JARQ 56 (1), 49-58 (2022) https://www.jircas.go.jp

Species Composition and Seasonal Abundance of Thrips (Thysanoptera: Thripidae) on Open-field Chrysanthemum (Asteraceae) and Surrounding Weeds in Shizuoka Prefecture, Central Japan

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Abstract

Damage by thrips is a problem during the cultivation of open-field chrysanthemum. We investigated the species composition and seasonal abundance of thrips on open-field chrysanthemum and surrounding weeds over the course of a year. On open-field chrysanthemum, *Thrips nigropilosus* Uzel, *T. tabaci* Lindeman, and *Frankliniella occidentalis* Pergande were dominant. The dominance of *T. tabaci* in May and that of *T. nigropilosus* from September to October was the same on both chrysanthemum and weeds. In addition, four species of thrips were identified on the mother stocks of chrysanthemum and weeds from December to February. Therefore, continuous weeding from May to October and from December to February may affect the density of thrips on open-field chrysanthemum.

Discipline: Agricultural Environment
Additional key words: *Chrysanthemum morifolium*, *Frankliniella occidentalis*, host plant, *Thrips nigropilosus*, *Thrips tabaci*

Introduction

In Japan, damage by thrips has long been a problem for the cultivation of *Chrysanthemum morifolium* Ramat. (Asteraceae) flowers. In particular, the dominant pest for Japanese chrysanthemum in recent years has been *Thrips nigropilosus* Uzel (Doi et al. 2011; Ganaha-Kikumura et al. 2012, 2014). Although *T. nigropilosus* is susceptible to many insecticides (Tatara et al. 2008, Ganaha-Kikumura et al. 2014), damage by thrips on chrysanthemum is ongoing. In recent years, damage by thrips to the shoots and leaves of open-field chrysanthemum has increased, and this has been a particular problem for cut flowers. As the leaves of chrysanthemum are also part of the cut flower product, the value is reduced even if only the leaves are damaged. The cause of the predominance of *T. nigropilosus* on chrysanthemum is unknown.

In recent years, management of insect pests has focused on the landscapes surrounding the fields. Factors of the landscape structure, such as the proportion of weedy plots, are known to increase the population size of insect pests and the indirect damage to agricultural crops (Carrière et al. 2006, Yasuda et al. 2011). Many species of thrips infest weeds (Miyazaki & Kudo 1988), and some thrips are found at high densities on several weed species (Katayama 2006, Larentzaki et al. 2007, Smith et al. 2011). In addition, it has been suggested that weeds can act as overwintering habitats for some of the species of thrips (Katayama & Ikeda 1995, Morishita 2005, Katayama 2006). Thus, it is possible that weeds could be sources of pests that can invade chrysanthemum fields. Katayama (2006) investigated the relationship between the abundance of thrips on chrysanthemum and weeds. However, in the study, only *Frankliniella occidentalis* was observed, and there are no concurrent studies of multiple species of thrips. In the present study, we investigated the species composition and seasonal abundance of thrips populations on open-field chrysanthemum grown for cut flowers and the surrounding weeds throughout the year in Hamamatsu City, a major chrysanthemum production

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Received 2 December 2020; accepted 26 February 2021.

area in Shizuoka Prefecture (Shizuoka Prefecture 2014).

Materials and methods

1. Species composition and seasonal abundance of thrips on open-field chrysanthemum

From May to October 2015 and from January to February 2016, once a month we collected axillary shoots (5 mm-10 mm) and lower leaves (50 mm-100 mm) of chrysanthemum from six to nine open fields in Hamamatsu City, Shizuoka Prefecture, Japan. The lower leaves were collected from the lower quarter of the plant. The survey field was set to the same fixed point every time. However, in January and February, there were no axillary shoots, so we collected only the lower leaves. The main cropping type of open-field chrysanthemum in Shizuoka Prefecture is the planting of mother stocks in November. In May, cuttings are taken from the healthy branches of the mother stock plants to be transplanted in the field in June. Finally, the flowers are harvested in October (Shizuoka Prefecture 2017). According to this cropping schedule for open-field chrysanthemum in Shizuoka Prefecture, we investigated the mother stock field in January, February, and May and the main field from June to October. This investigation was conducted following a modified method by Doi et al. (2011). We collected 10 axillary shoots and 10 lower leaves of chrysanthemum from each field and brought them back to the laboratory. The samples from each collection site were immersed in 70% ethanol and stirred approximately 20 times. After filtering with filter paper (GA-100, ADVANTEC Co., Ltd., Tokyo, Japan), thrips were collected. The collected individuals were immersed in 70% ethanol for fixation. They were mounted in Hoyer's medium on microscope slides after dehydration and fixation in 99.5% ethanol according to a method modified from Kudo & Miyazaki (1988). Adult thrips were identified using a light microscope following the method used by Kudo & Haga (1988), Masumoto & Okajima (2013a, 2013b, 2017), Masumoto et al. (2002), Mound & Kibby (1998), and Mound & Palmer (1981). Adult thrips of both sexes were identified. We had difficulty identifying some species, so they were identified for us by Dr. Masami Masumoto of the Yokohama Plant Protection Station. We did not identify thrips of the family Phlaeothripidae because their number in the samples was small, and larval thrips were not identified because identifying them morphologically is difficult.

