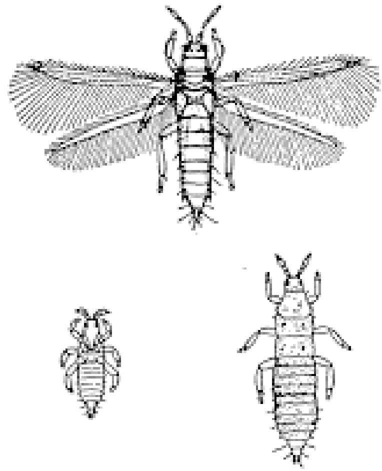
**PhD THESIS**

# Environmentally-friendly way of controlling onion crops against thrips populations



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**The applicant met the requirement of the PhD regulations of the Corvinus University of Budapest and the thesis is accepted for the defence process.**

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# 1. INTRODUCTION, GOALS

Introduction and spread of integrated pest management is only possible by knowledge about the relationship of cultivated plant and pest, population dynamics of pests, existence and role of antagonist organisms and tolerance of varieties against pests.

Horticultural production methods are changing very fast because of the competition for markets. New varieties and methods are introduced and traditional technologies are transforming. Changing any element of a well based production method can have an effect on the complicated ecological system of production. Changes have an impact on animal species living in the host plant community.

During my PhD studies I considered to my primary goal the assessment of the resistance of commercial varieties of onion, leek and bunching onion to onion thrips, to reveal the cause of different sensitivity of different varieties, and to determine importance of production method elements (use of varieties, timed production). Since at the time of my experiments there was no available data from Hungary on the thrips species other than *Thrips tabaci* causing damage on onion, I regarded the clearing up of the role that other thrips species could play highly important. By this time there have been only a few experiments published regarding the types or the possible sources of varietal resistance of onion to onion thrips. There were many presumptions about occurrence and rate of males in onion thrips populations, but no definite answer has been found yet. My goal was also to start experiments regarding the rate of males in thrips populations.

# 2. MATERIALS AND METHODS

*Role of thrips density in the forming of varietal resistance*

To determine whether there is a significant difference between onion varieties regarding density of thrips causing damage on them, I made preliminary experiments in greenhouses of Horticultural University. During winter of 2002, I studied six onion varieties grown from onion sets (Makói, Makói CR, Makói Fehér, Nemesített Makói, Stuttgarti, Braunschweigi), 100 plants per species. I ensured starting population of onion thrips by placing infected onion plants between healthy ones, because natural infestation was not sure. All thrips individuals had been washed off by alcohol after one and a half month, filtered in laboratory after the method of Coudriet et al. (1979), numbered and mounted by developmental stages.

*Outdoor assessment of the resistance of onion species by thrips damage*

Between 2002 and 2004, the following four-degree damage rating scale was elaborated based on the extent of the symptoms appearing on the leaves:

**0 –** no damage

**1 –** few symptoms, less than 10% of the leaf is covered

**2** – symptoms covering not more than 50 % of the leaf, leaves are still growing

**3 –** symptoms covering more than 50 % of the leaf, growth of leaves had stopped

Before the statistical analysis the ordinal values of the variety evaluation were transformed into proportional values. Each discrete value of the damage rating scale was replaced by the mathematical average of its limiting values (0: → 0; 1: 0 – 0,1 → 0,05; 2: 0,1-0,5→ 0,3; 3: 0,5-1,0→ 0,75). The transformed value was called damage index, and meant the percentage of damaged leaf area. Statistical analysis was performed on two variables, the mean number of onion thrips and the damage index. First the equality of the variances was tested by Welch's Levene test, then the equality of empirical averages by ANOVA if variances were equal. Welch, James and Brown-Forsythe tests were calculated for the comparison of empirical averages if variances were unequal. In case of both variables pair wise comparisons of the varieties were performed by Tukey-Kramer test if variances were equal and by Games-Howell test if variances were unequal. The software „Ministat" and „SPSS" were used for the statistical analysis.

Field screening test was done in 2002, in the fields of Róna Agricultural Cooperation in Szabadszállás. 2 onion and 2 bunching onion varieties were tested by the four-degree damage rating scale, 100 plants per species.

