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Investigation of thysanoptera populations in Hungarian greenhouses

Szilvia OROSZ,[1, 4*] Dávid ÉLIÁS,[2] Emese BALOG,[3] Ferenc TÓTH[2]

[1]National Food Chain Safety Office, Directorate of Plant Protection,
Soil Conservation and Agri-Environment, Plant Health and Molecular Biology
National Reference Laboratory, H-1118 Budapest Budaörsi út 141–145. Hungary

[2]Szent István University, Plant Protection Institute,
Faculty of Agricultural and Environmental Sciences,
H-2100 Gödöllő, Páter K. u. 1. Hungary

[3]Pest County Government Office, Food Chain Safety,
Plant and Soil Protection Department,
H-1135 Budapest, Lehel utca 43–47. Hungary

[4]Hungarian Natural History Museum, Department of Zoology,
H-1088 Budapest, Baross utca 13, Hungary

*corresponding author: oroszsz@nebih.gov.hu

Abstract. Studies were performed on sweet pepper and on weeds in their surroundings from 2005 to 2007 in the Jászság region, on different vegetables and ornamentals from 2015 to 2016 throughout Hungary, and on some indoor ornamental plants in Budapest and Kecskemét in 2017. These studies were carried out in greenhouses. The main objectives of this work was to clarify the consistency of Thysanoptera populations in these greenhouses and, secondly, as part of the official monitoring of *Thrips palmi* Karny and *Thrips setosus* Moulton, the study also focused on the first appearance of these pests in Hungary. An important additional aim was to determine which reservoirs were significant in the risk of Thysanoptera species transmitting tomato spotted wilt virus (TSWV). Regarding the surveys conducted, the most frequent Thysanoptera species present in large numbers during the investigation period in every greenhouse was *Frankliniella occidentalis* Pergande. Also, a significant amount of *Echinothrips americanus* Morgan was found on ornamentals in southern Hungary, whereas on indoor ornamental plants only *Hercinothrips femoralis* O. M. Reuter was found.

Keywords: *Frankliniella occidentalis*, greenhouses, invasive, ornamentals, thrips, vegetables, TSWV transmission

1. Introduction

The abundance of invasive Thysanoptera species in Hungarian agricultural and horticultural crops is significant. These non-native pests can cause significant damage mainly in ornamentals. In the last century, polyphagous greenhouse thrips, such as *Heliothrips haemorrhoidalis* Bouché, *Hercinothrips femoralis* O. M. Reuter, *Parthenothrips dracaenae* Heeger, *Frankliniella occidentalis* Pergande, and *Thrips simplex* Morison (only on *Gladiolus* sp.) were observed in Hungary in high population densities (Ripka 2010). Since most of these species originate from tropical areas, they are not able to overwinter outdoors in Hungary. *Echinothrips americanus* Morgan and *Microcephalothrips abdominalis* D. L. Crawford were observed in Hungary in 2004. Since both thrips species can be present on many ornamentals without the plant showing any sign of damage, they can easily spread with plant material (Vierbergen et al. 2006). None of these two species were found to have significant population densities in Hungary (Jenser 2012). In 2007, in a glasshouse in the town of Érd, the appearance and damage of *Dichromothrips corbetti* Preisner was first reported on *Cattleya* orchid. The pest is native to the Far East and was introduced to Hungary most likely with imported orchids. No further data is available on the occurrence of this species in Hungarian greenhouses (Szénási & Marczika 2011).

The most important Thysanoptera pests of sweet pepper are the invasive western flower thrips (*Frankliniella occidentalis* Pergande) and the cosmopolitan onion thrips (*Thrips tabaci* Lindeman). Among affected vegetables, the most severe damage by *F. occidentalis* appears on sweet pepper, making the yield unmarketable. Furthermore, its hidden lifestyle and resistance to insecticides hinder the efficient protection of these vegetables. The indirect damage of *T. tabaci* and *F. occidentalis* by transmitting tomato spotted wilt virus (TSWV) is even more important than the direct damage in greenhouses. The vectors of TSWV are *F. occidentalis* in greenhouses and *T. tabaci* both under field and greenhouse conditions. The last decades witnessed an increase in the frequency of epidemics caused by the virus, with the most important damage occurring in Hungary in sweet pepper greenhouses (Jenser 1995). The spread of TSWV in Europe has coincided with the spread of *F. occidentalis*. Reservoir weed hosts play a significant role in the spread of TSWV because they can maintain the virus after harvest until the next sowing of sensitive crops (Bos 1981). Furthermore, reservoir weeds can help the development of vector thrips species and thereby the spread of the virus (Bitterlich & MacDonald 1993). Host plants are usually the same for both the virus and the vectors, and this can further aid the maintenance and spread of the virus (Cho et al. 1986).

The main objectives of this work were to clarify the stability of Thysanoptera populations in vegetable and ornamental greenhouses, and, secondly, as this work was part of the official monitoring of *Thrips palmi* Karny and *Thrips setosus* Moulton, we also focused on the first appearance of these invasive species in Hungary. Our additional aim was to determine the reservoirs that are significant in Thysanoptera species transmitting TSWV.