2. Species composition and seasonal abundance of thrips on weeds around the open-field chrysanthemum

From March 2015 to February 2016, once a month we collected weeds from four to nine open-field chrysanthemum sites in Hamamatsu City. This investigation was conducted following a method modified by Morishita (2005). We collected a maximum of three species of dominant weeds growing around the open-field chrysanthemum (> 10 individuals were collected per species), placed them in a plastic bag, and then brought them to the laboratory. The dominance of weeds was determined by the degree of cover. Weeds were not collected if the area around chrysanthemum field had been weeded and there were no weeds or if 10 individuals could not be collected. We picked 10 stem tips measuring 10 cm for each weed species (including flowers during the flowering period), immersed them in 70% ethanol (10 stem tips per sample), and then stirred approximately 20 times. Adult thrips were collected, and specimens were mounted as in experiment 1. Species were identified by microscopy, as was done for the chrysanthemum samples.

Results

1. Species composition and seasonal abundance of thrips on open-field chrysanthemum

Table 1 shows the species composition and seasonal abundance of thrips on open-field chrysanthemum. On the open-field chrysanthemum, seven species of thrips were identified: *T. nigropilosus*, *T. tabaci* Lindeman, *T. hawaiiensis* (Morgan), *F. occidentalis*, *F. intonsa* (Trybom), *Scirtothrips dorsalis* Hood, and *Microcephalothrips abdominalis* (Crawford). Thrips of the family Phlaeothripidae were also collected. The species composition on axillary shoots was dominated by *T. tabaci* in May and by *T. nigropilosus* from June to October. The species composition on the lower leaves was dominated by *T. nigropilosus* from May to October and by *F. occidentalis* in February. *Thrips nigropilosus*, *T. hawaiiensis*, and larval thrips were also identified in February. The number of larval thrips decreased from May to July and was the highest in October. This trend was consistent with that on the axillary shoots and lower leaves.

There were 5.61 thrips individuals per axillary shoot in May, but this number decreased in July and August and stayed below 0.3 individuals in July and August. However, in October, the number of individuals collected per axillary shoot increased to 11.76. The number of thrips collected from the lower leaves was 2.10

individuals per leaf in May, but this number decreased in June and stayed below 0.3 individuals in July and August. However, in October, the number of individuals collected from the lower leaves increased to 7.53 per leaf. In the investigation of the mother stocks in winter, thrips were not identified in January, but in February, 0.4 individuals per lower leaf were collected (Table 1).

2. Species composition and seasonal abundance of thrips on weeds around the open-field chrysanthemum

Table 2 shows the species composition and seasonal abundance of thrips on the weeds in fields around the chrysanthemum fields. We identified 16 species of thrips: *T. nigropilosus*, *T. tabaci*, *T. hawaiiensis*, *T. trehernei* Priesner, *T. coloratus* Schmutz, *T. flavus* Schrank, *T. brevicornis* Priesner, *F. occidentalis*, *F. intonsa*, *S. dorsalis*, *M. abdominalis*, *Tenothrips frici* (Uzel), *Pseudodendrothrips maculatus* Masumoto & Okajima, *Chirothrips manicatus* (Haliday), *Megalurothrips distalis* (Karny), and *Stenchaetothrips pleioblasti* Masumoto & Okajima. Thrips of the family Phlaeothripidae were also collected from weeds around the chrysanthemum field. The dominant species of thrips on the weeds changed according to the date of collection. We collected 32 species of weeds around the open-field chrysanthemum, and different species compositions were found on each (Table 2). The highest density of *T. tabaci* was 0.53 individuals per stem tip of *Senecio vulgaris* L. in May. The highest density of *T. nigropilosus* was 0.50 individuals per stem tip of *Oxalis debilis* Kunth subsp. *corymbosa* (DC.) Lourteig in October. *Thrips nigropilosus*, *T. tabaci*, and *F. occidentalis* were collected from weeds in the winter (in December and February).

Discussion

In the present study, *T. nigropilosus* was the most dominant species of thrips on open-field chrysanthemum from June to October (Table 1; Appendix Fig. 1). This result was similar to that of Doi et al. (2011). This suggests that the dominance of *T. nigropilosus* on chrysanthemum did not change from 2009 to 2015. *Thrips tabaci* was dominant on the axillary shoots of chrysanthemum in May (Table 1; Appendix Fig. 1). Insecticide treatment for chrysanthemum typically occurs once a week, but mother stocks grown in May are sprayed more frequently (approximately twice a week). This is to prevent pests from being transferred to the main fields when cuttings are taken from the mother stocks. As *T. tabaci* has been reported to have decreased susceptibility to many insecticides (Allen et al. 2005, Morishita 2008), it is possible that the increased frequency of insecticide application may have affected the dominance of *T. tabaci* on chrysanthemum in May. *Frankliniella occidentalis* was the most dominant species on chrysanthemum in February (Table 1). This may be because *F. occidentalis* is more tolerant to low temperatures (Katayama & Ikeda 1995) and does not enter reproductive diapause during winter season (Ishida et al. 2003).