Between 2002 and 2003, resistance of onion varieties was assessed several times at the station of the National Institute for Agricultural Quality Control in Tordas, to determine damage caused by spontaneous infestation of onion thrips. During two years the assessment of 58 varieties was carried out. For each variety 10 onion plants were selected and evaluated by the four-degree damage rating scale.

In 2004 resistance of onion species was assessed at the Experimental Farm of the Faculty of Horticultural Sciences, Corvinus University of Budapest in Soroksár. Resistance of 9 onion, 3 bunching onion, and 7 leek varieties were assessed. Evaluations were done 3-5 times a year. For each variety, 10 plants were selected, all thrips individuals had been collected from them, and plants were evaluated by the four-degree damage rating scale.

Thrips collected were kept in vials containing 70% alcohol. Different developmental stages of onion thrips and predatory thrips were counted in laboratory.

*Effect of planting time of onion varieties on extent of thrips damage*

Effect of planting time on extent of thrips damage was assessed for four varieties in 2003 and for three varieties in 2004. Two varieties grown from onion sets (Makói CR, Stuttgarti), and two varieties grown from seeds (Makói Bronz, Pannónia) were tested in 2003, one variety grown from onion sets (Makói CR), and two varieties grown from seeds (Makói Bronz, Pannónia) were tested in 2004. Seeds were sown and onion sets were planted in three different planting times, with one month difference. Evaluations were done in each month by choosing 50 plants per varieties and using the four-degree rate damage scale.

*Monitoring thrips assemblages in onion species*

Along with field screening tests of onion species, I collected thrips at three locations: the station of the National Institute for Agricultural Quality Control in Tordas, Róna Agricultural Cooperation in Szabadszállás, and the Experimental Farm of the Faculty of Horticultural Sciences, Corvinus University of Budapest, in Soroksár. During the period of three years, I did sampling 32 times at 3 different locations.

*Observation of population dynamics*

During 2004, eight yellow sticky traps were placed in the experimental lots in Soroksár, above the onion plants. Traps were changed weekly between 7th of May and 25th of November. Collected traps were analysed via microscope, thrips individuals were counted and several thrips individuals were mounted on slides for identification.

*Natural enemies*

During field screening test, I paid attention to natural enemies and marked if adult or larvae of predatory thrips or other natural enemies (ex. lacewing, predatory bug) were present in samples. Several individuals were mounted on slides for identification. During mounting I was looking for entomopathogenous fungi in thrips individuals.

*Role of morphological characteristics of host plant in thrips resistance*

Between 2003 and 2004, two leek varieties with different leaf colour were compared by the number of thrips found on them. Between 2002 and 2004the role of angle of divergence of leaves were examined for onion and bunching onion varieties, in Szabadszállás and Soroksár.

*Occurrence of males*

During field screening test, I paid extreme attention to the occurrence and rate of male thrips, because I haven't found definite answer for this question in the literature. All male thrips found in samples were collected and mounted for identification.

## 3. RESULTS

I evaluated 100 plant per variety during the greenhouse experiment (all together 600 plants) and I collected 71 593 thrips, from which 8509 were adults, 25 777 were second stage larvae and 37 307 were first stage larvae. There was a significant difference between varieties by the average number of thrips found on them. The lowest number of thrips was found on the variety Makói, and similarly low number was found on variety Stuttgarti.

During field screening tests in Szabadszállás, bunching onion varieties were found significantly different from onion varieties, but bunching onion varieties did not differ from each other. Onion varieties were significantly different from bunching onion varieties, and also from each other.

There were 22 onion varieties in Tordas, which had been evaluated in years 2002 and 2003. Extent of thrips damage was higher in 2003 then in 2002, except varieties Dacapo and Makói Fehér. There was a significant difference between years for a few varieties: a Dacapo, Makói Fehér, Navarra, Robin, Daytona, and Cometa. Year effect can be demonstrated statistically; based on analysis of covariance, extent of thrips damage was significantly higher in 2003 then in 2002.

I evaluated three bunching onion varieties in Soroksár, in 2004. There was a difference between varieties only in the first evaluation out of three. Tétényi örökzöld was significantly different from the other varieties.

I evaluated nine onion varieties in Soroksár, in 2004. Average number of thrips was continuously decreasing during the vegetation period. There was significant difference between varieties, but it changed by date of evaluation, which variety differed from which one.