2. Materials and methods

Investigations into sweet pepper and their surroundings in the Jászság region (2005–2007)

Plant samples were collected from green pepper greenhouses with different cultivation techniques in Heves and Jász-Nagykun-Szolnok counties. Weed samples were collected from the surroundings of the greenhouses. A total of 51 greenhouses were tested in Jászfelsőszentgyörgy, Jászfényszaru, Szentlőrinckáta, Nagykáta, Pusztamonostor, Boldog, and Galgahévíz (*Fig. 1*). Farmers used chemical and biological control. There were several pesticide products, including Spintor SC 240, which were compatible with biological control, and, in addition, some of the commercially available natural enemies of thrips, namely *Amblyseius cucumeris* and *Orius laevigatus* from Biobest, were used. There were some greenhouses without any treatment during the investigation period. In the years of 2005–2007, 80% of the peppers were the Keceli variety.

Field studies were performed in the summers of 2005–2007. Greenhouses and their surroundings were sampled 3 times a year, for 2–3 days each, namely: from 21 to 23 June, from 27 to 30 July, and from 29 to 31 August in 2005; from 27 to 29 June, from 31 July to 2 August, and from 4 to 6 September in 2006; from 25 to 27 June, from 24 to 26 July, and from 4 to 5 September in 2007. In each greenhouse, 5 x 10 flower samples from different parts of the greenhouses were collected into plastic vials containing AGA solution (10 units of 60% ethyl-alcohol, 1 unit of glycerine, and 1 unit of glacial acetic acid). From flower samples, only 10–20 specimens of species found in high population and their larvae were mounted on the slide as specified in the standard method (Mound & Kibby 1998).

To investigate the surroundings of the greenhouses, weed samples (300 g/sample) were collected into textile bags at a frequency to represent the environment: plant species composition and their coverage. Weeds were determined to species level according to the diagnostic key of Ujvárosi (1973). From plant samples, arthropods were obtained by shaking the plants over a sheet of

white paper. Thrips species were identified to species level. To identify adult thrips, the morphological keys of Jenser (1982) and zur Strassen (2003) were used. Males and females were separately identified only in the case of the TSWV vector species *T. tabaci* and *F. occidentalis*. Regarding Thysanoptera larvae, only the TSWV vectors *T. tabaci* and *F. occidentalis* were identified based on the work of Vierbergen and Nakahara (1998) and Vierbergen et al. (2010). Among larval stages, only the second was considered because microscopic diagnostic methods are not suitable to determine specimens in their first larval stage to species level.

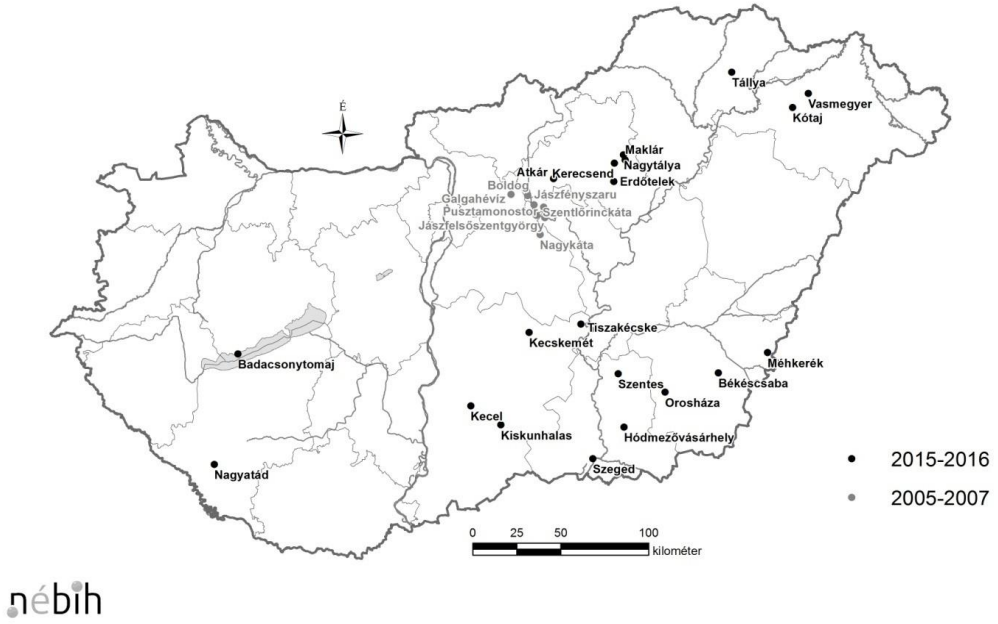

Figure 1. Greenhouse sampling sites, Hungary

Investigations into ornamental and vegetable greenhouses and indoor ornamentals (2015–2017)

Plant samples were collected from a total of 44 ornamental and vegetable greenhouses with different cultivation techniques throughout Hungary in Bács, Békés, Borsod, Csongrád, Heves, Somogy, Szabolcs, and Veszprém counties in the years of 2015–2016 (Fig. 1). The cultivated plants in these greenhouses were the

following: Begonia sp., Callistephus chinensis, Capsicum annuum, Caryopteris sp., Chrysanthemum sp., Cucumis melo, Cucumis sativus, Cucurbita pepo, Cyclamen sp., Dianthus caryophyllus, Gerbera sp., Mandevilla sp., Pelargonium sp., Petunia sp., Rosa sp., Solanum lycopersicum, Verbena sp., and Viola tricolor. Almost all the examined greenhouses were well equipped, operated in enclosed spaces, and in the most cases there were nearly no weeds in their surroundings. Growers relied on chemical and biological control methods, and most of them used seedlings imported from countries, including the Netherlands and Germany. Sampling took place in 2015 from June to November two times a month; in 2016, from August to November, also two times a month, and each time a different location was sampled. From ornamental and vegetable plant samples, thrips were obtained by shaking the plants over a sheet of white paper. In each greenhouse, thrips were collected randomly from different parts of the greenhouses, and they were immersed into plastic vials containing AGA solution (10 units of 60% ethyl-alcohol, 1 unit of glycerine, and 1 unit of glacial acetic acid). All sampled thrips specimens were mounted on the slide according to the standard method (Mound & Kibby 1998). Adult thrips were identified using the morphological keys of Jenser (1982) and zur Strassen (2003).