The density of *T. nigropilosus* on chrysanthemum increased in October (Table 1; Appendix Fig. 1). *Thrips nigropilosus* is susceptible to many insecticides (Tatara et al. 2008, Ganaha-Kikumura et al. 2014). However, Kijima et al. (2014) reported that in Okinawa Prefecture, southern Japan, the planting density of chrysanthemum

Table 1. Species composition and seasonal abundance of thrips on chrysanthemum in open-field cultivation in 2015-2016

Collection site	Collection date[a]	Number of fields surveyed	Number of fields in which thrips were collected	Total number of thrips collected (number of thrips per collected site)[b]									
				Thrips nigropilosus	*Thrips tabaci*	*Thrips hawaiiensis*	*Frankliniella occidentalis*	*Frankliniella intonsa*	*Scirtothrips dorsalis*	*Microcephalothrips abdominalis*	Phlaeothripidae	Larval thrips	Total
Axillary shoot	May 21	8	7	83 (1.04)	165 (2.06)	0 (0)	33 (0.41)	4 (0.05)	2 (0.03)	0 (0)	0 (0)	162 (2.03)	449 (5.61)
	June 23	7	7	131 (1.87)	8 (0.11)	0 (0)	8 (0.11)	0 (0)	0 (0)	0 (0)	3 (0.04)	79 (1.13)	229 (3.27)
	July 31	9	6	18 (0.20)	0 (0)	0 (0)	2 (0.02)	2 (0.02)	0 (0)	1 (0.01)	0 (0)	0 (0)	23 (0.26)
	Aug. 31	9	7	11 (0.12)	0 (0)	0 (0)	1 (0.01)	0 (0)	0 (0)	0 (0)	1 (0.01)	7 (0.08)	20 (0.22)
	Sep. 28	9	3	42 (0.47)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	168 (1.87)	210 (2.33)
	Oct. 28	9	7	217 (2.41)	0 (0)	0 (0)	2 (0.02)	0 (0)	0 (0)	0 (0)	0 (0)	839 (9.32)	1,058 (11.76)
Lower leaf	May 21	8	6	34 (0.43)	8 (0.10)	0 (0)	1 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)	125 (1.56)	168 (2.10)
	June 23	7	5	14 (0.20)	4 (0.06)	0 (0)	2 (0.03)	0 (0)	0 (0)	0 (0)	0 (0)	77 (1.10)	97 (1.39)
	July 31	9	2	4 (0.04)	1 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.01)	6 (0.07)
	Aug. 31	9	4	3 (0.03)	0 (0)	1 (0.01)	0 (0)	0 (0)	0 (0)	1 (0.01)	0 (0)	14 (0.16)	19 (0.21)
	Sep. 28	9	3	22 (0.24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	84 (0.93)	106 (1.18)
	Oct. 28	9	6	190 (2.11)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	488 (5.42)	678 (7.53)
	Jan. 20	6	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Feb. 25	6	3	8 (0.13)	0 (0)	1 (0.02)	12 (0.20)	0 (0)	0 (0)	0 (0)	0 (0)	3 (0.05)	24 (0.40)

[a] In January and February, there were no axillary shoots as only mother stocks of chrysanthemum were present. Therefore, only the lower leaves were collected.
[b] Results from May, January, and February are for the mother stock fields. Results from June to October are for the main fields.

Table 2. Species composition and seasonal abundance of thrips on weeds around the chrysanthemum fields in 2015-2016

