Investigation of Thysanoptera populations in sweet pepper greenhouses and in their surroundings

PhD thesis

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1. INTRODUCTION AND OBJECTIVES

The most important Thysanoptera pests of sweet pepper is the western flower thrips (*Frankliniella occidentalis* Pergande) and the onion thrips (*Thrips tabaci* Lindeman). Among the protected vegetables the most severe damage of *F. occidentalis* occurs on sweet pepper,, making the yield unmarketable. Furthermore the hidden life style and the resistance to insecticides make very difficult to protect efficiently the 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 the sweet pepper grown in greenhouses.

The vectors of TSWV are *F. occidentalis* in the greenhouses, and *T. tabaci* both under field and greenhouse conditions. In the last decades the frequency of epidemics caused by the virus increased, the most important damage occurs in the sweet pepper greenhouses in Hungary (Jenser, 1995). The spread of TSWV in Europe has coincided with the spread of *F. occidentalis*. The reservoir weed hosts play the most important role in the spread of TSWV. They can maintain the virus after harvest until the sowing of sensitive crops (Bos, 1981), futhermore the reservoir weed hosts can help the vector thrips species develop, and transmit the virus, thereby to spread the virus (Bitterlich and MacDonald, 1993). Usually the host plants are the same for both the virus and the vectors and this fact can help the virus maintain and spread (Cho et al., 1986).

The present studies were performed in Jászság, one of the most important sweet pepper growing areas in Hungary. The experimental greenhouses had different cultivation background and practices: they were either located in the outskirts of or within the localities; were heated-unheated; or were treated with insecticides-without treatment by insecticides; furthermore the weeds were also investigated in the surroundings of the greenhouses.

This area has important tradition for growing sweet pepper, most of the inhabitans grow vegetables in greenhouses.

The objectives of this work:

1. to investigate the Thysanoptera populations in the greenhouses with different production background and in their surroundings, mostly considering the populations of *F. occidentalis* and *T. tabaci* which cause important economic damages;

2. to determine whether *F. occidentalis* and *T. tabaci* can transmit TSWV virus between sweet pepper and the weed hosts in the surroundings of the greenhouses under continental climatic conditions and to what extent.

3. to determine the role the overwintering *F. occidentalis* and *T. tabaci* population can play in maintaining TSWV and in the initiation of TSWV epidemics.

2. MATERIALS AND METHODS

2.1 The sampling location and background of the cultivation

For the investigations plant samples were collected from the green pepper greenhouses located in the outskirts of and within the localities in Pest and Jász-Nagykun-Szolnok counties, and also from weed samples in the surroundings of the greenhouses. A total of 51 tested greenhouses was found in Jászfelsőszentgyörgy, Jászfényszaru, Szentlőrinckáta, Nagykáta, Pusztamonostor, Boldog and Galgahévíz. The planting time of sweet pepper lasted in the heated greenhouses usually from mid-February to March, in the non-heated greenhouses from April until the beginning of May. The growers used chemical and biological control methods. There are several pesticide products like Spintor SC 240 approved for biological control, and in addition the commercially available natural enemies of thrips, like *Amblyseius cucumeris* and *Orius laevigatus* from Biobest were used. There were some greenhouses without any treatments during the investigation period. In the years of 2005-2007, 80% of the examined pepper varieties were Keceli.

2.2 The sampling time

The studies were performed in the summer of 2005-2007. The greenhouses and their surroundings were investigated 3 times a year, each needing 2-3 days. Studies took place in 2005 from 21 to 23 June; from 27 to 30 July; from 29 to 31 August; in 2006 from 27 to 29 June; from 31 July to 2 August, and from 4 to 6 September; in 2007 from 25 to 27 June; from 24 to 26 July and from 4 to 5 September. The overwintering of TSWV vector thrips species was investigated in Boldog in five selected sites (a-e), where the number of *T. tabaci* and *F. occidentalis* adults was high during the vegetation period. The overwintering studies took place in November and December 2005, in April 2006, from early November 2006 to the end of May 2007, and from the end of October 2007 to the end of May 2008 by taking samples in every three weeks.