In May and July 2017, the occurrence of and damage by Thysanoptera species were observed in some offices of the National Food Chain Safety Office, Directorate of Plant Protection on certain indoor ornamental plants, including Freesia sp., Iresine herbstii, Podophyllum sp., Impatiens walleriana, Alocasia polly, Orchidea sp., and one specimen of Monstera deliciosa, which arrived from Kecskemét in January. Sampling and identification followed the protocol as described above.

3. Results and discussion

Investigations into sweet pepper and its surroundings in Jászság (*2005–2007*)

In the Jászság region, 12,695 thrips adults were collected in the 51 green pepper greenhouses in the years of 2005 to 2007, from June to August. The most frequent species of the greenhouses were the following: *Frankliniella occidentalis* (4,120 adults), *Thrips tabaci* (3,460 adults), *Frankliniella intonsa* (2,747 adults), *Aeolothrips intermedius* (1,155 adults), and *Thrips atratus* (1,103 adults). The other Thysanoptera species that were found in minimal numbers within the greenhouses were probably looking for alternative food sources inside (tables 1, 2).

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Table 1. Thysanoptera species of sweet pepper greenhouses and their surroundings (Jászság region, 2005–2007)

Thysanoptera species	Number of specimens		Total number of specimens
	within the greenhouses	outside the greenhouses	
Thrips tabaci (Lindeman 1888)	3,460	3,182	6,642
Frankliniella occidentalis (Pergande 1895)	4,120	365	4,485
Frankliniella intonsa (Trybom 1895)	2,747	1,511	4,258
Aeolothrips intermedius (Bagnall 1920)	1,155	880	2,035
Thrips atratus (Haliday 1836)	1,103	866	1,969
Haplothrips aculeatus (Fabricius 1803)	29	262	291
Haplothrips angusticornis (Priesner 1921)	8	103	111
Odontothrips confusus (Priesner 1926)	1	102	103
Taeniothrips spp.	1	75	76
Thrips nigropilosus (Uzel 1895)	25	33	58
Anaphothrips obscurus (Müller 1776)	8	46	54
Aeolothrips melaleucus (Haliday 1852)	3	37	40
Limothrips denticornis (Haliday 1836)	4	31	35
Chirothrips manicatus (Haliday 1836)	4	25	29
Thrips major (Uzel 1895)	4	18	22
Neohydatothrips gracilicornis (Williams 1916)	0	20	20
Thrips angusticeps (Uzel 1895)	4	14	18
Thrips physapus (Linnaeus 1758)	0	18	18
Thrips pillichi (Priesner 1924)	2	13	15
Scolothrips longicornis (Priesner 1926)	2	3	5
Thrips trehernei (Priesner 1927)	0	5	5
Frankliniella tenuicornis (Uzel 1895)	0	3	3
Limothrips angulicornis (Jablonowski 1894)	1	2	3
Thrips incognitus (Priesner 1914)	3	0	3
Aptinothrips rufus (Haliday 1836)	0	2	2
Haplothrips flavicinctus (Karny 1909)	0	2	2
Melanthrips spp.	0	2	2
Thrips dubius (Priesner 1927)	1	1	2
Bolothrips bicolor (Heeger 1852)	0	1	1
Thrips minutissimus (Linnaeus 1758)	0	1	1
Thrips validus (Karny 1910)	0	1	1
Total	12,685	7,624	20,309

Table 2. Thysanoptera species and their relative frequency in sweet pepper greenhouses (Jászság region)

Year 2005 (n =153)	Number of specimens	%
Thrips tabaci	1,871	29.4
Frankliniella occidentalis	1,286	20.2
Frankliniella intonsa	1,080	17
Aeolothrips intermedius	1,043	16.3
Thrips atratus	1,056	16.5
Other thrips species	40	0,6
Total	6,376	100
Year 2006 (n =153)		
Thrips tabaci	962	24
Frankliniella occidentalis	1,808	45
Frankliniella intonsa	1,132	28.4
Aeolothrips intermedius	23	0.7
Thrips atratus	41	1
Other thrips species	38	0.9
Total	4,004	100
Year 2007 (n =153)		
Thrips tabaci	627	27.1
Frankliniella occidentalis	1,026	44.3
Frankliniella intonsa	535	23.1
Aeolothrips intermedius	89	3.8
Thrips atratus	6	0.3
Other thrips species	32	1.4
Total	2,315	100

