SZENT ISTVÁN UNIVERSITY

INVESTIGATION OF INSECTICIDE-FREE CONTROL METHODS ON *FRANKLINIELLA OCCIDENTALIS* IN GREENHOUSE SWEET PEPPER

Summary of PhD Thesis

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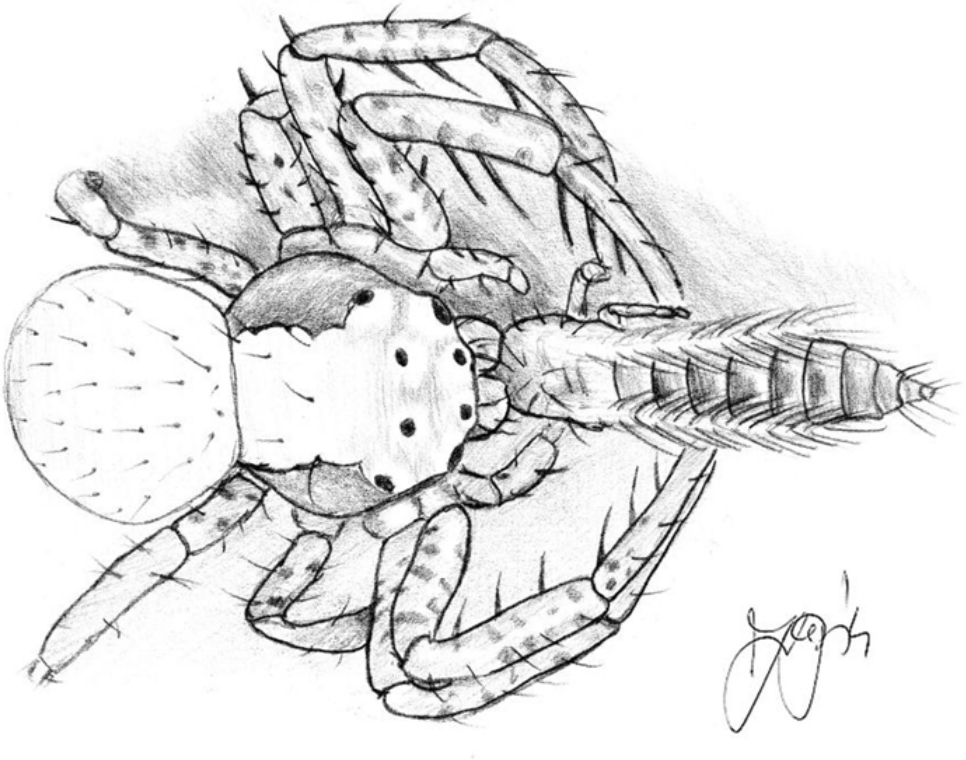
„Biological control is the most successful, most cost effective and environmentally safe safest way of pest management. Biological control is present in all ecosystems, both natural and manmade, and is always active." (Joop C. van Lenteren, 2008)



1 Introduction and objectives

Cecei type greenhouse sweet pepper (*Capsicum annuum* L.) as hungaricum became one of the most important crops of the Hungarian vegetable growing that can be bought on the fresh fruit market all year round. Growing of the greenhouse sweet pepper is carried out in greenhouses (2000-2800 ha) and also in glasshouses (50-60 ha) in our country (Szoboszlai, 2000; Tompos, 2006). This area is approximately half of the total surface utilized for sweet pepper growing, however almost 80% of the annual sweet pepper production of Hungary is harvested in greenhouses (Szoboszlai, 2000).

Presence of the western flower thrips (WFT) *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in Hungary was first detected in 1989 (Jenser and Tusnádi, 1989). Since then WFT has been a widespread pest (Vasziné et al., 2006) and causes damage in sweet pepper growing (Kassai et al., 2000). Phytosanitarial significance of this pest originated from three factors: **1)** *F. occidentalis* is a polyphagous pest that reduces the market-value of the crop attacked and **2)** thrips are the only vector for Tomato spotted wilt virus (TSWV) (Mound 2002, 2005) from among *F. occidentalis* is one of the most effective vector (Best, 1968; Peters et al., 1996; Wijkamp et al., 1995). The fact **3)** WFT is able to develop a solid resistance against the insecticides used for thrips control (Immaraju et al., 1992; Brødsgaard, 1994; Zhao et al., 1995), underlines its phytosanitarial importance and promotes a search for more sustainable pest management solutions, including biological control.