2.3 The sampling method

In each greenhouse 5x10 flower samples were collected in plastic vials containing 70% ethanol (a, b, c, d, e signed samples). Each vial had a code number and a letter. The letter showed that the samples come from the first, the middle or the last part of the greenhouses. The samples taken from the outside areas were collected from the weeds in the surroundings of the greenhouses. The weeds and alfalfa samples (300g/sample) were collected into textile bags at a frequency that represents the environment of the investigated plant species composition and their coverage. For the investigation of the overwintering *T. tabaci* and *F. occidentalis* adults, weed samples - mostly *Stellaria media* - were collected into textile bags from the surroundings of the five selected sampling sites (a-e signed sites) in Boldog. At these locations the number of individuals of *T. tabaci* and *F. occidentalis* was high during the vegetation period. The obtained results of population dynamic were compared with the meteorological data - monthly average temperature and monthly precipitation data - of the National Meteorological Service (OMSZ) for the investigated period of Jászság region. In the surroundings of the greenhouses in Boldog, the occurrence of the overwintered *F. occidentalis* adults was studied at different distances (0-5 m, 5-30 m) from the sites.

2.4 The method of sample processing

Samples taken from the greenhouses within the localities

The flowers samples were carefully selected from the ethanol, then this liquid was investigated in Petri dish, using a stereo-microscope. The thrips adults were also selected, according to their species and sex, counted, then put on the slide. -, Only 10-20 representative specimens of species and their larvae occurring in high population were put on the slide.

Samples taken from the greenhouses in the outskirts of localities

The weed species were determined according to the diagnostical key of Ujvárosi (1973). The species composition of the weeds and alfalfa was determined using % of incidence. From the plant samples arthropod were obtained by shaking the samples over a white paper. Thrips species were studied as mentioned above.

Identification of thrips

Identification of thrips adults were make using the morphological key of Jenser (1982) and Zur Strassen (2003). The males and females were considered only for the TSWV vector *T. tabaci* and *F. occidentalis* species. Regarding Thysanoptera larvae, the TSWV vectors *T. tabaci* and *F. occidentalis* were only considered, based on the work of Vierbergen and Nakahara (1998), and Vierbergen *et al.* (2010). Only the second larval stages were considered, because the first larval stage can not be determined with microscopical diagnostical methods.

2.5 Data processing

It was investigated how the number of individuals of the dominant phytophagous and predator Thysanoptera species developed in the different exposed greenhouses (outskirst / K / inside / B /), heated (F) - unheated (H), and in those where various control techniques (chemical, biological methods, no treatments). Furthermore, it was also observed how the number of individuals of the dominant phytophagous Thysanoptera species changed in the different blocks of the greenhouses (a, b, c, d, e). The differences in standard deviation of the average of sample were analyzed using a single-factor analysis of variance (ANOVA), with 95% confidence interval. In the case of unequal variance with two-sample t-test (Welch test), the null hypothesis significance was investigated. The rejection of the null hypothesis p (first kind error probability) = 0.05 significance value was used.

The plant diversity was illustrated with percentages, according to the plant samples collected from the surroundings of the greenhouses. The dominant phytophagous Thysanoptera adults, the TSWV vector larvae and the overwintering TSWV vector Thysanoptera species taken from the surroundings of the greenhouses were studied with analysis of variance.

3. RESULTS AND DISCUSSION

3.1 Investigation of Thysanoptera populations in the green pepper greenhouses

In Jászság, , 12685 thrips adults were collected in the 51 green pepper greenhouses in the years of 2005 to 2007, from June to August. The dominant species of the greenhouses that occurred with high number, are the following: *Frankliniella occidentalis* (4120 *adults), Thrips tabaci* (3460 *adults), Frankliniella intonsa* (2747 *adults), Aeolothrips intermedius* (1155 *adults), Thrips atratus* (1103 adults). The other Thysanoptera species of the greenhouses probably looked for alternative food sources.