In 2005, *T. tabaci* was the dominant species with a frequency of 29.4% in the greenhouses. This polyphagous species is assumed to have invaded the greenhouses in large numbers from the weeds in the surroundings. However, in 2006 and 2007, *F. occidentalis* was the dominant pest in the greenhouses, with a relative frequency of 45% and 44.3% resp. This species was also found in weed species in the surroundings of the greenhouses. The number of *F. occidentalis* males in greenhouses is a factor worth monitoring. In 2005, 2006, and 2007, there

were found 273, 326, and 189 male specimens resp. The ratio of males to females is approximately equal to the one stated by Lubinkhof and Foster (1977), that is: within a population, the number of females is usually four times higher than that of males. The polyphagous *F. intonsa* had a large number of individuals in the greenhouses during the investigated period. In 2006, its frequency (28.4%) was higher than that of *T. tabaci*. In our study, *F. intonsa* occurred in smaller numbers on the weeds of the surroundings than in the sweet pepper greenhouse. *Thrips atratus*, on the other hand, damages mainly the species of families Caryophyllaceae and Lamiaceae (Jenser 1998). In 2005, this thrips species had an extremely high number of individuals in sweet pepper (16.5%). However, the population collapsed in 2006 (1%), and in 2007 it completely disappeared (0.3%) from the greenhouses. The reason behind this phenomenon is yet to be discovered. In 2005, the predator *A. intermedius* was found settled within the greenhouses in a relatively large number (16.3%) from the weeds in the surrounding environment, and the appearance of this predator species probably also contributed to the decline in the number of phytophagous Thysanoptera species, especially *T. tabaci*, in the population of 2006. However, the following two years witnessed a decrease in the population of *A. intermedius*. In 2006, the relative frequency of this species was 0.7%, whereas in 2007 it was slightly higher, with a value of 3.8%. In 2007, the total number of the most frequent Thysanoptera species declined by 36.5% compared to the year 2005 (*Table 2*).

Our study investigated which weed species *F. occidentalis* occurred on during the vegetation period in the surroundings of the greenhouses (*Table 3*). In 2005–2007, the following weed species played important roles in maintaining colonies of *F. occidentalis* in the surroundings of the studied greenhouses: *Medicago sativa*, *Galinsoga parviflora*, *Convolvulus arvensis*, *Erigeron annuus*, *Trifolium pratense*, *T. repens*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, and *Chenopodium album*. Being the major elements of the plant assemblage of the surroundings of the greenhouses, these species were quite frequent and presented a relatively high coverage during the study – so, they played an important role during the vegetation period. According to literature, *F. occidentalis* does not occur in large numbers in the field on any of the following weed species: *E. annuus*, *T. pratense*, or *A. artemisiifolia*. During the study, *F. occidentalis* was found on these plants in small numbers and with low frequency. Furthermore, no literature mentions the following species as sources of *F. occidentalis* in the fields: *Calystegia sepium*, *Galium verum*, *Lactuca serriola*, and *Lamium amplexicaule*. The ratio of males in the weeds of the surroundings of greenhouses was approximately 50%. *T. tabaci* was found in high numbers within greenhouses and on the plants outside. The onion thrips was present in large numbers in the surroundings of the greenhouses.

This species occurred on almost all investigated weeds except the following: *Cirsium arvense*, *Cichorium inthybus*, and *Crepis rhoeadifolia*. However, these weeds were not frequent during the investigation period. *Convolvulus arvensis*, *Lamium amplexicaule*, *Anthemis arvensis*, and *Trifolium* species, on the other hand, were common during the years of the study and were present with a relatively high coverage, but *T. tabaci* had a relatively low population on these particular weeds. In summary, we found that large numbers of this pest may establish and propagate within the greenhouses from the weed composition of the surroundings. The species number and relative frequency of the polyphagous *F. intonsa* was lower on the examined weeds than those of *T. tabaci*. The most important sources for *F. intonsa* colonization in the study period were *Medicago sativa*, *Convulvulus arvensis*, *Trifolium repens*, *Trifolium pratense*, and *Melilotus officinalis*; and although the thrips was present in relatively high numbers also on *Calystegia sepium*, the weed was not so frequent and had a lower coverage. We found that *F. intonsa* had higher average number of individuals on certain plants as compared to *T. tabaci*. We also observed the presence of *T. atratus*, a polyphagous pest that mainly damages members of families Caryophyllaceae and Lamiaceae (Jenser 1998). *T. atratus* occurred in the highest numbers during the investigation years in the following plants: *Conium maculatum*, *Cytisus nigricans*, *Medicago sativa*, *Sambucus ebulus*, *Galium verum*, *Senecio vulgaris*, *Stellaria media*, and *Taraxacum officinale*. During our survey, *A. intermedius* was found on most plants; however, the most important sources for its establishment are probably the following species: *Melilotus officinalis*, *Medicago sativa*, *Conyza canadensis*, *Conium maculatum*, *Anthemis arvensis*, and *Erigeron annuus*. In 2005, *A. intermedius* adults were found in the vicinity of the greenhouses with a relative frequency of 75%, and the same species also had a high relative frequency (16.5%) within greenhouses that year (*Table 2*). In the following years, the population declined on greenhouse plants. According to Franco et al. (1999), *A. intermedius* is able to reduce the number of phytophagous Thysanoptera species mostly under field conditions, its predator role not being important in the greenhouses mainly because this species cannot complete its development on *F. occidentalis*.