Following predator species are used for thrips control in Hungary: *Orius laevigatus* (Fieber) (Heteroptera: Anthocoridae), *Neoseiulus cucumeris* (*syn. Amblyseius cucumeris*) (Oudemans) and *Iphiseius degenerans* (*syn. Amblyseius degenerans)* (Berlese) (Acarina: Phytoseiidae) (Ocskó and Erdős, 2008). No doubt, producers and distributors of these species were right when they have chosen these non-indigenous species for control a pest like WFT that is able for overwintering in greenhouses under the Hungarian climatic conditions. However, not only the potentials inherent in antagonistic organisms, living in the temperate zone remains unused but also new non-indigenous species will be carried into Europe, furthermore the plant protectional agent itself derives out of Hungary and Europe.

An additional problem with the Hungarian pest control practice: farmers use such control methods that could further increase the costs of production, leaving the biological and agricultural basis of plant protection. This statement can be true also for biological control in certain cases. We have not found references in to the effects of the cultivar and foliage modification (i.e. pruning). In our view, the agricultural basis of plant growing, including plant protection does not get enough attention however, these methods ranked on the first two places in the hierarchy of our phytosanitary doctrines.

According to the problems presented above pest control abilities of a spider species that indigenous to Hungarian fauna and commonly occurs on cultivated lands like grasslands, meadows, cereal fields, vineyards and orchards (Laub and Luna, 1992; Clarck et. al., 1994; Bogya, 1995; Marc and Canard, 1997; Bogya, 1999; Lang et al., 1999; Samu and Szinetár, 2002) have been studied. The reason of choosing the common crab spider (*Xystichus kochi* Thorell [Araneae: Thomisidae]) as a biocontrol agent candidate were that this species tolerates the antropogeneous disturbance on cultivated lands and, regarding our former non-published results, accepts WFT as a prey. Furthermore role of the cultivar and foliage modification (pruning) as agricultural control methods in greenhouse sweet pepper were studied, using three commonly grown cultivars and three commonly used pruning methods. Our objectives were:

1) Investigation of the suitability of the second stage larvae of *X. kochi* for pest control and
2) investigation of their effectiveness, furthermore expression of their efficiency using different levels applied in a phytosanitarial decision making procedure.
3) In case of a positive control effect, investigation of the backgrounds of the damage reduction will be attempted.
4) Afterwards an estimation will be carried out in order to identify the minimum spider density have to be kept or augmentatively released in a greenhouse to reach the adequate pest suppression effect.
5) Whether pruning methods as an agrotechnical basis of pepper growing inherents further pest control potentials, will also be investigated and
6) Effects of the cultivar on the different sexes and life stages of WFT population and on feeding-damage caused by the WFT will also be investigated.
7) Results, deriving from these studies will be expressed using different levels applied in a phytosanitarial decision making procedure.
8) Based on our results practical advices will be given for the growers.

2 Materials and methods

2.1 Effectiveness-studies of *Xysticus kochi*

Adult spider specimens used for mass rearing were collected every year during April – June with an approximately ± 2 weeks deviation according to the season with sweep netting on cultivated alfalfa (*Medicago sativa* L) fields. Fields used for collecting spiders were year-by-year different but were the same in an entire year. After taxonomical identification other *Xysticus* specimens were placed back to the original field they were collected before. *Xysticus kochi* specimens were placed in a breeding cabinet, sub-adult females after moulting and also virgin ones were mated with males. Egg-sacs were removed from the females after hatching ***pre-larvae***[1] and then ***larvae***[2] were stored (50 larvae / test-tube) without feeding (only water source was served for the larvae) in a household refrigerator on +5°C for approximately 2 weeks. *F. occidentalis* specimens used for infestation were collected in infested greenhouses together with pepper flowers. After collecting the thrips they were kept – similarly to the spider larvae – in a household refrigerator on +5°C (one tube contains 10 pepper flowers and thrips living in flowers). Characteristics of the experiments carried out are summarised in **Table 1.**

2.2 Effect of cultivar and pruning on WFT damage

Formerly we have found a hierarchy in the appearance of feeding damage seen on the pepper's surface. When it occurs then always visible around the calyx, an extended damage around the calyx is also more-or-less commonly visible, but appears only occasionally on the lateral surface of the pepper fruit. Damage on the lateral surface mostly appears on adjoining surfaces when e.g. a leaf covers the fruit. Similar finding was reported by Molnár (2008). For controlling our assumption two different experiments have been carried out. In the first one the hypothesis was controlled, while in the second one (in a two years-long experiment) the possible effects of the pruning methods on the degree of the feeding damage was examined.

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1 New specimens hatch from eggs as partly developed embryos and moult once before leaving the egg-sac (Horner and Starks, 1972). This developmental stage called ***pre-larva*** (Kiss, 2003).

2 After the first moulting the ***larvae*** leave the egg-sac, using yolk as a nutrient before feeding independently. (Kiss, 2003).