Collection date	Number of fields surveyed	Collected weeds [a]	Number of fields collected weeds	Total number of thrips collected (number of thrips per collected site) [b]						
				Thrips nigropilosus	*Thrips tabaci*	*Thrips hawaiiensis*	*Thrips trehernei*	*Thrips coloratus*	*Thrips flavus*	*Thrips brevicornis*
Mar. 18	9	*Capsella bursa-pastoris* var. *triangularis*	2							
		Cerastium glomeratum	1							
		Lamium amplexicaule	5							
		Senecio vulgaris	4					2 (0.05)		
		Sonchus oleraceus	3		3 (0.10)					
		Taraxacum officinale	1							
		Veronica persica	1							
		Vicia sativa subsp. *nigra* var. *nigra*	2							
Apr. 16	10	*Capsella bursa-pastoris* var. *triangularis*	1							
		Corydalis incisa	1							
		Galium spurium var. *echinospermon*	1							
		Lamium amplexicaule	1							
		Nuttallanthus texanus	2		1 (0.05)		3 (0.15)			
		Senecio vulgaris	4							
		Sonchus oleraceus	6		1 (0.02)		5 (0.08)			
		Stellaria media	1							
		Taraxacum officinale	9				12 (0.13)			
		Vicia sativa subsp. *nigra* var. *nigra*	2							
May 21	8	*Hypochaeris radicata*	2							
		Oenothera laciniata var. *laciniata*	2							
		Oxalis corniculata	2		1 (0.05)					
		Oxalis dillenii	1		1 (0.10)					
		Pseudognaphalium affine	6		4 (0.07)					
		Senecio vulgaris	4		21 (0.53)					
		Sonchus oleraceus	4		2 (0.05)		1 (0.03)	1 (0.03)		1 (0.03)
		Taraxacum officinale	2		3 (0.15)	51 (2.55)	39 (1.95)			
June 23	4	*Erigeron annuus*	2		1 (0.05)	1 (0.05)				
		Oenothera laciniata var. *laciniata*	1	1 (0.10)	16 (1.60)		4 (0.40)			
		Oxalis corniculata	2				1 (0.05)			
		Oxalis debilis subsp. *corymbosa*	1							
		Stellaria media	1		1 (0.10)					
		Taraxacum officinale	1	1 (0.10)	1 (0.10)		1 (0.10)			
July 31	5	*Artemisia princeps*	1	1 (0.10)						
		Erigeron sumatrensis	4		1 (0.03)					
		Oenothera biennis	1							
		Oenothera laciniata var. *laciniata*	2							
		Sonchus oleraceus	2	2 (0.10)						
Aug. 31	8	*Achyranthes bidentata* var. *fauriei*	1	1 (0.10)						
		Artemisia princeps	1							
		Bidens pilosa var. *pilosa*	2							
		Erigeron canadensis	4							
		Erigeron sumatrensis	3							
		Mirabilis jalapa	1							
		Oenothera biennis	1							
		Solidago altissima	1							
		Sonchus oleraceus	1							
Sep. 28	6	*Artemisia princeps*	1	2 (0.20)						
		Bidens pilosa var. *pilosa*	5							
		Erigeron canadensis	5							
		Solanum nigrum	1	1 (0.10)					3 (0.30)	
		Solidago altissima	3	3 (0.10)						
Oct. 28	8	*Bidens pilosa* var. *pilosa*	8	1 (0.01)		1 (0.01)				
		Erigeron annuus	2							
		Erigeron canadensis	1							
		Oxalis debilis subsp. *corymbosa*	2	10 (0.50)						
		Solidago altissima	6	3 (0.05)	3 (0.05)	1 (0.02)	2 (0.03)			
Nov. 27	9	*Bidens pilosa* var. *pilosa*	6							
		Lamium amplexicaule	2							
		Senecio vulgaris	3							
		Solidago altissima	1							
		Sonchus oleraceus	7		1 (0.01)					
Dec. 18	9	*Bidens pilosa* var. *pilosa*	4							
		Crassocephalum crepidioides	3							
		Gamochaeta pensylvanica	1							
		Lamium amplexicaule	2							
		Nuttallanthus canadensis	1	1 (0.10)	1 (0.10)					
		Senecio vulgaris	4		4 (0.10)					
		Sonchus oleraceus	6							
Jan. 20	8	*Bidens pilosa* var. *pilosa*	2							
		Erigeron sumatrensis	5		2 (0.04)					
		Nuttallanthus canadensis	1							
		Senecio vulgaris	5		2 (0.04)					
		Sonchus oleraceus	6							
Feb. 25	7	*Artemisia princeps*	1							
		Capsella bursa-pastoris var. *triangularis*	1		2 (0.20)					
		Lamium amplexicaule	4	5 (0.13)	1 (0.03)					
		Senecio vulgaris	4	1 (0.03)	6 (0.15)					
		Vicia sativa subsp. *nigra* var. *nigra*	3		3 (0.10)					

[a] Gray indicates that the weeds were flowering.
[b] We picked 10 cm of 10 stem tips for each weed species including flowers during the flowering period.

(Continued on next page)

Table 2. Species composition and seasonal abundance of thrips on weeds around the chrysanthemum fields in 2015-2016 (Continued 1)