In 2005 *T. tabaci* was the dominant species with 29,4% in the greenhouses. This polyphagous species could come in the greenhouses in large number from the weeds in the environment. However in 2006 and 2007 *F. occidentalis* was the dominant pest in the greenhouses, with a participation rate of 45% and 44.3%, resp. This species was also found outside in some weed species in the surroundings of the greenhouses. It is important to mention the number of *F. occidentalis* males in the greenhouses. In 2005, 2006 and in 2007 273 , 326 and 189 male specimens were found, resp. This ratio is approximately equal to the statement of Lubinkhof and Foster (1977) specifying that within a population the number of females is usually four times higher than that of males. The polyphagous *F. intonsa* had large number of individuals in the greenhouses during the investigated period. In 2006, its proportion (28.4%) was higher than the number of *T. tabaci.* In our study *F. intonsa* occurred with smaller number on the weeds of the surroundings than in the protected sweet pepper. As for *Thrips atratus*, it damages firstly the plants of the families Caryophyllaceae and Lamiaceae (Jenser, 1982). In 2005 this sepcies had an extremly high number of individuals in sweet pepper (16.5%), hovewer in 2006 the population collapsed (1%), and in 2007, completely disappeared (0.3%) from the greenhouses. In 2005 the predator *A. intermedius* introduced into the greenhouses with a relatively large number (16.3%) from the weeds in the environment. The predator role of this species probably contributed also to the declined of the number of phytophagous Thysanoptera species in 2006 especially the *T. tabaci* population. However, the population of *A. intermedius* decreased in the following two years. In 2006, the proportion of this species was 0.7%, in 2007 it was slightly higher, 3.8%. In 2007, the total number of the dominant Thysanoptera species declined by 63,5% compared to the year of 2005.

Using the single-factor analysis of variance (ANOVA) we found that, inside the tents, in the longitudinal study blocks (a-e) there was no significant difference between the number of individuals, regarding the distribution of dominant Thysanoptera populations. Using the single-factor analysis of variance, we also found that the number of dominant Thysanoptera species primarily depended on the climates in the sweet pepper greenhouses found in the outskirts of and within the localities, whether they were heated, unheated, or chemically and non chemically treated , furthermore there were no substantial significant differences in the population number between the different tested categories. So it was not possibile to establish a logical trend that could show the correct changing of the number of individuals and the damages regarding the investigated years.

3.2 Investigation of Thysanoptera populations in the surroundings of the greenhouses

It was investigated on which weed species *F. occidentalis* occurred during the vegetation period in the surroundings of the greenhouses. In 2005-2007 the following weed species played the most important role in maintaining *F. occidentalis* in the surroundings of the studied greenhouses located in the outskirts of or within the localities: *Medicago sativa, Galinsoga parviflora, Convolvulus arvensis, Erigeron annuus, Trifolium pratense, T. repens, Amaranthus retroflexus, Ambrosia artemisiifolia, Chenopodium album.* These species were quite frequent and presented relatively high coverage during the study, so they played an important role as major species compositon in the surroundings of the greenhouses during the vegetation period. According to literature data *F. occidentalis* has not occurred with large number in the field on either *E. annuus, T. pratense,* or *A. artemisiifolia.* During the study *F. occidentalis* was collected from these weed species in small number and with low frequency. Furthermore literature data do not mention these species like a source of *F. occidentalis* in the fields: *Calystegia sepium, Galium verum, Lactuca serriola, Lamium amplexicaule.* The proportion of males in the weeds of the surroundings of the greenhouses was approximately 50%. We investigated the occurrence of *T. tabaci*, found in high number in the greenhouses, and on the plants of the surroundings of greenhouses located both in the outskirts of and within the localities. Regarding the onion thrips we found that it was present in large numbers in the surroundings of the greenhouses found in any relation to the inhabited areas. This species occurred almost on all investigated weeds except the followings: *Cirsium arvense, Cichorium inthybus, Crepis rhoeadifolia.* However, theey did not frequently occur during the investigation period. *Convolvulus arvensis, Lamium amplexicaule, Anthemis arvensis* and *Trifolium* species were common during the years of study and were present with relatively high coverage, but *T. tabaci* had relatively low population on these weeds. In summary, we found that large number of this species could establish in the greenhouses from the weed of the surroundings, and propagate there. The polyphagous *F. intonsa* had lower numbers and frequency on the examined weeds than *T. tabaci.* The most important sources for *F. intonsa* colonization in the studied years: *M. sativa, C. arvensis, T. repens, T. pratense, M. officinalis,* but it was present in relatively high number also on *Calystegia sepium*, which was not so frequent and was not present in high coverage. We found that *F. intonsa* had higher average number of individuals on certain plants compared to *T. tabaci*. We observed also the occurrence of *T. atratus* wich is polyphagous, but primarily damages Caryophyllaceae and Lamiaceae (Jenser, 1982). It occurred in the highest number during the investigated years in the following plants: *Conium maculatum, Cytisus nigricans, Medicago sativa, Sambucus ebulus, Galium verum, Senecio vulgaris, Stellaria media, Taraxacum officinale.* During the surveys, *A. intermedius* occurred in most plants, however, could be the most important source for the establishment of the followings: *Melilotus officinalis, Medicago sativa, Conyza canadensis, Conium maculatum, Anthemis arvensis, Erigeron annuus.* In 2005 *A. intermedius* adults occurred in the vicinity of the greenhouses with 75%, involving that the species in the greenhouses in that year was also found in a significant number (16.5%). In the following years the population declined on the plants in the greenhouses located both in the outskirts of and within the localities.