Table 1. Overview of the *Xysticus kochi* biocontrol efficiency experiments

Experiment	Treatments	Collected data	Remarks
***Xysticus kochi* biocontrol efficiency test 2002 (individual plant-cage technique)**	**8 replication** (8 individually caged plants) 1) Control (no thrips, no spider) 2) Infested (only with thrips) 3) Larvae (with both thrips and spiders) 4) Juvenile (with thrips and juvenile spiders)	**with 8-times pepper harvest**, registered data: 1) pieces of pepper fruits (per plant cage) 2) weight (per piece of fruit) 3) surface damage according to the following description: **a)** damage-free; **b)** damage slightly borders the calyx; **c)** extended damage is visible around the calyx; **d)** damage is visible even on the lateral surface of the fruit; **e)** extended damage is visible on the lateral surface of the fruit	
***Xysticus kochi* biocontrol efficiency test 2003 (individual plant-cage technique)**	**10 replication** (10 individually caged plants) 1) Control (no thrips, no spider) 2) Infested (only with thrips) 3) Xysticus (with both thrips and spiders) 4) Mulch (with thrips and ground coverage with oak leaf-litter in 10cm thickness) 5) Xysticus + Mulch (combined treatment of treatments 3 and 4)	**with 7-times pepper harvest**, registered data: 1) damaged surface [***DSU***] (percentage of damaged fruit surface) per fruit and then per plant-cage average 2) commercial categories of the yield (weight and quantity per fruit): **a)** according to the Hungarian Food Codex (extra, first class, second class, 'stew'); **b)** canning industrial (first class, sliced); **c)** non-marketable 3) crop value (calculated with the wholesale prices and industrial prices of sweet pepper)	Experimental greenhouse was naturally infested with *Frankliniella intonsa* Trybom (Thysanoptera: Thripidae) indigenous to Hungary
***Xysticus kochi* biocontrol efficiency test 2004 (block-cage technique)**	**3 replications** (4x25 plants per block-cage planted in twin-rows) 1) Infested (only with thrips) 2) Xysticus (with both thrips and spiders) 3) Xysticus + Mulch (combination of treatments 1 and 2)	**with 9-times floral-faunistic sampling** (collecting 10 pepper flowers / replication = block cage), sampled and calculated data 1) *F. occidentalis* female 2) *F. occidentalis* male 3) *F. occidentalis* larvae 4) larvae / female	
Determination of minimu *Xysticus* density (individual plant-cage technique)	**5 replications** (5 individually caged pepper plants) 1) Infested (only with thrips) 2) 5 (thrips and 5 *Xysticus* larvae) 3) 30 (thrips and 30 *Xysticus* larvae) 4) 55 (thrips and 55 *Xysticus* larvae) 5) 80 (thrips and 80 *Xysticus* larvae) 6) 105 (thrips and 105 *Xysticus* larvae)	**with 4-times pepper harvest,** registered data: **1)** damaged surface [***DSU***] (percentage of damaged fruit surface) per fruit and then per plant-cage average	

The experiments were carried out in both years (2005 and 2006) in a greenhouse that was naturally infested by WFT. Experimental design was a complete-block design.

Three commonly grown sweet pepper cultivars were tested, like: **1)** Keceli Fehér F1 (susceptible to the WFT feeding damage); **2)** Century F1 (less susceptible to the WFT feeding damage); **3)** Cecil F1 (unknown susceptibility to the WFT feeding damage). These cultivars were treated with three commonly used pruning methods according to Terbe and Gyúrós (1999a, b), like: **1)** one-branch pruning (6.25 shoots / m^2); **2)** two-branch pruning (12.5 shoots / m^2); **3)** no pruning (more than 37.5 shoots / m^2). One treatment (a cultivar in combination with a pruning method) consisted of 20 pepper plants and was done in 8 replications. In 2006 Keceli Fehér F1 were replaced by a cultivar candidate – called 'Candidate' – that has similar characteristics like Keceli Fehér F1. The rest of the parameters were similar in both years. In the 2005 sampling period a total of 5 fruit harvests and 8 times flower samplings (according to Shipp and Zariffa, 1991) were carried out. During 2006 number of the samplings was reduced to 4 times fruit harvests and 4 times blossom samplings. During harvests the total yield of the treatments (20 plants per replicate) were collected, classified and used for statistical analysis, while during blossom samplings 5 fully opened pepper blossoms were collected per treatment. Following data have been registered:

1) Category of the fruit (per treatment in g): **a)** extra, **b)** first-, **c)** second- and **d)** stew classes have been created but **e)** non-marketable yield were also harvested (into the non-marketable category only peppers with WFT damage were classified).
2) Crop-value calculated with the actual wholesale prices regarding the market categories.
3) Sex and developmental stage of *F. occidentalis*: **a)** female, **b)** male, **c)** larvae (L_1 and L_2 mixed group).
4) Other blossom dwelling taxonomical groups.