Possibilities of transmitting tomato spotted wilt virus (TSWV) in the Jászság region (2005–2007)

Literature shows that out of the 43 weed species we found in the surroundings of the greenhouses 26 proved to be TSWV reservoir hosts (*Table 3*). During our study, the most important reservoir TSWV host plant was sweet pepper (*Capsicum annuum*) (Hausbeck et al. 1992, Bitterlich & MacDonald 1993). During the

summers, TSWV reservoir weed hosts with relatively high frequency and coverage were: *Amaranthus retroflexus*, *Ambrosia artemisiifolia* (Stobbs et al. 1992), *Anthemis arvensis* (Chatzivassiliou et al. 2000), *Chenopodium album* (Cho et al. 1986; Stobbs et al. 1992, Latham and Jones 1997), *Conyza canadensis* (Stobbs et al. 1992), *Convolvulus arvensis* (Stobbs et al. 1992, Mertelik et al. 1996), *Galinsoga parviflora* (Cho et al. 1986, Mertelik et al. 1996), *Lamium amplexicaule* (Stobbs et al. 1992), *Sonchus oleraceus* (Cho et al. 1986, Stobbs et al. 1992, Bitterlich & MacDonald 1993), *Stellaria media* (Cho et al. 1986, Stobbs et al., 1992, Bitterlich & MacDonald 1993, Latham & Jones 1997), and *Trifolium repens* (Stobbs et al. 1992).

In Hungary, *F. occidentalis* and *T. tabaci* both play a special role in the transmission of TSWV in the greenhouses and in the fields resp. (Jenser & Gáborjányi 1998). The TSWV is acquired from reservoir plants by the vector Thysanoptera larvae, and the adults are responsible for its transmission (Sakimura 1960). Based on our study, the most important TSWV weed hosts with high frequency and cover in the surroundings of the greenhouses, on which mass population of *T. tabaci* adults and larvae occurred, are the following: *A. retroflexus*, *A. artemisiifolia*, *A. arvensis*, *C. canadensis*, *C. arvensis*, *G. parviflora*, *L. amplexicaule*, *S. media*, *T. officinale*, and *T. repens*. In the vicinity of the examined greenhouses, *S. media* occurred the whole year (spring, summer, autumn, winter) with a relatively large cover. On this plant, the number of *T. tabaci* larvae was the highest in the summer months (from June to August).

Table 3. Weed species in the surroundings of sweet pepper greenhouses (Jászság region, 2005–2007)

Weed species	TSWV reservoir (+)
Achillea millefolium	-
Amaranthus retloflexus	+
Ambrosia artemisiifolia	+
Anthemis arvensis	-
Artiplex tatarica	-
Calystegia sepium	-
Capsella bursa-pastoris	+
Capsicum annuum	+
Chenopodium album	+
Cichorium inthybus	+
Cirsium arvense	+

Weed species	TSWV reservoir (+)
Conium maculatum	+
Convulvulus arvensis	+
Conyza canadensis	-
Crepis rhoeadifolia	-
Cytisus nigricans	-
Erigeron annuus	-
Galinsoga parviflora	+
Gallium verum	+
Galium aparine	+
Lactuca serriola	+
Lamium amplexicaule	+
Lepidium draba	-
Lotus coeniculatus	-
Matricaria maritima	+
Medicago sativa	-
Melandrium album	-
Melilotus officinalis	+
Raphanus raphanistrum	-
Rumex obsutifolius	+
Sambucus ebulus	-
Senecio vulgaris	+
Sysimbrium sophia	-
Sonchus oleraceus	+
Stellaria media	+
Stenactis annua	-
Taraxacum officinale	+
Thalspi arvense	-
Trifolium pratense	+
Trifolium repens	+
Urtica dioica	+
Vicia villosa	-
Viola oleracea	-

Table 4. Occurrence of *Thrips tabaci* males (Jászság region)

Date of collection	Plant species	Number of specimens
28.07.2005	*Capsicum annuum*	1
30.07.2005	*Erigeron annuus*	2
31.07.2006	*Conyza canadensis*	1
02.08.2006	*Ambrosia artemsiifolia*	1
25.07.2007	*Medicago sativa*	1
26.07.2007	*Conium maculatum*	1
04.09.2007	*Capsicum annuum*	1
05.09.2007	*Galinsoga parviflora*	2

The arrhenotokous populations of *T. tabaci* – in which males are present – are efficient vectors of TSWV, while the thelotokous populations are not able to transmit the virus (Zawirska 1976, Chatzivassiliou et al. 1999). Since the presence of *T. tabaci* males was proven in the vicinity of our investigated greenhouses, we came to the conclusion that in our country *T. tabaci tabaci* populations also transmit TSWV. From June 2005 to September 2007, 10 male specimens were collected in the Jászság region. According to literature, the following plants have not yet been cited as potential hosts of *T. tabaci* males: *Ambrosia artemisiifolia*, *Capsicum. annuum*, *Conium maculatum*, *Conyza canadensis*, and *Erigeron annuus* (*Table 4*). From June 2005 to September 2007, 12 *F. occidentalis* larvae were collected from the following plants: *Amaranthus retroflexus*, *Chenopodium album*, *Gallinsoga parviflora*, and *Medicago sativa* (*Table 5*).