Collection date	Number of fields surveyed	Collected weeds [a]	Number of fields collected weeds	Total number of thrips collected (number of thrips per collected site) [b]					
				Frankliniella occidentalis	*Frankliniella intonsa*	*Scirtothrips dorsalis*	*Microcephalothrips abdominalis*	*Tenothrips frici*	*Pseudodendrothrips maculatus*
Mar. 18	9	*Capsella bursa-pastoris* var. *triangularis*	2						
		Cerastium glomeratum	1						
		Lamium amplexicaule	5						
		Senecio vulgaris	4						
		Sonchus oleraceus	3		1 (0.03)				
		Taraxacum officinale	1	1 (0.10)					
		Veronica persica	1						
		Vicia sativa subsp. *nigra* var. *nigra*	2						
Apr. 16	10	*Capsella bursa-pastoris* var. *triangularis*	1				1 (0.10)		
		Corydalis incisa	1						
		Galium spurium var. *echinospermon*	1						
		Lamium amplexicaule	1						
		Nuttallanthus texanus	2						
		Senecio vulgaris	4	1 (0.03)					
		Sonchus oleraceus	6					1 (0.02)	
		Stellaria media	1						
		Taraxacum officinale	9	2 (0.02)					
		Vicia sativa subsp. *nigra* var. *nigra*	2			1 (0.05)			
May 21	8	*Hypochaeris radicata*	2						
		Oenothera laciniata var. *laciniata*	2	2 (0.10)	1 (0.05)				
		Oxalis corniculata	2	1 (0.05)	1 (0.05)				
		Oxalis dillenii	1	1					
		Pseudognaphalium affine	6						
		Senecio vulgaris	4	2					
		Sonchus oleraceus	4						
		Taraxacum officinale	2	4 (0.20)	3 (0.15)				
June 23	4	*Erigeron annuus*	2	2 (0.10)	6 (0.30)			11 (0.55)	
		Oenothera laciniata var. *laciniata*	1		1 (0.10)		5 (0.50)		
		Oxalis corniculata	2			1 (0.05)			
		Oxalis debilis subsp. *corymbosa*	1						
		Stellaria media	1						
		Taraxacum officinale	1		4 (0.40)			17 (1.70)	
July 31	5	*Artemisia princeps*	1						
		Erigeron sumatrensis	4				1 (0.03)		
		Oenothera biennis	1		15 (1.50)				
		Oenothera laciniata var. *laciniata*	2						
		Sonchus oleraceus	2					1 (0.05)	
Aug. 31	8	*Achyranthes bidentata* var. *fauriei*	1						
		Artemisia princeps	1						
		Bidens pilosa var. *pilosa*	2				2 (0.10)		
		Erigeron canadensis	4						
		Erigeron sumatrensis	3				3 (0.10)		
		Mirabilis jalapa	1						
		Oenothera biennis	1		1 (0.10)				
		Solidago altissima	1						
		Sonchus oleraceus	1						
Sep. 28	6	*Artemisia princeps*	1	1 (0.10)					
		Bidens pilosa var. *pilosa*	5						
		Erigeron canadensis	5				1 (0.02)		
		Solanum nigrum	1						4 (0.40)
		Solidago altissima	3						1 (0.03)
Oct. 28	8	*Bidens pilosa* var. *pilosa*	8				1 (0.01)		
		Erigeron annuus	2	2 (0.10)	1 (0.05)		5 (0.25)		
		Erigeron canadensis	1						
		Oxalis debilis subsp. *corymbosa*	2						
		Solidago altissima	6	5 (0.08)	7 (0.12)				
Nov. 27	9	*Bidens pilosa* var. *pilosa*	6						
		Lamium amplexicaule	2						
		Senecio vulgaris	3						
		Solidago altissima	1						
		Sonchus oleraceus	7	1 (0.01)					
Dec. 18	9	*Bidens pilosa* var. *pilosa*	4						
		Crassocephalum crepidioides	3						
		Gamochaeta pensylvanica	1						
		Lamium amplexicaule	2						
		Nuttallanthus canadensis	1	1 (0.10)					
		Senecio vulgaris	4						
		Sonchus oleraceus	6						
Jan. 20	8	*Bidens pilosa* var. *pilosa*	2						
		Erigeron sumatrensis	5						
		Nuttallanthus canadensis	1						
		Senecio vulgaris	5	1 (0.02)					
		Sonchus oleraceus	6	1 (0.02)					
Feb. 25	7	*Artemisia princeps*	1						
		Capsella bursa-pastoris var. *triangularis*	1						
		Lamium amplexicaule	4						
		Senecio vulgaris	4						
		Vicia sativa subsp. *nigra* var. *nigra*	3						

[a] Gray indicates that the weeds were flowering.
[b] We picked 10 cm of 10 stem tips for each weed species including flowers during the flowering period.

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Table 2. Species composition and seasonal abundance of thrips on weeds around the chrysanthemum fields in 2015-2016 (Continued 2)