2.3 Effects of the touching surfaces on the WFT damage

In this sub-experiment, a single leaf was attached with a soft rubber band to pepper fruits for two weeks, between the fifth and third week prior to harvest with reference to Shipp et al. (1998a,b). Damaged surface was measured with percentage estimation; with treated or untreated fruit surfaces being one hundred percent. Data were pooled for further analysis. This experiment was carried out with ‘Century F1’ and ‘Keceli Fehér F1’ cultivar plants in twenty replications and the whole experiment was repeated three times.

2.4 Data analysis

With reference to Pólya (1920), it was not necessary to control the normality of the data for carrying out a parametric probe. Nevertheless normality of the data was checked with Kolmogorov-Smirnov test and a Levene-test was used for verifying the homogeneity of the variances. Differences in the variance of the data were tested with ANOVA analysis and multiple comparisons were carried out by Least Significant Difference test (Fischer LSD-test). A significance level of 0.05 was used to reject the null hypothesis. Statistical analysis was carried out with STATISTICA 6.0 (StatSoft®).

3 Results

3.1 Effectiveness-studies of *Xysticus kochi*

3.1.1 Effects of the treatments on the quality composition of harvest

In 2002 treatments resulted in a significant effect on the first- (ANOVA, F=2.90, p<0.05), on the second- (ANOVA, F=4.66, p<0.01) and also on the third- (ANOVA, F=2.75, p<0.05) class product. We have not found treatment effect in the fourth - fifth merged category (ANOVA, F=1.09, p>0.05). Treatment with juvenile spiders resulted in a significant increase of the amount of the first category fruits but there was no further difference between the other treatments in this category. In the second category significantly less yield were harvested in the Juvenile treatment compare to the Infested or to the Larvae treatments. There was no significant difference among the treatments in the third category. Control treatment yielded only first category fruits.

Treatments had a significant effect on various product categories in 2003: **1)** fresh-market (ANOVA, F=27.30, p<0.01); **2)** sliced (ANOVA F=8.45, p<0.01); **3)** non-marketable (ANOVA F=6.18, p<0.01). There was no significant effect on the quantity of the **4)** canning industrial yield (ANOVA F=1.60, p>0.05). Significantly higher quantity of fresh-market fruit yielded in the Xysticus and Xysticus+Mulch treatments, compared to the other treatments. Control, Mulch, Xysticus and Xysticus+Mulch treatments yielded significantly less non-marketable pepper than the Infested treatment. There were no significant differences among treatments in the canning industrial category, furthermore Xysticus and Xysticus+Mulch treatments resulted in a significantly lower sliced pepper yield.

3.1.2 Effects of treatments on *DSU*

Damaged surface units were significantly different between the various treatments (ANOVA, F=9.27, p<0.01). We discovered that the introduced *F. occidentalis* resulted in a damage level clearly distinguishable from the initial infestation of *F. intonsa*. Although no significant differences were observed between the Infested and Mulch treatments, and between the Xysticus and Xysticus+Mulch treatments, the estimated *DSU* levels were consistently lower for the treatments containing mulch. *DSU* was significantly lower in the Xysticus than in the Infested treatment and the same relationship was noted between the Xysticus+Mulch and Infested treatments.

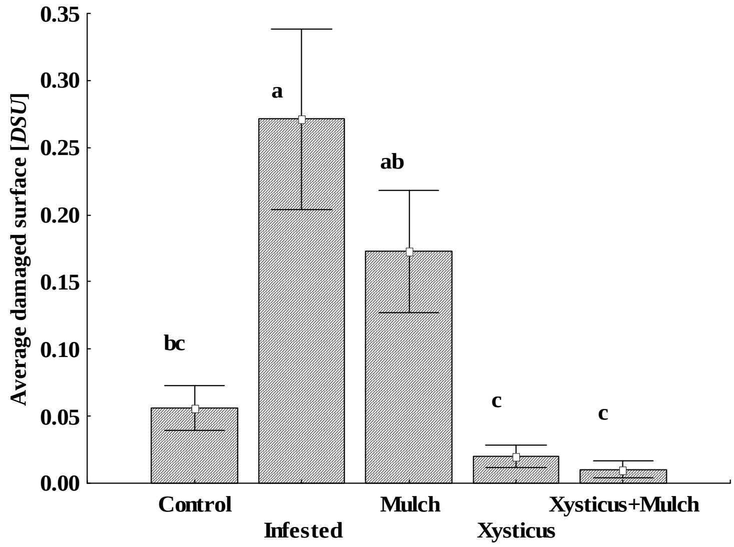

Figure 1. Effects of introducing *Xysticus kochi* spiderlings and supplementing of mulch to caged sweet pepper plants infested with thrips on mean (± SE) damaged surface unit (*DSU*).. Biological control experiment on *Frankliniella occidenatlis* (Gödöllő, 2003)

Aesthetical damage was caused by *Frankliniella occidentalis* and *F. intonsa*, except in the Control treatment where it was exclusively from *F. intonsa*. *DSU*=Σ(D_i x P_i) where D_i is the percentage of the damaged surface and P_i ist the frequency of D_i. Bars topped by the same letter are not significantly different (Fisher LSD test, p>0.05). N=70.