I evaluated seven leek varieties in Soroksár, in 2004. Average number of thrips was fluctuating during the vegetation period. There was no big difference between varieties, and values showed very big variances.

During the research period of three years, a total number of 3216 thrips adults belonging to 6 species, and 558 second-stage larvae belonging to two species were collected from onion species. Every year *Thrips tabaci* was the predominant species among both the adults and larvae. On the average of 3 years, it represented 92,9 % of adults and 82,2 % of larvae. Out of the species, only adults of *Frankliniella tenuicornis* and *Aeolothrips intermedius* occurred by higher rate than 1 % on average, although there was a big fluctuation between years.

Number of thrips captured by yellow sticky traps was evaluated 16 times. Average number of thrips captured by traps was compared to temperature and precipitation data of the given period on a graph. Number of thrips increased with temperature during the vegetation period, and decreased when temperature decreased.

In the body of 15 thrips adults, out of 108 thrips collected in Szabadszállás, in November of 2003, resting spores of a fungus had been found. Infested individuals were mostly adults, except a few nymphs. After examining carefully these spores and comparing them with literature, I found these resting spores belonging to the species *Neozygites parvispora*, an entomopathogenic fungus.

Male thrips individuals had been found in each year, in each location, and on each type of onion. I have correct data only from 2004, when I collected and counted all thrips from plants. 8 males were found in 2002, 11 males in 2003, and 284 males in 2004.

**New scientific results**

1. I have found and identified *Neozygites parvispora,* an entomopathogenic fungus, new for Hungary, attacking thrips individuals.
2. I have identified that males are present in thrips populations on onion plants in Hungary, so these populations can reproduce by arrhenotoky. During my experiments I have identified frequency of males in onion, bunching onion, and leek crops.
3. I have identified the resistance of 63 onion varieties, 7 leek varieties and 3 bunching onion varieties against the onion thrips. Castillo was the most resistant onion variety, Lincoln and Sheriff were the most resistant leek varieties, and all the bunching onion varieties were resistant.

4. I have observed high number of *Aeolotrhips intermedius,* a predatory thrips, and I have identified frequency of predatory thrips on different onion species.
5. I have identified thrips species accepting onion species as host plant and I have determined their importance in causing damage. Population of *Thrips tabaci* occurred in highest number on onion species.
6. I have identified that leaf angle of divergence and leaf colour can have a role in resistance against the onion thrips.
7. I have identified importance of planting time in the development of thrips damage on onion varieties.
8. I have identified that there is a significant difference between onion species regarding damage caused by onion thrips. The most serious damage has been observed on onion, less on leek and the least on bunching onion.

## 4. DISCUSSIONS AND CONCLUSIONS

The preliminary greenhouse experiment showed that there is a significant difference between onion varieties, regarding number of thrips found on them, although this difference is not remarkable; practically there is no difference whether 90 or 140 thrips are feeding on the host plants. In Kendall's (1987) greenhouse experiment, already 10 thrips per onion plant caused 7% yield decrease.

However, the number of thrips alone does not always truly reflect the resistance of a variety. If the resistance of a variety is of the tolerance type, for example, although the number of thrips in this variety will be similar to that in susceptible variety, the damage will be lower.

We picked up on smaller thrips damage on bunching onion in Szabadszállás. Leaves of onion plants on the same field were more damaged than leaves of bunching onion plants. Results also proved that there is a significant difference between species regarding thrips damage. Bunching onion plants were not completely free of thrips there was a slight damage on them too.

I evaluated several onion varieties at the station of the National Institute for Agricultural Quality Control in Tordas. There was no damage-free variety among the examined varieties, and the difference was not big between varieties. Results showed that thrips damage was more serious in 2003 than in 2002. Its cause can be the warm and dry summer, which favour to reproduction of onion thrips. Based on results, I can declare that there was no resistant variety among the examined varieties. The right choice of variety can decrease extent of thrips damage, and number of insecticide treatments, but it cannot give complete protection against onion thrips. Thrips damage was serious even on the least damaged varieties like Mundo, Banco, Cometa, and Makói Fehér.