Collection date	Number of fields surveyed	Collected weeds [a]	Number of fields collected weeds	Total number of thrips collected (number of thrips per collected site) [b]					
				Chirothrips manicatus	*Megalurothrips distalis*	*Stenchaetothrips pleioblasti*	Phlaeothripidae	Larval thrips	Total
Mar. 18	9	*Capsella bursa-pastoris* var. *triangularis*	2				1 (0.05)		1 (0.05)
		Cerastium glomeratum	1						0 (0)
		Lamium amplexicaule	5					1 (0.02)	1 (0.02)
		Senecio vulgaris	4						2 (0.05)
		Sonchus oleraceus	3						4 (0.13)
		Taraxacum officinale	1		1 (0.10)		4 (0.40)		6 (0.60)
		Veronica persica	1						0 (0)
		Vicia sativa subsp. *nigra* var. *nigra*	2						0 (0)
Apr. 16	10	*Capsella bursa-pastoris* var. *triangularis*	1						1 (0.10)
		Corydalis incisa	1				1 (0.10)		1 (0.10)
		Galium spurium var. *echinospermon*	1						0 (0)
		Lamium amplexicaule	1						0 (0)
		Nuttallanthus texanus	2						4 (0.20)
		Senecio vulgaris	4					2 (0.05)	3 (0.08)
		Sonchus oleraceus	6						7 (0.12)
		Stellaria media	1				1 (0.10)		1 (0.10)
		Taraxacum officinale	9					41 (0.46)	55 (0.61)
		Vicia sativa subsp. *nigra* var. *nigra*	2				1 (0.05)		2 (0.10)
May 21	8	*Hypochaeris radicata*	2						0 (0)
		Oenothera laciniata var. *laciniata*	2					2 (0.10)	5 (0.25)
		Oxalis corniculata	2					1 (0.05)	4 (0.20)
		Oxalis dillenii	1					1 (0.10)	3 (0.30)
		Pseudognaphalium affine	6	1 (0.02)			2 (0.03)	6 (0.10)	13 (0.22)
		Senecio vulgaris	4				1 (0.03)	17 (0.43)	41 (1.03)
		Sonchus oleraceus	4						5 (0.13)
		Taraxacum officinale	2					12 (0.60)	112 (5.60)
June 23	4	*Erigeron annuus*	2				1 (0.05)		22 (1.10)
		Oenothera laciniata var. *laciniata*	1					5 (0.50)	32 (3.20)
		Oxalis corniculata	2						2 (0.10)
		Oxalis debilis subsp. *corymbosa*	1					1 (0.10)	1 (0.10)
		Stellaria media	1						1 (0.10)
		Taraxacum officinale	1					11 (1.10)	35 (3.50)
July 31	5	*Artemisia princeps*	1						1 (0.10)
		Erigeron sumatrensis	4				1 (0.03)		3 (0.08)
		Oenothera biennis	1						15 (1.50)
		Oenothera laciniata var. *laciniata*	2					2 (0.10)	2 (0.10)
		Sonchus oleraceus	2						3 (0.15)
Aug. 31	8	*Achyranthes bidentata* var. *fauriei*	1						1 (0.10)
		Artemisia princeps	1						0 (0)
		Bidens pilosa var. *pilosa*	2						2 (0.10)
		Erigeron canadensis	4	1 (0.03)					1 (0.03)
		Erigeron sumatrensis	3						3 (0.10)
		Mirabilis jalapa	1						0 (0)
		Oenothera biennis	1				1 (0.10)		2 (0.20)
		Solidago altissima	1					3 (0.30)	3 (0.30)
		Sonchus oleraceus	1				1 (0.10)		1 (0.10)
Sep. 28	6	*Artemisia princeps*	1				1 (0.10)		4 (0.40)
		Bidens pilosa var. *pilosa*	5				3 (0.06)		3 (0.06)
		Erigeron canadensis	5						1 (0.02)
		Solanum nigrum	1			1 (0.10)		2 (0.20)	11 (1.10)
		Solidago altissima	3						4 (0.13)
Oct. 28	8	*Bidens pilosa* var. *pilosa*	8					7 (0.09)	10 (0.13)
		Erigeron annuus	2					8 (0.40)	16 (0.80)
		Erigeron canadensis	1						0 (0)
		Oxalis debilis subsp. *corymbosa*	2					33 (1.65)	43 (2.15)
		Solidago altissima	6				2 (0.03)	67 (1.12)	90 (1.50)
Nov. 27	9	*Bidens pilosa* var. *pilosa*	6						0 (0)
		Lamium amplexicaule	2						0 (0)
		Senecio vulgaris	3						0 (0)
		Solidago altissima	1						0 (0)
		Sonchus oleraceus	7						2 (0.03)
Dec. 18	9	*Bidens pilosa* var. *pilosa*	4						0 (0)
		Crassocephalum crepidioides	3						0 (0)
		Gamochaeta pensylvanica	1						0 (0)
		Lamium amplexicaule	2						0 (0)
		Nuttallanthus canadensis	1						3 (0.30)
		Senecio vulgaris	4					2 (0.05)	6 (0.15)
		Sonchus oleraceus	6						0 (0)
Jan. 20	8	*Bidens pilosa* var. *pilosa*	2						0 (0)
		Erigeron sumatrensis	5						2 (0.04)
		Nuttallanthus canadensis	1						0 (0)
		Senecio vulgaris	5					4 (0.08)	7 (0.14)
		Sonchus oleraceus	6						1 (0.02)
Feb. 25	7	*Artemisia princeps*	1						0 (0)
		Capsella bursa-pastoris var. *triangularis*	1						2 (0.20)
		Lamium amplexicaule	4						6 (0.15)
		Senecio vulgaris	4						7 (0.18)
		Vicia sativa subsp. *nigra* var. *nigra*	3						3 (0.10)

[a] Gray indicates that the weeds were flowering.
[b] We picked 10 cm of 10 stem tips for each weed species including flowers during the flowering period.

was so high that the adhesion amount of chemical liquid deposition on the abaxial side of the leaves was insufficient even if ordinary insecticide spraying were to be applied. The planting density was also high (40-50 stocks/m^2) in Shizuoka Prefecture, where our study field is located, and in the latter half of the cultivation, spraying the insecticide on the abaxial side of the lower leaves becomes difficult. This may have influenced the increased density of *T. nigropilosus* on chrysanthemum in October.

Thrips nigropilosus, *T. hawaiiensis*, and *F. occidentalis* were identified on the mother stocks of chrysanthemum in February (Table 1). Among these species, *F. occidentalis* had already been reported overwintering on mother stocks (Katayama & Ikeda 1995). However, the overwintering of *T. nigropilosus* and *T. hawaiiensis* was newly identified on the mother stocks of chrysanthemum in this study. As *T. nigropilosus*, *T. tabaci*, and *F. occidentalis* were identified on weeds from December to February (Table 2; Appendix Fig. 2), it can be concluded that spraying insecticides on mother stocks in winter as well is necessary.