3.1.3 Effects of treatments on the yield and on the commercial value of the crop

Treatments had in both years a significant effect on the yield (number of pepper-fruits per plant cage): ANOVA $F=3.20$, $p<0.05$ (2002) and ANOVA $F=3.11$, $p<0.05$ (2003). Number of fruits harvested in Infested treatment were not statistically different from the number of fruits harvested in Juvenile or in Larvae treatments. Significantly less fruits were harvested in Control treatment compared to the Larvae or to the Juvenile treatments. Average yield harvested in Control and in Infested treatments were also not significantly different. During the next year (2003) significantly higher fresh-market pepper yields resulted from the Xysticus and Xysticus+Mulch treatments than from the other three treatments.

Crop commercial values were significantly different between the various treatments (ANOVA, $F=14.57$, $p<0.001$). Commercial fruit values were significantly higher in the Xysticus and Xysticus+Mulch treatments, compared to the Infested treatment. The commercial value for the Mulch treatment was about double that of the Infested treatment, but this difference was not statistically significant (Fischer LSD; $p>0.50$).

3.1.4 Effects of treatments on the abundance of *Frankliniella occidentalis*

Treatments resulted in a significant effect on changes of the female and larval thrips populations during the first 35 days of the experiment. Contrarily no significant effect was found in case of the offspring ratio. Respectively: ANOVA $F=11.24$; $p<0.001$ (female); ANOVA $F=5.31$; $p<0.05$ (larvae) and ANOVA $F=0.06$; $p>0.9$ (offspring ratio). Results were proved by the multiple comparisons of the means of the samples. Contrarily, no difference was found among the abundance data registered in the different treatments during the last 28 days of the experiment: ANOVA $F=1.47$; $p>0.1$ (female); ANOVA $F=1.18$; $p>0.1$ (larvae) and ANOVA $F=0.57$; $p>0.5$ (offspring ratio).

3.1.5 Determination of the larval *Xysticus kochi* dose with caged-plant technique

Examining the minimum dose of the larval *X. kochi* we have found that increasing the “spider dose” decreases the damaged surface alongside a square function. We have noted that even introduction of 5 spider specimens resulted in a significant decrease of the damaged surface. At the same time further increase of the number of the spider larvae introduced into the plant cages brought no further significant decrease of the *DSU*.

3.2 Effects of the cultivar and pruning on the damage caused by *Frankliniella occidentalis*

3.2.1 Effects of the cultivar and pruning on the abundance of *Frankliniella occidentalis*

According to ANOVA, pruning technology had a significant effect on the abundance of blossom dwelling WFT females ($F= 5.47$, $p<0.01$). Detailed analysis of the abundance of females shows that this difference appeared only in 2006, when significantly lower amount of females aggregated in the blossoms of non-pruned plants than both in the flowers of 1-branch and 2-branch pruned plants. Pruning technology does not seem to have a significant effect either on the abundance of males or larval thrips.

Analysis of variances have indicated a mutual effect of the time (experimental year) and cultivar in case of the larval thrips (ANOVA, $F=8.75$; $p<0.05$). In 2005 significantly more larval WFT developed in the flowers of Cecil F1 than in the flowers of Century F1 or Keceli Fehér F1 cultivars, however there was no significant difference between the average numbers of WFT larvae counted in the blossoms of Cecil F1 and Century F1 cultivars during the next year.

3.2.2 Effects of the touching surfaces

ANOVA has proven that fastening a leaf to pepper fruits had a significant effect ($F= 71.15$, $p=0.00$) on the size of the damaged surface. There is no significant difference between cultivars, differences appeared only between the treated and non-treated surfaces (**Figure 2**).