3.3 The tomato spotted wilt virus (TSWV), the possibility of transmission

Literature data show that out of the examined 43 weed species in the surroundings of the greenhouses, 26 plant species proved to be TSWV reservoir hosts. During our study the most important reservoir TSWW host plant was sweet pepper *(Capsicum annuum)* (Haus Beck *et al.*

1992; Bitterlich and MacDonald, 1993; Mertelik *et al.,* 1996). During the summer studies, TSWV reservoir weeds 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, Ochoa *et al.,* 1996*), 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 and MacDonald, 1993), *Stellaria media* (Cho et al. 1986; Stobbs et al., 1992, Latham and Jones, 1997; Bitterlich and MacDonald*,* 1993), *Trifolium repens* (Stobbs *et al.,* 1992*).* In the winter studies, the most common and most important TSWV reservoirs weed hosts in the vicinity of the greenhouses were *Stellaria media,* and in early spring *Capsella-bursa-pastoris* (Cho *et al.*, 1986; Stobbs *et al.,* 1992, Ochoa *et al.,* 1996*;* Bitterlich and MacDonald, 1993; Mertelik *et al.,* 1996).

In Hungary, *F. occidentalis* and *T. tabaci* play special role in the transmission of TSWV, both in the greenhouses and in the fields, resp. (Jenser and Gáborjányi, 1998). Based on our study the most important TSWV weed hosts with high frequency and covering in the surroundings of the greenhouses, and 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, T. repens.* In the vicinity of the examined greenhouses *S. media* occurred in the whole year (spring, summer, autumn, winter) with relatively large covering. On this plant the number of *T. tabaci* larvae was the highest in the summer months, from June to August. The arrhenotokous populations of *T. tabaci* - in which males are present – is an efficient vector of TSWV, while the thelotokous populations are not able to transmit the virus (Zawirska, 1976; Chatzivassiliou *et al.,* 1999, 2002). These studies confirmed the presence of the *T. tabaci* males in the vicinity of the greenhouses. So it can be concluded that in our country also the *T. tabaci tabaci* populations transmit the TSWV. From June 2005 to September 2007, 10 male specimens were collected in Jászság. According to literature, the following plants have not yet been cited for the possible presence of *T. tabaci* males: *A. artemisiifolia, C. annuum, C. maculatum, C. canadensis, E. annuus.* From June 2005 to September 2007, 12 *F. occidentalis* larvae were collected from the following plants: *A retroflexus, C. album, G. parviflora, M. sativa.*

3.4 Investigation of the overwintering of TSWV vector Thysanoptera species

During the winter studies *Stellaria media* proved to be the most common and frequent weed, which was present in each investigated site and on which both *T. tabaci* and TSWV virus can overwinter (Szénási *et al.,* 2002; Mertelik *et al.,* 1996). From November 2006 to May 2008 during the winter and spring periods, the number of *T. tabaci* females were investigated on *S. media* and the number of eggs counted in the body of them. We found that the hibernation, the egg production and the starting of eggs laying, depended on the meteorological conditions, mainly on temperature, although the precipitation also played an important role in the vegetation to wash off the overwintering adults. During the hibernation as time progresses, the number of overwintering adults decreased on chickweed in each study period, because of the low temperature and precipitation in winter. However in spring the number of individuals began to rise slowly because of the warmer weather. Using the data of the National Meteorological Service the winter period of 2006-2007 proved to be much milder than the period of 2007-2008. In parallel, we observed that in this period the number of overwintering adults also was higher, in the body of the specimens the egg production was continuous, on the contrary of the following