On weeds, the dominant species of thrips varied by month (Table 2), and more species were identified than on chrysanthemum. This shows that many more species of thrips live on weeds. Interspecific competition has been reported in thrips (Tobin et al. 2011, Zhao et al. 2017), and it may inhibit the reproduction of *T. nigropilosus*, *T. tabaci*, and *F. occidentalis* on weeds. Further investigation should be conducted on interspecific competition in thrips on weeds and on the evaluation of weeds as sources of pest insects. The dominance of *T. tabaci* in May and that of *T. nigropilosus* from September to October was the same on chrysanthemum and weeds (Tables 1 and 2; Appendices 1 and 2). There are three possible causes. First, the abundance of *T. tabaci* and *T. nigropilosus* on weeds may have some effect on the abundance of these species on chrysanthemum. Second, the abundance of thrips on chrysanthemum may have some effect on the abundance of thrips on weeds. Third, crops around chrysanthemum fields may be a source of thrips. It is not clear which of these three is the cause; therefore, further investigation is warranted.

Thrips nigropilosus and *T. tabaci* were collected regardless of whether the weeds were flowering, whereas *F. occidentalis* and *F. intonsa* were collected only from flowering weeds (Table 2). This may be due to the differences in the distribution of species of thrips on individual plants. Lewis (1972) reported a few species of thrips that spread over the whole plant, e.g., on Liliaceae, *T. tabaci* infests the bulbs, leaves, and flowers, but most species of thrips are concentrated on specific parts of the host plant. On weeds, larval thrips were confirmed, except in November and February (Table 2; Appendix Fig. 2). This suggests that thrips are active on weeds throughout the year, except in winter.

Katayama (2006) reported that *F. occidentalis* inhabits and reproduces predominately on weed species flowering around the fields in spring; therefore, the removal of weeds in early spring is important for the control of *F. occidentalis*. In the present study, *T. tabaci* was the dominant species on weeds in May, June, and February, and *T. nigropilosus* was the dominant species on weeds in September and October (Table 2; Appendix Fig. 2). In addition, *T. nigropilosus*, *T. tabaci*, and *F. occidentalis* were identified on weeds from December to February (Table 2; Appendix Fig. 2). The weeds may be used by thrips as a refuge from the insecticide spraying in chrysanthemum fields. Among the weeds, the density of *T. tabaci* increased in May and June, especially on *S. vulgaris* and *Oenothera laciniata*, and the density of *T. nigropilosus* increased in October, especially on *O. debilis* (Table 2). Assuming that the weeds are the site of thrips reproduction, it can be suggested that continuous weeding from May to October and from December to February and especially *S. vulgaris* weeding in May, *O. laciniata* weeding in June, and *O. debilis* weeding in October may reduce the density of thrips. Further studies are warranted to provide a more detailed investigation of the potential numbers of *T. nigropilosus*, *T. tabaci*, and *F. occidentalis* on weeds and examine the effect of weeding on controlling thrips.

Acknowledgements

We would like to thank Dr. Masami Masumoto (Yokohama Plant Protection Station) for guidance on thrips identification and for the identification of some thrips, Dr. Toshio Kishimoto (Museum of Natural and Environmental History, Shizuoka) for storing the specimens of *P. maculatus*, Dr. Haruki Katayama (Shizuoka Prefectural Office Industrial Innovation Promotion Division) for the helpful discussions, and Mr. Makoto Doi (Shizuoka Prefectural Research Institute of Agriculture and Forestry) for teaching us the method of investigation.

