. nigropilosus* is an important pest species of chrysanthemum in Okinawa, which was unexpected considering that it has not been recognized as a pest of chrysanthemum in Okinawa (Nagamine 1994), although it was collected from an unidentified asteraceous plant on Okinawa Island in 1994 (Nakao & Yabu 1998).

Thrips nigropilosus is widespread around the world (Mound 2010) and has been reported as a pest of various crops in many countries: *Chrysanthemum cinerariaefolium* (Asteraceae) in Kenya (Bullock 1965); *Chrysanthemum morifolium* in the USA (north America) (Stannard 1968), UK (Mound *et al*. 1976) and temperate areas of Japan (Umeya & Okada 2003); *Plantago lanceolata* and *Plantago maritima* (Plantaginaceae) in the UK (Mound *et al*. 1976); and other crops including *Cucumis sativus* (Cucurbitaceae) and *Lactuca sativa* (Asteraceae) in Hawaii (Sakimura 1939). However, most of these reports were made more than 35 years ago, and recently this species has received little attention as a pest (Mound 2010). Walker and Michaux (1989) stated that the widespread use of pesticides has reduced the pest status of *T. nigropilosus*. In Okinawa, pesticides are more frequently applied on chrysanthemum than on other crops such as vegetables and fruits. At present, the reason why this thrips species occurred so frequently in chrysanthemum fields on Okinawa is unclear. It is pos-

sible that *T. nigropilosus* populations of Okinawa are resistant to pesticides, which should be clarified in the near future.

Thrips palmi had been regarded as the most important pest of chrysanthemum among thrips species in Okinawa (Nagamine 1994). Our results indicated that this species is the second most abundant species followed by *T. nigropilosus*, suggesting that *T. palmi* may not be the most important pest. However, considering this together with the fact that even a small number of *T. palmi* individuals causes damage to chrysanthemum leaves (Kawai 1986), the species may also be one of the important pests of chrysanthemum in Okinawa. Since *T. nigropilosus* and *T. palmi* often co-occurred in the same field, we should clarify whether they cause different symptoms and degrees of damage to chrysanthemum leaves or not. *Thrips tabaci* and *Frankliniella occidentalis* (Pergande) are also known to be pests of chrysanthemum leaves in temperate areas of Japan in addition to *T. palmi* (Uesumi & Nishimura 1975; Katayama 1997). Our results showed that the frequency of occurrence of *T. tabaci* was low, and *F. occidentalis* was not found in chrysanthemum fields in Okinawa.

The infestation frequency of *T. nigropilosus* was highest on leaves but low on flowers. In contrast, *T. tabaci* was frequently found on flowers but rarely on leaves, although this species has been shown to cause damage to leaves, not to flowers, in temperate areas of Japan (Uesumi & Nishimura 1975). Because pollen feeding prolongs the life span and increases the fecundity of *T. tabaci* females (Murai 2000), this species might prefer flowers to leaves. *Thrips palmi* was the second most abundant species on both leaves and flowers. Since *T. palmi* inhabits not only leaves but also fully opened flowers and fruit skins beneath the calyxes of solanaceous plants (Yamamoto *et al.* 1982), it is possible that this species also prefers such parts of chrysanthemum.

Spider mites were found in 19 of the 57 fields surveyed; this is a frequency of occurrence higher than that of *T. palmi*, the second most abundant thrips species. In this study, *T. urticae* (green form) was the only species found irrespective of collection period, island or cultivation environment, indicating that it is the most important spider mite pest of chrysanthemum in Okinawa. *Tetranychus urticae* (green form) is also an important pest of chrysanthemum in other areas including temperate regions of Japan (e.g. Takafuji *et al.* 1989; Morishita 1997). In contrast to the eight *Tetranychus* species that infest vegetables on Okinawa Island and surrounding islands (Ohno *et al.* 2009), only one species was found on chrysanthemum in that area, which is of great interest. One possible cause of this simple species composition is interspecific differences in performance on chrysanthemum. In fact, some species such as *Tetranychus okinawanus* Ehara, *Tetranychus pueraricola* Ehara and Gotoh and *Tetranychus kanzawai* Kishida have been shown to be less well developed on chrysanthemum leaves (Takafuji *et al.* 1996; Morishita 1997; Gotoh *et al.* 2004). Even though chrysanthemum is not a preferred host for *T. urticae* (green form), the mite shows higher performance on chrysanthemum than does *T. kanzawai* (Morishita 1997). Another possible cause is the relatively frequent application of pesticides to chrysanthemum fields compared to other crops. *Tetranychus urticae* (green form) has been shown to be resistant to various pesticides in many areas (e.g. Kuwahara *et al.* 1983), and Okinawan populations of the species are also less susceptible to many agrochemicals than the other eight congeners inhabiting Okinawa (Ohno *et al.* 2010). Therefore, frequent pesticide applications might have reduced the species diversity of spider mites on chrysanthemum in Okinawa.

The occurrence of *T. urticae* (green form) on vegetables in Okinawa was extremely biased toward the greenhouse cultivation (Gotoh *et al.* 1996; Ohno *et al.* 2009), but this was not the case on chrysanthemum (present study). The reason why *T. urticae* (green form) frequently occurs not only in greenhouses but also in open fields of chrysanthemum should be clarified in the future.

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REFERENCES

Bullock JA (1965) The assessment of population of *Thrips nigropilosus* Uzel. on pyrethrum. *Annals of Applied Biology* **55**, 1–12.

Department of Agriculture, Forestry and Fisheries, Okinawa Prefectural Government (ed.) (2009) [*Horticulture and Distribution in Okinawa Prefecture*]. Department of Agriculture, Forestry and Fishers, Okinawa Prefectural Government, Naha, Okinawa. (In Japanese.)

