The control of two-spotted spider mite *(Tetranychus urticae)* by acarophagous predators with the help of released predatory mite *Typhlodromus pyri* within IPM and organic hop growing in Saaz hop growing region (eleven years´ experience).

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Abstract
Two-spotted spider mite *(Tetranychus urticae)* is the most dangerous pest of hops, especially in Saaz (Žatec) hop growing region, typical for low precipitations. Contemporary hop protection against this pest, based entirely on application of miticides, has become difficult as their future using is uncertain either because of their decreasing efficiency or their toxicity on non-target organisms. One possible way of controlling resistant populations of *T. urticae* is to increase the efficiency of the natural control by native acarophagous predators supported by released predatory mite *Typhlodromus pyri*.
In 2008 *T. pyri* was released in nine hop-yards (10.5 ha) under IPM strategy and in four hop-yards under organic hop growing strategy (6.5 ha) at the research farm of Hop Research Institute (IPM, 2x BIO) and Líšťany (2x BIO). Spider mites and their predators were checked in regular intervals during growing seasons. Whereas in some of the hop-yards one release was enough, in most of them predatory mites had to be released repeatedly (2-3x) since 2008. Thanks to predatory mites the density of acarophagous predators has established at the level able to control *T. urticae* without the necessity of miticides applications. The ability of predators to keep spider mites under the economic threshold showed also under the extraordinary hot and dry weather conditions of the year 2018, when numerous miticide sprays had to be carried out to control this dangerous pest in other conventional hop yards.

Key words: IPM, organic hops, two-spotted spider mite (*Tetranychus urticae* Koch), predatory mites, *Typhlodromus pyri* Scheuten, release, over-wintering, control, acarophagous predators, miticides.

Introduction

The beginning of **organic hop growing** in Czech Republic dates back to 2009. Nevertheless, it has its origin in the early eighties of the 20th century within a research project in the cooperation between Hop Research Institute and Entomological Institute of Czechoslovak Academy of Sciences (Růžička et al., 1986; 1988). Unfortunately, there used to be no demand for organic hops from breweries at that time and therefore we did not continue in this research even though some field trials with predatory mites *Typhlodromus pyri, Amblyseius californicus, Amblyseius cucumeris* or *Phytoseiulus persimilis* were carried out in the nineties and at the beginning of the new millennium (Vostřel, 2003).
Nevertheless, the situation has changed nowadays and there are emerging breweries, which demand organic hops so as to be able to brew organic beer. It was also the reason why Hop Research Institute persuaded some hop growers in CR to enter the transition period. The acreage of organic hop gardens in this period in CR amounts to 10.5 ha. The first officially certified organic Czech hops were available from the harvest of 2012 (Vostrel, 2013b).
Efficient control of downy mildew and major pests: damson-hop aphid and two-spotted spider mite is the most important task to manage to produce good quality organic hops. In the case of *T. urticae* creation of natural balance between spider mites and their enemies is very important so as to be able to control this dangerous pest. Predatory mites *Typhlodromus* pyri are released to help indigenous natural enemies (acarophagous thrips, predatory bugs, tiny lady birds *Stethorus* spp., gall midges *Feltiella acarisuga* and others) to prevent damage caused by spider mites (Vostrel, 2013a).
Field experiments with predatory mites were carried out as early as the beginning of the 1970s in hop yards in Yakima valley (WA). *Typhlodromus occidentalis* appeared to be a better candidate than *P. persimilis* (Pruszynski & Cone, 1972). In hop yards of Willamette valley (OR) inoculative release of Phytoseiid mites and the important question of spatial aggregation and refugia of *T. urticae* and predatory mite *Neoseiulus fallacis* were studied by Strong and Croft (1995; 1997). The most effective control was reached by *N. fallacis* and *T. occidentalis* or by mixture of the both species. In English Kent Campbell and Lilley (1999) studied the effect of timing and rates of *P. persimilis* release in dwarf hops. On all treatments the numbers of *T. urticae* decreased when the prey and predator ratio reached the value of 10:1. In Hallertau two-spotted spider mite appeared to be more manageable pest for biological control than damson-hop aphid (Benker, 1997).
In trials carried out in Czech Republic *P. persimilis* was able to control two-spotted spider mite on leaves of rootstocks in a nursery school. *T pyri* and *A. californicus* succeeded to keep *T. urticae* under its economic injury level on a small experimental hop garden under weather conditions suitable for the development of this pest (Vostřel, 2001). At the beginning of the 1990s, however, there seemed to be little hope of using *T. pyri* or other predators to control spider mites while aphids had to be controlled by chemicals, which were not sufficiently selective to avoid destroying the predators (Neve, 1991). Nevertheless, the situation rather changed within the decade when a selective insecticide pymetrozine emerged. Pymetrozine was used to control aphids in an experimental hop garden together with *T. pyri* and *A. californicus* and in this way the both major pests were efficiently controlled (Vostřel, 2003). Recently, the spectrum of selective pesticides has been enriched by another efficient aphicide, flonicamid (Vostrel, 2013a), which is necessary for an efficient **IPM system** in hop cultivation. Good selectivity of the aphicide pymetrozine and miticide bifenezate were found out by James (2002). Unfortuately, pymetrozine will not be possible to use anymore since 2020 but the other selective aphicide, flonicamide is even more efficient and has a sufficient selectivity to aphidophagous and acarophagous predators as well.