Table 5. Occurrence of *Frankliniella occidentalis* larvae (Jászság region)

Date of collection	Plant species	Number of specimens
28.07.2005	*Medicago sativa*	2
31.07.2006	*Medicago sativa*	3
25.06.2007	*Medicago sativa*	2
25.07.2007	*Medicago sativa*	1
25.07.2007	*Amaranthus retroflexus*	1
04.09.2007	*Chenopodium album*	1
05.09.2007	*Galinsoga parviflora*	2

We concluded that in the vicinity of the sweet pepper greenhouses in the Jászság region the risk of TSWV transmission is quite high since the number of TSWV reservoir host weed species present with large coverage in the surroundings was high. These plants can play a significant role in *T. tabaci* transmitting TSWV to sweet pepper during the vegetation period. This virus overwinters within Stellaria media or within other annual or perennial weeds (*Capsella bursa-pastoris*, *Lamium amplexicaule*, *Convolvulus arvensis*, and *Melilotus officinalis*). Certain TSWV reservoir weeds found present until late October/early November, such as *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Conyza canadensis*, and *Galinsoga parviflora* in our surveys, may play an important role in supplying TSWV to overwintering *T. tabaci* females. The most important TSWV reservoir hosts in the vicinity of the greenhouses are *Stellaria media* and *Galinsoga parviflora* (Zawirska et al. 1983, Mertelik & Mokra, 1996, Jenser et al. 2009). We found that in the vicinity of the greenhouses in the Jászság region there is a high risk of *T. tabaci* transmitting TSWV, as the number of adults and larvae was high, and a wide range of TSWV reservoir weed hosts had high large cover values in the vicinity of the greenhouses. *T. tabaci* males occurred on many weed species; so, *T. tabaci tabaci* populations can also transmit TSWV in Hungary. The frequency of *F. occidentalis* males on weeds in the vicinity of the greenhouses was approximately 50%. F. occidentalis males proved to be more efficient vectors than females within a population (van de Wetering et al. 1998). As *F. occidentalis* is a more efficient vector of TSWV than *T. tabaci* (Wijkamp et al. 1995, Chatzivasiliou et al. 2002) and, taking into account the extremely high number of males in the environment of greenhouses, *F. occidentalis* is safe to say to have a major role in the risk of developing TSWV epidemics in sweet pepper greenhouses. The presence of *T. tabaci* and *F. occidentalis* together poses a high risk for sweet pepper because, after overwintering, *T. tabaci* females can infest the crop in the spring, while the adults of *F. occidentalis* can infest the plants during autumn.

Investigations into different ornamental and vegetable greenhouses and indoor ornamentals (2015–2017)

Throughout Hungary, a total of 3,194 thrips adults were collected in the 44 different greenhouses in the years of 2015 and 2016, from June to November. The most abundant species within all greenhouses, with the highest number of individuals was *Frankliniella occidentalis* (2,330 females, 176 males), with a relative frequency of 78.45% (*Table 6*). It was found in large numbers in all the studied places, but the highest colonies of *F. occidentalis* were found on the following plants: *Callistephus chinensis*, *Capsicum annuum*, *Chrysanthemum sp.*,

Dianthus caryophyllus, and *Gerbera sp*. (*Table 7*). In 2015–2016, the number of *T. tabaci* was extremely low in the greenhouses; its relative frequency was only 1.6%. From the total catch of 51 *T. tabaci*, 31 specimens occurred in one particular sweet pepper greenhouse covered with weeds in its surroundings (23. 06. 2015, Vasmegyer). The remaining 20 *T. tabaci* specimens were found scattered in the other studied areas. The main reason of this situation was probably that almost all the examined greenhouses were well equipped and in most cases there were no weeds in their surroundings, and *T. tabaci* normally invades greenhouses from the environment. The polyphagous *F. intonsa* also had a low number of individuals within the greenhouses, yet the figures were higher than those of *T. tabaci* during the investigated period, with a relative frequency of 11%. From the total of 348 *F. intonsa* captured, 221 specimens were found on *Cucumis melo* (08. 07. 2015, Erdőtelek), and the remaining specimens were found in very low numbers in other studied areas. We believe *F. intonsa* was also unable to invade greenhouses in high numbers from outside for the same reason *T. tabaci* was not. Following the same reasoning, the predator *Aeolothrips intermedius* is also unable to colonize greenhouses from the environment. To support our assumption, a total of only 12 specimens were counted within the greenhouses during the entire study period. The additionally found Thysanoptera species of greenhouses (*Thrips atratus*, *Thrips timidus*, and *Taeniothrips spp*. with 1-1 specimen) were probably only seeking alternative food sources (*Table 6*).

Table 6. Thysanoptera species and their relative frequency in different ornamental and vegetable greenhouses

Years 2015–2016 (n = 44)	Number of specimens	%
Frankliniella occidentalis	2,506	78.45
Frankliniella intonsa	348	11
Echinothrips americanus	274	8.55
Thrips tabaci	51	1.6
Aeolothrips intermedius	12	0.3
Other thrips species	3	0.1
Total	3,194	100

Table 7. Occurrence of *Frankliniella occidentalis* on different ornamental and vegetable greenhouses (Hungary, 2015–2016)

Host plant	Total number of specimens	Total number of samples (n)	Number of specimens/ Sample units
Begonia spp.	102	3	34
Callistephus chinensis	104	1	104
Capsicum annuum	653	7	93
Caryopteris spp.	22	1	22
Chrysanthemum spp.	761	12	64
Cucumis melo	24	3	8
Cucumis sativus	110	1	55
Cucurbita pepo	1	1	1
Cyclamen spp.	24	2	12
Dianthus caryophyllus	122	1	122
Gerbera spp.	242	2	121
Mandevilla spp.	58	1	58
Pelargonium spp.	98	2	49
Petunia sp.	16	1	16
Rosa sp.	9	1	9
Solanum lycopersicum	102	3	34
Verbena spp.	41	1	41
Viola tricolor	17	1	17

Table 8. Occurrence of *Echinothrips americanus* on ornamental greenhouses (Southern Hungary, 2015–2016)