Ehara S, Gotoh T (eds) (2009) [*Colored Guide to the Plant Mites of Japan*]. Zenkoku Nôson Kyôiku Kyôkai, Tokyo. (In Japanese.)

Gotoh T, Suwa A, Kitashima Y (2004) Development and oviposition of *Tetranychus puerariicola* Ehara and Gotoh (Acari: Tetranychidae) on various plants. *Journal of the Acarological Society of Japan* **13,** 135–140.

Gotoh T, Takafuji A, Gomi K (1996) Tetranychid mites of Okinawa Island (Acari: Tetranychidae). *Journal of the Acarological Society of Japan* **5,** 89–94.

Katayama H (1997) [Occurrence of the western flower thrips, *Frankliniella occidentalis* (Pergande) and damage of chrysanthemum by this species]. *Proceedings of the Kansai Plant Protection Society* **39,** 5–7. (In Japanese with English abstract.)

Kawai A (1986) [Studies on population ecology of *Thrips palmi* Karny. X. Differences in population growth on various crops]. *Japanese Journal of Applied Entomology and Zoology* **30,** 7–11. (In Japanese with English abstract.)

Kuwahara M, Sawada M, Kubota A, Iwata N (1983) [Susceptibility of the Kanzawa spider mite, *Tetranychus kanzawai*, and the two-spotted spider mite, *T. urticae*, collected from vegetable and ornamental plants to organophosphorous insecticides and specific acaricides]. *Japanese Journal of Applied Entomology and Zoology* **4,** 289–294. (In Japanese with English abstract.)

Masumoto M, Okajima S (2004) [Key to species of the genus *Frankliniella* Karny (Thysanoptera: Thripidae) in Japan]. *Plant Protection* **58,** 316–319. (In Japanese.)

Morishita M (1997) [Intercrop movement of the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) from chrysanthemum to pea field]. *Japanese Journal of Applied Entomology and Zoology* **41,** 33–38. (In Japanese with English abstract.)

Mound LA (2010) Species of the genus *Thrips* (Thysanoptera, Thripidae) from the Afro-tropical region. *Zootaxa* **2423,** 1–24.

Mound LA, Kibby G (1998) *Thysanoptera: An Identification Guide*, 2nd edn, CAB International, London.

Mound LA, Morison GD, Pitkin BR, Palmer JM (1976) *Thysanoptera: Handbooks for the Identification of British Insects Vol. 1, Part 11*. Royal Entomological Society, London.

Murai T (2000) Effect of temperature on development and reproduction of the onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), on pollen and honey solution. *Applied Entomology and Zoology* **35,** 499–504.

Nagamine Y (1994) [Notes on the important pest species on chrysanthemum and orchid and their control in Okinawa Prefecture]. *Noko to Engei* **49,** 129–131. (In Japanese.)

Nakao S, Yabu S (1998) [Ethological and chemical discrimination between thelytokous and arrehenotokous *Thrips nigropilosus* Uzel, with discussion of taxonomy}. *Japanese Journal of Applied Entomology and Zoology* **42,** 77–83. (In Japanese with English abstract.)

Ohno S, Miyagi A, Ganaha-Kikumura T *et al*. (2009) Species composition of spider mites (Acari: Tetranychidae) on vegetables in Okinawa, southwestern Japan. *Applied Entomology and Zoology* **44,** 628–633.

Ohno S, Miyagi A, Ganaha-Kikumura T, Kijima K (2010) [Effect of several commercial pesticides on the survival of nine *Tetranychus* species (Acari: Tetranychidae) inhabiting Okinawa, southwestern Japan]. *Kyushu Plant Protection Research* **56,** 58–65. (In Japanese with English abstract.)

Palmer JM (1992) *Thrips* (Thysanoptera) from Pakistan to the Pacific: A review. *Bulletin of the British Museum of Natural History (Entomology)* **61,** 1–76.

Sakimura K (1939) On the host plants of some Hawaiian thrips. *Proceedings of the Hawaiian Entomological Society* **10,** 251–254.

Stannard LJ (1968) The thrips, or Thysanoptera, of Illinois. *Bulletin of the Illinois Natural History Survey* **29,** 213–552.

Takafuji A, Inoue M, Oda M (1989) [The distribution of the two-spotted spider mite, *Tetranychus urticae* Koch, on various crops in Nara Prefecture, Japan]. *Japanese Journal of Applied Entomology and Zoology* **33,** 157–160. (In Japanese.)

Takafuji A, Yokotsuka T, Goka K, Kishimoto H (1996) Ecological performance of the spider mite, *Tetranychus okinawanus* Ehara (Acari, Tetranychidae), a species newly described from Okinawa islands (1). *Journal of the Acarological Society of Japan* **5,** 75–81.

Uesumi Y, Nishimura J (1975) *[Diseases and Insect Pests of Ornamental Flowers in Colors]*. Nobunkyo Press, Tokyo. (In Japanese.)

Umeya K, Okada T (eds) (2003) *[Agricultural Insect Pests in Japan]*. Zenkoku Nôson Kyôiku Kyôkai, Tokyo. (In Japanese.)

Walker AK, Michaux B (1989) The chrysanthemum thrips, *Thrips nigropilosus* Uzel (Terebrantia: Thysanoptera), on Scotch thistle, *Cirsium vulgare* (Savi) Ten. (Compositae: Cynareae) in New Zealand. *New Zealand Entomologist* **12,** 17–19.

Yamamoto E, Nagai K, Nonaka K (1982) [Ecology and control of the thrips infesting fruit vegetables. 3. Sites for infestation and pupation of *Thrips palmi*]. *Kyushu Agricultural Research* **44,** 118. (In Japanese.)