cold period, when the body of specimens did not contain eggs. The first larvae (L_2 stages), possibly appeared on *S. media* after the mild winter period on 4 April 2007, after the colder winter period on 27 April 2008. The first larval stages of *T. tabaci* may be about a week earlier (Jenser *et al.*, 1998), the egg laying about five days earlier- taking into consideration that after five days hatch the larvae emerged from the laid eggs (Jenser *et al*., 1998). In the beginning of spring *T. tabaci* larvae appeared only on *S. media* and on *C. bursa-pastoris*, however on *C. bursa-pastoris* the larvae appeared in a few weeks later than on *S. media.*The first *T. tabaci* larvae appeared on the other investigated plants from the end of May. The life cycle of the overwintering female adults lasted until the laying of the first egg colonies. During springtime in the surrounding of the sweet pepper greenhouses we found that the following plants could play roles in the TSWV transmission: *S. media, C. bursa pastoris, S. vulgaris, R. obtusifolius, S. arvensis, C. maculatum, L. purpureum, T. officinale, T. repens.* From November 2007 to May 2006, during the mild winter period and the good early spring weather conditions, overwintering *F. occidentalis* specimens were collected from the field on *S. media.* We found the largest number of overwintering adults on *S. media* inside the empty greenhouses (without cultivation). Regarding *S. media* grown outside the greenhouses, the number of the overwintering *F. occidentalis* decreased from November to April, probably the rain washed down the adults. From April 2007 *F. occidentalis* occurred in numerous weeds in the field *(S. media, C. bursa-pastoris, S. vulgaris, T. officinale, Rumex obtusifolius).* During this period, based on the data from the National Meteorological Service, the average temperature was higher than the biological null point of the species - which is 7.9 °C and 9.5 °C according to McDonald *et al.* (1998), and to Gaum *et al.* (1994) and Katayama (1997), resp.- so the first appearance of larvae must have been expected, but no larvae were found in either plants. In May 2007, both male and female adults were found on the weeds *(A. arvensis, G. aparine and M. sativa, R. obtusifolius, S. oleraceus, S. media, S. annua).* Regarding the winter-spring study periods of 2007-2008, the adults of *F. occidentalis* occurred in winter only until the end of November 2007 on *S. media* and on C. *bursa-pastoris* in the fields. During the winter period of 2007-2008 no overwintering specimens were found. Taking the meteorological data into consideration, the beginning of the winter and the spring was rather cool. The first adults - that were males - appeared in the fields at the end of March on *S. media* and on *C. bursa-pastoris.* Based on the above facts it can be concluded that in spring the following reservoir weeds can play a role in the risk of TSWV transmission by *F. occidentalis*: *A. arvensis,* C. *bursa-pastoris, S. media, S. oleraceus, S. vulgaris, T. officinale, R. obtusifolius.* During the very mild winter and spring period of 2006-2007, *Thrips atratus* constantly occurred on the weeds in the vicinity of the greenhouses, mostly on: *S. media, C. bursa-pastoris, G. aparine, R. obstusifolius R. raphanistrum*. In March and May 2007 this species could be found in large number also on *S. media*. During the cold winter and spring periods of 2007-2008, this species was found from late March on the weeds, but only a few specimens were counted. So the winter-spring occurrence of *T. atratus* on weeds depended on the good weather, especially on the temperature factors. During the overwintering study from November 2006 to May 2008, *Frankliniella intonsa* appeared only in the spring in the vicinity of the examined greenhouses. 92% of the adults occurred in the spring of 2007, while only 8% of the adults were found in th e spring of 2008. This tendency can be taken in parallel with the first examined period with favourable meteorological conditions. 70% of the overwintering adults of *Thrips nigropilosus* appeared in the mild winter-spring period of 2006-2007, while 30% of them were found in the following cold period in this study. Most individuals were found on *S. media*. The overwintering specimens of *T. nigropilosus* were brachypterae (those with vestigial wings). During the surveys *Aeolothrips intermedius* was recovered on weeds only from the end of April.