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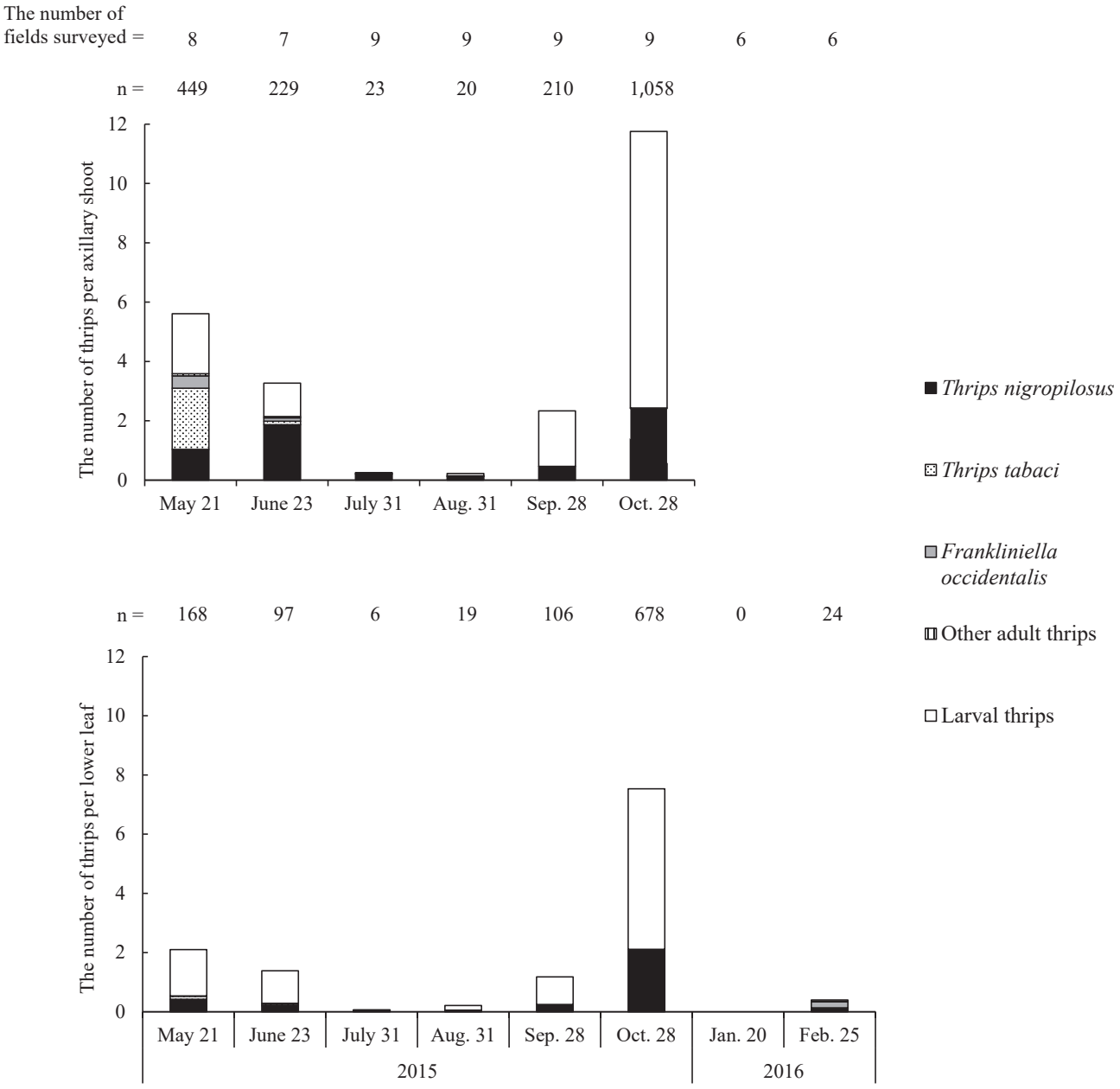
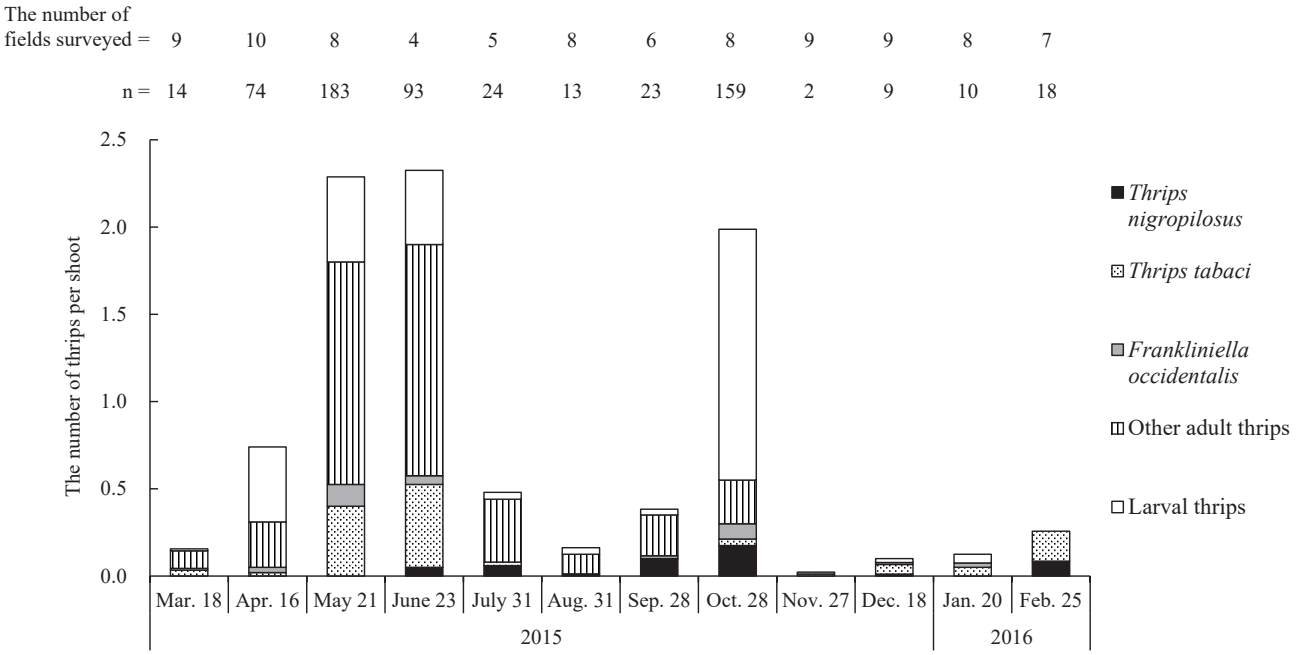


Appendix Fig. 1. Seasonal abundance of thrips on chrysanthemum in open-field cultivation in 2015-2016



Appendix Fig. 2. Seasonal abundance of thrips on weeds around the chrysanthemum fields in 2015-2016