3.2.3 Effects of cultivar and pruning on the quality composition of harvest

Foliage modification has proven a significant effect on the quantity of the fruit in different market categories in both years. **1)** 2005: ANOVA $F=20.26$; $p=0.00$ (extra class), ANOVA $F=5.15$, $p<0.01$ (damaged class); **2**) 2006: ANOVA $F=33.72$; $p=0.00$ (extra class), ANOVA $F=10.85$, $p<0.01$ (damaged class). During 2005, a higher amount of extra pepper yield was harvested from plants pruned to 1-branch than plants pruned to 2-branch or non-pruned. No-pruning technology increased the damaged pepper yield in comparison to the 1- or 2-branch pruning technologies. Mean values of first-class, second-class and stew pepper were not affected by the modification of the foliage. During 2006 the greatest amount of extra pepper yield was harvested from plants pruned to 1-branch. In this year, pruning technology also influenced the amount first-class product harvested resulted in a higher amount of first-class pepper yield from non pruned-plants. In case of stew and damaged quality classes, we found a significant difference only between the mean values of pepper harvested from 1-branch-pruned plants and non-pruned plants. Second-class pepper yield was not affected by pruning.

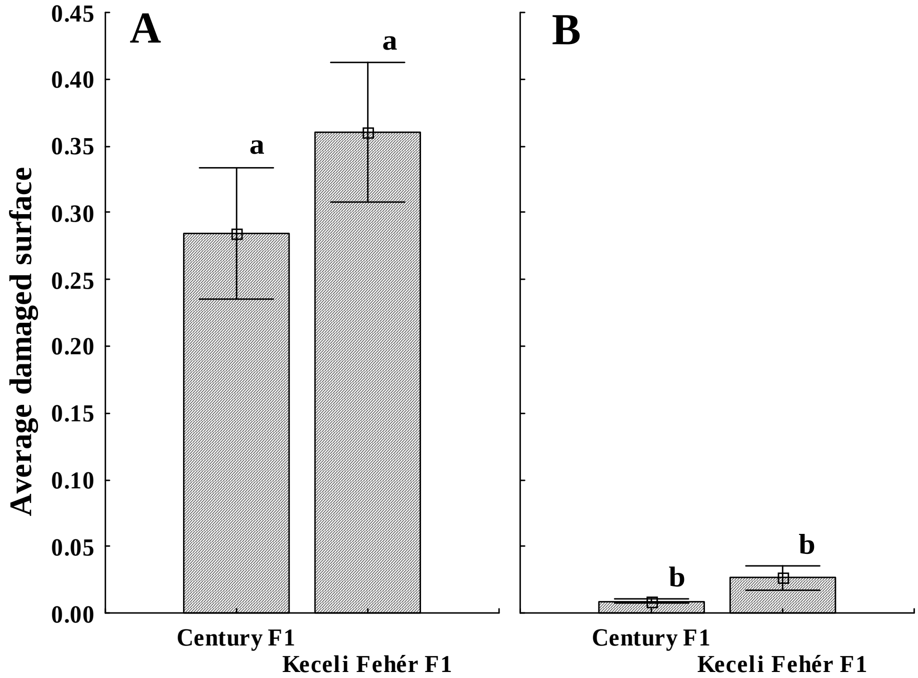

Figure 2. Effects of touching surfaces on the degree of aesthetical damage (*DSU*) caused by *Frankliniella occidentalis* on greenhouse sweet pepper. Agrotechnical control experiment on *F. occidentalis* (Jászfényszaru, 2005)

(A) treated (B) non-treated fruit parts. Aesthetical damage was caused by *F. occidentalis*. Bars topped by the same letter are not sugnificantly different (Fisher LSD test, p>0.05). *N*=120

Similarly to the pruning, with one exception cultivar also had a significant effect on the quality composition of the yield. **1**) 2005: F=57.8, p=0.00 (extra class); ANOVA F=41.35, p=0.00 (damaged class); **2**) 2006: ANOVA F=68.57, p=0.00 (extra class); ANOVA F=1.39, p=0.25 (damaged class). In 2005, the smallest amount of extra-class pepper yield was harvested from Keceli Fehér F1. This cultivar however produced significantly higher amount of fruit in the second, stew and damaged quality classes. In case of first-class category, the average pepper yields of Century F1 and Keceli Fehér F1 cultivars were significantly different. Cecil F1 and Century F1 yielded higher amount of extra-class peppers than Candidate plants during 2006. In case of first-class pepper, the results were reversed. All three cultivars produced different amounts of second-class pepper, but the stew-class pepper yields differed significantly only between cultivars Century F1 and Candidate. In 2006 no difference was found among the cultivars in the damaged-class.

3.2.4 Effects of cultivar and pruning on the commercial crop value

During 2005, different treatments (i.e. combinations of different cultivars and pruning technologies) also affected the averages of this indicator (ANOVA, F= 8.55, p=0.00). The highest commercial crop value was produced by the 1-branch pruned Century F1 plants. The mean commercial crop values of 2-branch or non-pruned Century F1 plants and technological variations of Cecil F1 plants did not differ significantly from the commercial value measured for Century F1 x 1-branch. Keceli Fehér F1 plants produced the lowest quantities of commercial crop values, regardless of foliage modification (**Table 2**).