Results of experiments performed on Soroksár confirmed our presumptions, that bunching onions are generally more tolerant to thrips damage than other onion species. There was only a slight difference between bunching onion varieties during the vegetation period regarding either the number of thrips or the extent of damage. Emsweller and Jones recognized in 1935, during an experiment, that Nebuka type of *Allium fistulosum* is resistant to thrips, thank to its cylindrical leaf. Field screening test in India showed that the variety Spanish White, which is a bunching onion variety, was the most resistant among 8 varieties examined (Lall et Singh 1968).

Bunching onion possesses morphological characteristics which can play a major role in resistance against onion thrips (Jones et al. 1934). These characteristics are for example, the cylindrical shape of the leaves, the angle of divergence of leaves and the distance apart of the leaf blades on the sheath column. Bunching onion has another several favourable characteristics, which could motivate wider production in Hungary.

If commercial varieties of onion had these leaf characters, one might secure a more efficient control against onion thrips, but breeding is very difficult, because genetic background of these characters is not known.

All varieties of onion had been damaged, and there was only a slight difference between varieties, although there were a few varieties which differed significantly from each other regarding the number of thrips. On the contrary, results of Bognár and Shanab (1969) showed no significant difference between onion varieties examined by them. Fournier et al. (1995) had also identified no significant difference between onion varieties. There was one exception among onion varieties examined in my experiments, the variety Castillo, which showed only a slight damage during the vegetation period. Leaves of Castillo were deep green compared to other varieties which had bluish grey leaves.

Evaluations performed at different dates well indicate that the number of thrips on plants decreased continuously as plants got closer to maturity and leaf development has stopped. On the contrary, damage index increased, because plants were not developing anymore, and thrips continued feeding on the already damaged leaf area. Time of evaluation is very important when evaluating onion varieties. One should pay attention to the number of thrips on plants, and also the rate of different developmental stages; if mostly adults are found, it can mean that the onion thrips is not able to reproduce on the plant, so the plant has some kind of resistance (Coudriet et al. 1979). The more larvae are on a plant, the bigger can be the damage, because larvae cause the main damage (Krauthausen et al. 2001). In the same time, one should pay attention to the extent of damage too, if the resistance of a variety is of the tolerance type, for example, although the number of thrips in this variety will be similar to that in susceptible variety, the damage will be lower. Above all, one should evaluate changes in the weight of onion head, because it can happen that leaves are damaged, but it does not cause a decrease in yield. The conclusion is that evaluation of resistance of onion varieties against onion thrips is a very complex challenge, because several factors can influence results. Reviewing the literature, I could not find a method reliable from all the point of view for evaluating thrips resistance.

Extent of damage can not be neglected in case of leek varieties, because leeks are sold together with leaves, so leek plants should stand to esthetical expectations. The average number of thrips was the highest on the variety Tétényi áttelelő among the leek varieties in my experiments. Damage index was also the highest for this variety. There was only a slight difference between leek varieties during evaluations, due to the big variances compared to averages. So, during the pair wise comparisons, only big differences could be proved statistically. In case of damage index, the difference was very slight between varieties, but none of the varieties reached the highest damage index.

Stoner and Shelton (1988) had already proved the role of planting time in the protection of cabbage against the onion thrips. Similar experiments were performed for onion (Kisha 1977) and bunching onion varieties (Grevsen 1989), and the conclusion was that earlier planted plants had slighter damage, because the number of thrips is smaller during their development, and plants got strong by the time thrips number increased. These conclusions can not be applied equally for the different production methods in Hungary. One should evaluate separately importance of timing for onions grown from onion set and seeds.

In case of onion sets, the development is faster and plants get strong by the time thrips number increases, and also their vegetation period is shorter, so their exposure to thrips damage is shorter. But my results proved statement of Pénzes (1994), that adults wintering on onion sets has importance in starting thrips population.

Extent of damage was significantly smaller for the earliest planting time in 2003, than for the other planting times. However there was no difference between planting times in 2004. Extent of damage was similar in both years. Results of 2004 can be explained by higher infestation of onion sets, because thrips population could develop faster. First planting was performed almost in the same time for both years, but plants finished development three weeks later in 2004. Apparently weather and development of host plant influence together population of onion thrips.

In case of onion seeds, plants planted earlier showed higher damage, than plants planted later. It is caused by slower development of onion plants produced from seeds, and plants are more sensitive to damage of thrips; later they „grow out" thrips damage. However variance was big, so in most experiments there was no significant difference between varieties, although I worked with higher sample number.