Host plant	Number of specimens	Location	Date of collection
Gerbera spp.	53	Szeged	27.08.2015
Begonia spp.	65	Hódmezővásárhely	27.08.2015
Pelargonium sp.	43	Hódmezővásárhely	27.08.2015
Petunia spp.	10	Hódmezővásárhely	27.08.2015
Verbena spp.	23	Hódmezővásárhely	27.08.2015
Gerbera spp.	45	Szeged	06.10.2016
Callistephus chinensis	35	Hódmezővásárhely	06.10.2016

Table 9. Occurrence of *Hercinothrips femoralis* on indoor ornamentals

Host plant	Number of specimens	Location	Date of collection
Monstera deliciosa	13	Kecskemét	24.01.2017
Freesia spp.	16	Budapest	09.05.2017
Iresine herbstii	18	Budapest	09.05.2017
Podophyllum spp.	23	Budapest	09.05.2017
Impatiens walleriana	11	Budapest	09.05.2017
Alocasia polly	15	Budapest	09.05.2017
Orchidea spp.	8	Budapest	03.07.2017

A relatively high number of *Echinothrips americanus* (274 adults) were found on ornamentals (*Gerbera* sp., *Begonia* sp., *Pelargonium* sp., *Petunia* sp., *Verbena* sp., and *Callistephus chinensis*) in Szeged and Hódmezővásárhely (southern Hungary) (tables 6, 8). Feeding on leaves, the invasive, polyphagous *E. americanus* is known to cause a direct damage to ornamentals in greenhouses. The favourite host families of this species are Araceae and Balsaminaceae. Being a Nearctic species with a native distribution area including the eastern parts of North America, *E. americanus* was first described as a greenhouse pest in the USA in 1984, with *Impatiens* spp. (Oetting 1987) as the most important hosts. It was first recorded in Europe within a tropical glasshouse in England in 1989. In France, the first author collected the species in 1997 on *Hibiscus* spp. The damage caused to infested plants was described as discoloured spots on leaves, a typical symptom caused by the sucking of thrips larvae and adults (Vierbergen 1998). Because of the lack of obvious damage on commonly cultivated hosts, such as *Syngonium* and *Dieffenbachia*, the species spread fast within Europe. The first appearance of *E. americanus* was recorded in 2004 in Hungary in August, when 14 specimens were found on an imported *Dieffenbachia* in Szeged, southern Hungary (Vierbergen et al. 2006). Till now, E. *americanus* has remained somewhat isolated around the original site, Szeged, and although the pest was found in the greenhouses in the neighbouring town of Hódmezővásárhely as well, in 2017, specimens of *Hercinothrips femoralis* were found with signs of their damage on some indoor ornamental plants, such as *Monstera deliciosa*, *Freesia*, *Iresine herbstii*, *Podophyllum*, *Impatiens walleriana*, *Alocasia polly*, and *Orchidea* (*Table 9*). Infested plants had spots of discolouration on their leaves. *H. femoralis*, a polyphagous species is native to tropical areas. In Europe, it damages both greenhouse and indoor ornamentals (zur Strassen 2003). The first appearance of *H.*

femoralis was recorded in 1938 in Hungary. In our country, the damage of *H. femoralis* is known mainly on *Cordyline*, *Dracaena*, *Aspidistra*, *Cyperus alternifolius*, and *Tradescantia virginiana* (Jenser 1988).

During our survey, there were observed no signs of some well-documented polyphagous invasive greenhouse thrips species such as *Helio-thrips haemorrhoidalis*, *Parthenothrips dracaenae*, *Microcephalothrips abdominalis*, *Thrips setosus*, or *Thrips palmi*.

Conclusions

During the study, the most abundant species within all greenhouses, with the highest number of individuals, was *Frankliniella occidentalis*. It was determined which reservoirs were significant in the risk of Thysanoptera species transmitting TSWV. During the official surveys, no signs of *Thrips palmi* and *Thrips setosus* were observed.

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References

[1] Bitterlich, I., MacDonald, L. S. (1993), The prevalence of tomato spotted wilt virus in weeds and crops in southwestern British Columbia. *Canadian Plant Disease Survey* 73(2), 137–139.

[2] Bos, L. (1981), Wild plants in the ecology of virus diseases. In: K. Maramorosch, K. F. Harrys (eds.), *Plant diseases and vectors: ecology and epidemiology*. New York: Academic Press.

[3] Chatzivassiliou, E. K., Nagata, T., Katis, N. I., Peters, D. (1999), Transmission of tomato spotted wilt tospovirus by *Thrips tabaci* populations originating from leek. *Plant Patology* 48, 700–706.