Table 2. Ranking and influenece of cultivar and pruning technology on damaged pepper yield (weight) and on commercial crop value produced.

2005			2006		
Kezelés	**Károsított**	**Té**	**Kezelés**	**Károsított**	**Té**
Century F1 x 1-branch	2 **a**	1 **a**	Cecil F1 x 1-branch	3 **a,b**	1 **a**
Cecil F1 x 1-branch	1 **a**	2 **a**	Cecil F1 x no pruning	9 **d**	2 **a,b**
Century F1 x 2-branch	4 **a**	3 **a**	Candidate x 1-branch	5 **b,c**	3 **a,b**
Cecil F1 x 2-branch	3 **a**	4 **a,b**	Century F1 x 1-branch	1 **a**	4 **a,b**
Cecil F1 x no pruning	6 **b,c**	5 **a,b**	Candidate x no pruning	4 **b,c**	5 **a,b**
Century F1 x no pruning	5 **b**	6 **a,b**	Cecil F1 x 2-branch	1 **a**	6 **a,b**
Keceli Fehér F1 x 1-branch	7 **b,c**	7 **b,c**	Century F1 x no pruning	7 **c,d**	7 **a,b**
Keceli Fehér F1 x 2-branch	8 **c**	8 **c**	Candidate x 2-branch	6 **c,d**	8 **b**
Keceli Fehér F1 x no pruning	9 **c**	9 **c**	Century F1 x 2-branch	8 **c,d**	9 **b**

Only pepper yield damaged by *Frankliniella occidentalis* was classified as ’damaged’. Treatments (cultivar x technology) are arranged in a decreasing order in each year according to the commercial crop value (i.e. treatments in which the highest amount of commercial crop value produced is the first). Rank values followed by the same letter in a column are not significantly different (Fisher LSD test; p>0.05). *N*=360 (2005), *N*=288(2006).

During 2006 cultivars combined with different pruning technologies also was found to have an effect on commercial crop value (ANOVA, F=3.26, p<0.05). The best commercial crop values were yielded among the 1-branch pruned cultivars with Cecil F1 ranking first. In

2006 we found only 3 major differences between the mean values of commercial crop value: Candidate x 2-branch and Century F1 x 2-branch treatments did not differ from each other significantly but both did from the Cecil F1 x 1-branch combination. Our statistical analysis did not find difference among other treatments (cultivar x pruning technology) (**Table 2**).

4 New scientific results

Effectiveness of larval *Xysticus kochi* that considered an epigeic spider species (Tóth, 1997; Szymkowiak és mtsai; 1998; Bogya és Markó, 1999) have been firstly tested against *Frankliniella occidentalis* in greenhouse sweet pepper. Our experiments were carried out in a greenhouse, however international researchers study the plant protectional role of the spiders on arable lands, vineyards and orchards (Laub és Luna, 1992; Clarck et. al., 1994; Bogya, 1995; Marc és Canard, 1997; Bogya, 1999; Lang et al., 1999; Samu és Szinetár, 2002). Most of the papers dealing with pest control function of spider species, focus on spider assemblages (Riechert és Lockley, 1984; Young és Edwards, 1990; Provencher és Riechert, 1994; Marc és Canard, 1997; Marc et al., 1999; Riechert, 1999; Riechert et al. 1999; Maloney et al., 2003) instead of single species. At the same time, in our work a single spider species was used against *F. occidentalis*. The third factor that makes our work unique was using a spider considered epigeic species against a pest of which targeted developmental stages live in blossoms and / or on the leaf canopy.

1) We have found that larval *X. kochi* are able to suppress the gradation of *F. occidentalis* during five weeks after their introduction into the plant-cages.

2) Studying of the effectiveness of the spiders a 10-weeks long effect was found on the commercial crop-value level.

3) Decreasing abundance of the blossom dwelling mature and larval stages of the herbivorous species was found as an effect of the presence of the spider larvae.

4) We have found that presence of the spider larvae may positively affect even the pollination. Presence of the spider larvae not only reduced the abundance of the thrips and the surface damage but also increased the fruit production of the plants.

5) Consequently, treatments with spiders resulted in an improved quality composition of the yield, thus a higher commercial crop-value was found in treatments where larval *Xysticus* specimens were present.
6) Neither damage caused by the thrips nor the abundance of the thrips have affected by the leaf litter used.
7) In 2003 also *F. intonsa* was present in the experimental greenhouse and caused damage in the control treatment. We suggest scientist should pay more attention to this species that native to the Hungarian fauna but its damage in pepper culture was not reported before our work.

Effects of the pruning technology on the damage caused by thrips have also been firstly examined in our work. We are not the first when it is about the cultivar but we haven't found an example for such a practice oriented investigation, we have done.