Based on results, I concluded that efficiency of timing depends on weather conditions, so protection against onion thrips can not only based on it. Pénzes (1980) concluded that extent of damage is determined by the sensitivity of variety, the length of suitable period for damaging and the abundance of *Thrips tabaci*, and I can agree on that based on my results.

Every year *Thrips tabaci* was the predominant species among both the adults and larvae, but there was difference between years. For example, *Thrips tabaci* represented 85,9% of adults in 2002, while 93 and 94 % of adults in 2003-2004.

As I collected both males and females, I think that population reproducing by arrhenotoky damages onion crops in Hungary.

*Frankliniella tenuicornis* represented 5 % of adults in 2002, 1 % in 2003, and less than 1 % in 2004.

Summarizing my results I conclude that onion thrips is the predominant thrips species on onion. Beside *Thrips tabaci*, only predatory thrips appeared in higher ratio.

Comparing number of thrips captured by yellow sticky traps and weather information, result is not surprising. Several researchers analysed population dynamics of thrips and its tight relation with weather elements in the last decades, and I could agree on their results.

In the body of thrips collected from leek in Szabadszállás, in November of 2003, resting spores of a fungus had been found. There was no data yet about its occurrence in Hungary. Circumstances of its finding coincide with literature data. Infested individuals were mostly adults, except a few nymphs. I could not find an answer for the questions: why there, why then.  Answers can be that leek has not been yet examined from entomological point of view or nobody collected samples late in November. My results from Soroksár contradict to it, because I left leek plants in the field during winter, but the fungus did not occur.

Rate of predatory thrips was 6 % in average during the vegetation period, which coincides with literature. Torres-Vila et al. (1994) identified that rate of predatory thrips on *Allium* species was 7-8 % in Spain. Vierbergen and Ester (2000) found only small number of larvae of predatory thrips on leek, in the Netherlands. On the contrary, Fail found only a few adults on cabbage, in Hungary, and only on the outer leaves of cabbage head. High number of predatory thrips in my samples could be explained by the pesticide-free production method, I also found several larvae of lacewing and ladybug. Natural enemies alone were not able to reduce thrips population, but their limiting role can be important. It was interesting to see that rate of predatory thrips was 13 % on onion, 8,3 % on bunching onion, and only 3,4 % on leek.

Data was found in literature that shape and divergence of leaves can play a role in resistance of plants against onion thrips (Emsweller and Jones 1935; Lall and Singh 1968; Coudriet et al. 1979; Pénzes 1994). Cylindrical leaves and wide angle between leaves helps to restrict the thrips population by reducing the protective environment to a minimum. It would not be good to change onion to bunching onion, because it does not form onion head. Solution could be to carry over good characteristics of bunching onion to onion by breeders or to choose varieties with cylindrical leaves or wider leaf angle by selection.

Colour of leaf can also pay a role in resistance. As the polyphagous onion thrips can be trapped by yellow traps (Czencz 1987, Szénási 2002), but green colour does not attract them (Czencz 1987), it can happen that yellowish varieties are more attractive for thrips than greenish ones. Szénási (2002) observed better efficiency of yellow traps compared to greenish traps in her experiments. Presumably greenish colour of varieties could keep away thrips and it can be a source of antixenotic resistance. To prove it more experiments are needed.

My results concerning occurrence of males do not coincide with findings of many authors. Vierbergen and Ester (2000) said that populations reproducing by arrhenotoky can appear only on places with hot summer (continental, subtropical or tropical climate). Moritz (1997) agreed on it, that more males appear on higher temperature. It could be true for Hungary, because we have continental climate with hot summer, but my results show it differently. Rate of males were higher in 2004 than in 2003, although year 2004 was colder and had more precipitation. (368,8 mm rain in 2003, while 577 mm in 2004). Pénzes (1980) found males but only in stored onion. Based on his results, only thelitoky appears under field conditions. However my results showed that probably populations reproduced by arrhenotoky are present in different onion crops under field conditions. Rate of males was 5,6 % in average in 2004, which means that almost 1♂:17♀ was the male:female ratio. It is similar to results of Vierbergen and Ester (2000) from the Netherlands, where this ratio was 1♂:25♀

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