3.5 New results

- We found that inside of the greenhouses, in the longitudinal blocks there was no significant difference in the number of individuals, regarding the distribution of the dominant Thysanoptera populations.
- We found that the number of the dominant Thysanoptera species in the greenhouses located both in the outskirts of and within the localities; heated, unheated; treated by chemicals and without chemicals, depended only on the effects of the particular year-, there were no relavant significant differences between the different investigated categories.
- During the study *F. occidentalis* occurred with high frequency and relatively large number on *Erigeron annuus*, *Trifolium pratense*, and *Ambrosia artemisiifolia* in the vicinity of the greenhouses.
- We determined the TSWV reservoir weed hosts on which the larvae of *T. tabaci* occurred, i.e. which plants can play an important role in the transmission of TSWV in Jászság. These plants are the followings: *Amaranthus retroflexus, Ambrosia artemisiifolia, Anthemis arvensis, Conyza canadensis, Convolvulus arvensis, Galinsoga parviflora, Lamium amplexicaule, Stellaria media, Taraxacum officinale, Trifolium repens*.
- *T. tabaci* males were collected from some plants, and literature data have not yet reported on their presence. These plants are the followings: *Ambrosia artemisiifolia, Capsicum annuum, Conium maculatum, Conyza canadensis, Erigeron annuus.*
- We determined the TSWV reservoir weed hosts on which the larvae of *F. occidentalis* occurred, i.e. which plants can play an important role in the transmission of TSWV in Jászság. These plants are the followings: *Amaranthus retroflexus, Chenopodium album, Galinsoga parviflora.*
- We determined that depending on temperature the first *T. tabaci* larvae may appear from the end of March to the end of April on *Stellaria media* and *Capsella bursa-pastoris*. These reservoir weeds play a primary role in initiating the first TSWV epidemics in spring in the surroundings of the sweet pepper greenhouses in Jászság.
- During the overwintering surveys in 2006-2007, survival of *F. occidentalis* specimens were found in the fields on *Stellaria media*.

4. CONCLUSIONS

4.1 Investigation of Thysanoptera populations, in sweet pepper greenhouses

Studies were performed in 2005-2007, in Jászság, which is one of the most important sweet pepper growing area in Hungary. Investigations took place in sweet pepper greenhouses with different production backgrounds (greenhouses located both in the outskirts of and within the localities, heated - unheated, treated by chemicals-biological control methods). Regarding the surveys conducted in 2005-2007, the dominant Thysanoptera species that were present together with their larvae with large number of individuals during the three years in the greenhouses, were the followings: *Frankliniella occidentalis, Thrips tabaci, Frankliniella intonsa, Aeolothrips intermedius, Thrips atratus.* The most important pests of sweet pepper are *F. occidentalis* and *T. tabaci.*

According to our hypothesis in the greenhouses located in the outskirts (K) - which environment theoretically has richer weed composition and larger coverage – the number of phytophagous Thysanoptera species is probably lower , because from the environment with more complex plants population, larger numbers of natural enemies *(Orius* and *Aeolothrips* species) could establish in the greenhouses . In the unheated greenhouses (K / H) the number of phytophagous thrips (along with the extent of damage) may be smaller than in the heated (K / F), where *F. occidentalis* has more time for reproduction. In the greenhouses located within the localities (B) the number of phytophagous thrips population and their damage are likely to be higher. Regarding our hypothesis, the vicinity of these greenhouses is poorer in weed species and has less coverage. The above mentioned hypothesis is also valid for the heated (B / F) and unheated (B/H) greenhouses. In summary, we established the following hypothesis based on the damage and the population dynamics of the Thysanoptera species, regarding the greenhouses with different backgrounds: K/H <K/F <B/H <B/F. This study aimed to confirm or refute this hypothesis, taking into account the various control techniques. It was concluded that there was no significant difference in the diversity and the covering of the plants in the vicinity either greenhouses. Furthermore we found that, the number of dominant Thysanoptera species in the greenhouses located both in the outskirts of and within the localities, , heated, unheated, furthermore in the chemically and non chemically treated sweet pepper greenhouses depended primarily on the climate, there were no substantial significant differences between the different tested categories. The above mentioned hypothesis could not be approved or confirmed because of the contradictory results.

4.2 Investigation of Thysanoptera populations in the surroundings of the greenhouses

We examined the surroundings of the sweet pepper greenhouses in Jászság, focused on the dominant weed species of the summer, autumn, winter and spring periods, regarding especially the TSWV reservoir plants. We concluded that, in the years of 2005 and 2007, during the vegetation period there were no significant differences between the composition and the coverage of the plants in the surroundings of the greenhouses greenhouses located either in the outskirts of or within the localities. Out of the 43 investigated plant species 26 proved to be TSWV reservoir, according to literature.