1) Experimentally proved that cultivars show different suscaptibility to the damage caused by thrips, thus a cultivar effect was found in the quality composition of the yield. According to our results, there is no difference in sensitivity among the cultivars tested in our experiments.
2) We have proved the pruning technology has an effect on the damage caused by thrips, thus on the quality composition of the yield.
3) The increased number of touching surfaces (leaf-fruit, contact) in a dense leaf canopy offering an attractive shelter for the thrips is most probably a key factor of the increasing damage found in non-pruned technology.
4) Working with given cultivars in combination with given pruning technologies the possible economic loss were determined with that farmers should calculate in regions infested by *F. occidentalis* or where appearance of this pest is most probable.

5 Conclusions

5.1 Suitability of larval *Xysticus kochi* for plant protectional purposes against *Frankliniella occidentalis* in greenhouse sweet pepper

Although our results show that common crab spider can be used for stabilising population of *Frankliniella occidentalis* on a low level, further investigations are necessary aiming clearing up the ecological interactions between the two species. To be able to use *Xysticus kochi* for mass release, technique of mass-rearing, dosing and storage should be solved and these questions were not subjects of our work. If we would like to gain spontaneous spider immigration into the greenhouses, further studies are necessary aiming how to manage the inner and outer environment of the greenhouses. As it can be seen plant protectional use of this species is still not possible.

As spiders are generalist predators, they are able and ready to choose between the available prey species according to their abundance (Riechert és Lockley, 1984) and nutrient composition (Mayntz és mtsai, 2005). It is necessary to study how far and until which developmental stage accepts the predator WFT as a prey in a prey-rich environment. Switching between prey species and intragild predation that is not infrequent among spiders (Rosenheim et al., 1995) raises the question of coexistence with other antagonistic species used for plant protection purposes.

Larvae of the *X. kochi* that considered a sit-and-wait epigeic preadtor decreased the abundance and damage of a blossom dwelling pest. A possible explanation of this phenomenon: larvae of this spider species – at least until a certain developmental stage – are foliage dwelling. It is also possible that larvae of *X. kochi* are not sit-and-wait predators than actively search for prey – as it was reported by McDaniel and Sterling (1982) – furthermore that *Xysticus* larvae are able to pray on the nymphs of *F. occidentalis*.

Because of the promising results reported in this paper, it would be useful to carry out higher scale experiments before trying to solve the technical problems concerning plant protectional use mentioned above. It would be even more important to assess a basic question: whether spider larvae were emigrate from the greenhouse if it is possible? If yes, what factors influences the emigration. Scientific works dealing with the role of spiders in plant protection were mostly carried out on arable lands, meadows and orchards. Thus scientists working on biological control and arachnologists should examine the effect of other spider species on herbivorous pests in greenhouses.

Presence of the organisms living in the leaf litter introduced in the certain treatments remains unknown. These might influence the survival and success of both predator and prey species. Naturally, introducing of other predators or prey species that could be an alternative food source for spiders cannot be excluded. Even if one species proved to be successful as a biocontrol agent and its success can be increased with modifying the environment, further investigations of the modified environment are necessary.

5.2 Plant protectional aspects of foliage modification and a need for interdisciplinary studies

On regions infested by *F. occidentalis* safe and productive growing methods should be developed with long term experiments. Comparing our results with recommendations of horticultural experiments (Jovicich et al., 2003) became clear that even a productive growing technology could carry phytosanitarial risks. Consequently such interdisciplinary researches are necessary that provide productive and safe growing methods. According to our results even susceptibility of cultivars to the feeding damage of thrips should be taken into consideration in plant breeding programs.

Literary data (Shipp és Zariffa, 1991; Venzon et al., 2000; Tommasini, 2003) and also our results prove that a dense foliage canopy carries phytosanitarial risk in sweet pepper growing.

Our findings supports that not only the risk assessment methods based on the economic injury level but also the damaged yield depends on many other factors. To be able to serve more accurate data for decision making in plant protection, further and interdisciplinary researches are necessary. As in our studies number of the plants per square meter was a constant value and only the number of the shoots per plant was changed by pruning, further search for the optimal number of shoot per square meter is necessary in regions infested with *F. occidentalis*.

Despite of our above statements after our two years study the following advices should be taken into consideration in regions infested with the pest by all means in greenhouses where the pest were already present:

1) If the capacities and resources of the farmers make possible, growing technologies omit pruning should be avoided and should be replaced with one- or two-branch pruning methods.

2) If the breeder or distributor has no information regarding the susceptibility of a cultivar to the feeding damage of WFT, farmers need to change their experiences before changing the cultivar.

3) From the cultivar and pruning technology combinations discussed in this study, the followings carry the less risk: Century F1 or Cecil F1 in combination with one- or two-branch pruning technology.

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