[4] Chatzivassiliou, E. K., Livieratos, I., Jenser, G., Katis, N. I. (2000), Ornamental plants and thrips population associated with tomato spotted wilt virus in Greece. *Phytoparasitica* 28(3), 257–264.
[5] Chatzivassiliou, E. K., Peters, D., Katis, N. I. (2002), The efficiency by which *Thrips tabaci* population transmits tomato spotted wilt virus depends on their host preference and reproductive strategy. *Phytopathology* 92, 603–609.
[6] Cho, J. J., Mau, R. F. L., Gonsalves, D., Mitchell, W. C. (1986), Reservoir weed hosts of tomato spotted wilt virus. *Plant Disease* 70, 1014–1017.
[7] Franco, S., Beignet, P., Rat, E., Thibout, E. (1999), The effect of thrips on wild and cultivated alliaceous plants in France. *Phytoma* 514, 41–44.
[8] Hausbeck, M. K., Welliver, R. A., Derr, M. A., Gildow, F. E. (1992), Tomato spotted wilt virus survey among greenhouse ornamentals in Pensylvania. *Plant Disease* 76(8), 795–799.
[9] Jenser, G. (1982), Tripszek – *Thysanoptera*. In: *Magyarország Állatvilága (Fauna Hungariae)* V, 13. Akadémiai Kiadó, Budapest, 8–156 (in Hungarian).
[10] Jenser, G. (1988), Tripszek – *Thysanoptera*. In: Jermy, T., Balázs, K. (eds.), *A növényvédelmi állattan kézikönyve 1*. Budapest, Akadémiai Kiadó, 283–304 (in Hungarian).
[11] Jenser, G. (1995), The role of the *Thysanoptera* species in the spread of tomato spotted wilt tospovirus. *Növényvédelem* 31(11), 541–545 (in Hungarian).
[12] Jenser, G., Almási, A., Kazinczi, G., Takács, A., Szénási, Á., Gáborjányi, R. (2009), Ecological background of the epidemics of *tomato spotted wilt virus* in Central Europe. *Acta Phytopatol. et Entomol. Hung.* 44(2), 213–223.
[13] Jenser, G. (2012), Introduced *Thysanoptera* species in Hungary. *Növényvédelem* 48(4), 173–175 (in Hungarian).
[14] Latham, L. J., Jones, A. C. (1997), Occurrence of tomato spotted wilt tospovirus in native flora, weeds, and horticultural crops. *Aust. J. Agric. Res.* 48, 359–369.
[15] Lubinkhof, J., Foster, D. E. (1977), Development and reproductive capacity of *Frankliniella occidentalis* reared at three temperatures. *Journal of the Kansas Entomological Society* 50, 313–316.
[16] Mertelik, J., Götzova, B., Mokra, V. (1996), Epidemiological aspects of tomato spotted wilt virus infection in the Czech Republic. *Acta Horticulturae* 432, 368–375.
[17] Mound, L. A., Kibby, G. (1998), Thysanoptera: an identification guide. 2nd ed. CAB Int. Wallingford.
[18] Nakahara, S., Vierbergen, G. (1998), Second instar larvae of *Frankliniella* species in Europe (Thysanoptera: Thripidae). *Proceedings of 6th Int. Symp. on Thysanoptera. Antalya, Turkey*. 113–120.
[19] Oetting, R. D. (1987), *Echinothrips americanus*, a thrips of increased significance on ornamentals. *Proceedings of the 32nd Southern Nurserymen Association Research Conference*. 194–195.
[20] Ripka, G. (2010), An overview of the alien arthropod pest species in Hungary (I). *Növényvédelem* 46(2), 45–58 (in Hungarian).
[21] Sakimura, K. (1960), The present status of thrips-borne viruses. *Technical Paper* 276, 1–7. Pineapple Research Institute of Hawaii.
[22] Stobbs, L. W., Broadbent, A. B., Allen, W. R., Stirling, A. L. (1992), Transmission of tomato spotted wilt virus by the western flower thrips to weeds and native plants found in Southern Ontario. *Plant Disease* 76(1), 23–28.
[23] Szénási, Á., Marczika A. (2011), The occurrence of *Dichromothrips corbetti* Priesner in a Hungarian greenhouse. *Növényvédelem* 47(10), 435–436 (in Hungarian).

[24] Ujvárosi, M. (1973), *Gyomnövények*. Mezőgazdasági Kiadó, Budapest.
[25] Vierbergen, G. (1998), *Echinothrips americanus* Morgan, a new thrips in Dutch greenhouses (Thysanoptera: Thripidae). *Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society (N. E. Y.)* 9, 155–160.
[26] Vierbergen, G., Cean, M., Szellér, I. H., Jenser, G., Masten, T., Šimala, M. (2006), Spread of two thrips pests in Europe: *Echinothrips americanus* and *Microcephalothrips abdominalis* (Thysanoptera: Thripidae). *Acta Phytopathologica et Entomologica Hungarica* 41, 287–296.
[27] Vierbergen, G., Kucharczyk, H., Kirk, W. (2010), A key to the second instar larvae of the Thripidae of the Western Palaearctic region (Thysanoptera). *Tijdschrift voor Entomologie* 153, 100–160.
[28] Wetering, F. van de, Hulshof, J., Posthuma, K., Harrewijn, P., Goldbach, R., Peters, D. (1998), Distinct feeding behaviour between sexes of *Frankliniella occidentalis* results in higher scar production and lower tospovirus transmission by females. *Entomol. Exp. et Appl.* 88, 9–15.
[29] Wijkamp, I., Almarza, N., Goldbach, R., Peters, D. (1995), Distinct level of specificity in thrips transmission of tospoviruses. *Phytopathology* 85, 1069–1074.
[30] Zawirska, I. (1976), Untersuchungen über zwei biologische Typen von *Thrips tabaci* Lind. (Thysanoptera, Thripidae) in der VR. Polen. *Arch. Phytopathol. Pflanzeschutz* 12, 411–422.
[31] Zawirska, I., Ruszkiewicz, M., Micinski, B. (1983), *The problem of tomato spotted wilt virus (TSWV) in Poland* [Zesztyty Problemowe postepow nauk Rolniczych] 291, 293–405.
[32] Zur Strassen, R. (2003), *Die Terebreneten Thysanopteren Europas*. Goecke and Evers, Keltern.