We examined the possible source of introduction of the dominant Thysanoptera species into the sweet pepper greenhouses, and it was furthermore investigated which plant species could play

a major role in the maintanance of *F. occidentalis* during the growing season. In our surveys *F. occidentalis* occurred with high frequency and relatively large number of individuals on *Medicago sativa* and on numerous weeds in the surroundings of the greenhouses. *T. tabaci* was found in almost all investigated plant species, so it could establish in the greenhouses with a large number, where it could propagate. The polyphagous *F. intonsa* was found only on certain plant species in a large number of individuals. *A. intermedius* occurred in most plants. 75% of *A. intermedius* adults occurred in the vicinity of the greenhouses in 2005, taking the fact that, this species can be found in the greenhouses in that year also with significant number (16.5%). In the following years the population collapsed on all plants in the greenhouses located both in the outskirts of and within the localities . According to Franco *et al.* (1999), *A. intermedius* can reduce the number of phytophagous Thysanoptera species under field conditions, hovewer it has a less significant role inside of the greenhouse.

We found that alfalfa *(M. sativa)* plays a key role as a most important source for colonisation and maintaining of the dominant Thysanoptera species in the fields, in the surroundings of sweet pepper greenhouses.

4.3 Possibilities of transmitting Tomato spotted wilt virus (TSWV)

Out of the examined 43 plant species 26 species proved to be TSWV reservoir hosts in the vicinity of the greenhouses. We concluded that, in the vicinity of the sweet pepper greenhouses in Jászság, the risk of TSWV transmission is quite high, regarding the numerous TSWV reservoir host weed species present with large coverage in the surroundings. These plants can play a significant role in TSWV virus transmission by *T. tabaci* into sweet pepper during the vegetation period. The virus can overwinter on *Stellaria media*, on other annual plants in the winter and also on perennial weeds *(Capsella bursa- pastoris, Lamium amplexicaule, Convolvulus arvensis, Melilotus officinalis).* Some TSWV reservoir weeds present until late October, early November - such as *Amaranthus retroflexus, Ambrosia artemisiifolia, Conyza canadensis, Galinsoga parviflora*, in our surveys, could play an important role in supplying the TSWV virus to the overwintering *T. tabaci* females. The most important TSWV reservoir hosts in the vicinity of the greenhouses are *Stellaria media* and *Galinsoga pariflora* (Zawirska *et al.,* 1983; Mertelik and Mokra, 1996; Jenser *et al.,* 2009). We found that in the vicinity of the greenhouses in Jászság, there is a high risk of TSWV virus transmission by *T. tabaci*, as there are numerous adults and larvae also on the numerous TSWV reservoir weed hosts, which were present with large coverage in the vicinity of the greenhouses. *T. tabaci* males occurred on numerous weed species, so it can be concluded that also the *T. tabaci tabaci* populations can transmit the TSWV virus in Hungary. The ratio 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 TSVW than *T. tabaci* (Wijkamp *et al.,* 1995; Chatzivasiliou *et al.,* 2002; Jenser and Szénási, 2004), and taking into account the extremely high number of males in the environment of greenhouses, it is concluded that *F. occidentalis* has a major role in the risk of developing TSWV epidemics in sweet pepper greenhouses. The presence of *T. tabaci* and *F. occidentalis* together poses high risk for sweet pepper, because the overwintered females of *T. tabaci* can infest sweet pepper in spring, while the adults of *F. occidentalis* can infest the plant in autumn.

4.4 Investigation of overwintering of the TSWV vector Thysanoptera species

We found that the first *T. tabaci* larvae could appear on *Stellaria media* and *Capsella bursa-pastoris* from the end of April to the end of March, depending on temperature. These reservoir weeds can play a primary role in initiating the TSWV epidemics in the vicinity of greenhouses in Jászság.

During the overwintering studies in the winter periods of 2006-2007, the survival of *F. occidentalis* adults was found in the open fields on *Stellaria media*, in the vicinity of the greenhouses. Based on literature data, it has not occurred under continental climatic conditions. The presence of the other thrips species on weeds in the winter and spring periods depends on the favourable weather conditions, particularly on temperature.

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6. LIST OF RELATED PUBLICATIONS

6.1 Approved articles in Hungarian

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