Material and Methods

The research started In 2008 when *T. pyri* was released in nine hop-yards (10.5 ha) under IPM strategy and in four hop-yards under organic hop growing strategy (6.5 ha) at the **research farm of Hop Research Institute** (IPM, 2x BIO) and Líšťany (2x BIO). Spider mites and their predators were checked in regular intervals during growing seasons. Experimental hop gardens in **Listany (Rocov cooperative farm, resp. Mr David's hop garden)** are also situated in Saaz hop region approximately 20 km from Žatec. The cultivated variety is Saazer (Osvald's clone). Since 2009 the hop gardens had been in the transitional period from commercial to organic hop growing system. This period was finished by the harvest in 2011 and therefore the crop of 2012 already had the status of fully certified organic hops. Varieties Saazer, resp. Premiant are cultivated under the system of organic growing in the research farm in Stekník (5 km from Žatec), whereas all hop gardens under **IPM system** were planted with new perspective hop genotypes before their aplying for registration trials.
Fifty leaves were sampled regularly at two weeks' intervals. Predatory mites *T. pyri* were obtained from Biola Chelčice (dr. Oldřich Pultar), the official dealer of bio-agents including *T. pyri* in CR. Predatory mites were released in the rate of three strips of cloth containing five gravid females/pole = **1.5 predatory mites/plant) in late spring (at the turn of May and June), when the first symptoms of damage caused by *T.urticae* were visible on lower leaves.** Samples were taken to the laboratory in plastic bags where numbers of eggs and mobile stages of spider mites and predatory mites as well as other species of acarophagous predators were either directly checked or put into a refrigerator and checked the following day. Mites were counted with a binocular microscope.
Whereas damson-hop aphid was controlled with the help of extract from a tropical plant Quassia amara (if necessary) and native predators (BIO), bio-fungicide Polyversum (a.i. *Pythium oligandrum*), Alginure (extract from marine algae) and one spray with allowed amount of copper (6.0, resp. 4.0 kg/ha/year) were commonly used to control downy mildew. None of them had negative effect on *T. pyri* populations.
In commercial hop gardens planted with perspective hop genotypes within IPM system only selective insecticides (flonicamide, pymetrozine) were used to control aphids and to enable predatory mites to survive and control spider mites next year. Common registered fungicides (fosetyl-Al, azoxystrobin, metalaxyl, cymoxanil and cooper fungicides and later also boscalid and pyraclostrobine) were used according to a short time prognoses model of downy mildew to control this disease.

Results and Discussion

Over-wintering populations of Phytoseiids together with other species of acarophagous predators managed to to prevent damage caused by spider mites within the experimental hop garden for eleven years following the release of *T. pyri*. Number of spider mites rarely exceeded the threshold level (5 mobile stages per leaf) during this period. If so another release was carried out in the above-mentioned rate of **1.5 predatory mites/plant.** Anthocorid bugs of the genus *Orius,* acarophagous tiny lady birds *Stethorus* spp., predatory gall midges *Feltiella acarisuga*, acarophagous thrips, rove beetles *Oligota* spp. and larvae of lacewings were the common indigenous predators of *T. urticae* naturally occuring in the experimental hop gardens during that period. Low population density of *T. urticae* corresponded with numbers of predatory mites and other acarophagous species.

Our eleven years' experience hitherto with predatory mite *T. pyri* can be summarized in the following way:

1. *T. pyri* is a suitable bio-agent for the control of *T. urticae* on organic hops. Nevertheless, optimal release rate is still questionable. It is impossible to determine it in a uniform way as it depends on a location of a hop garden as well as on the population density of T. urticae. On the base of our long experience with the control of two-spotted spider mites with the help of predatory mites and other acarophagous species we can conclude the following: if there is no focus of over-wintering females and if there was not an outbreak of this pest at the end of the previous season, we can recommend releasing 1-2 females per plant (crown), i.e. 3.5-7.000 ex./ha. Otherwise, it is necessary to increase the rate on the standard number of 5 ex./plant (crown), i.e. 16.000 ex./ha.

2. After reaching the **natural balance** between acarophagous predators, including native natural enemies of spider mites, we suppose that another release would be necessary only if the number of spider mites reaches the value of economic threshold (5 mobile stages/leaf) and predatory mites and/or native acarophagous predators will be present only in low densities.

3. On the base of our long-term research we can conclude that ***T. pyri* is able to over-winter in Bohemian hop gardens. The over-wintering generation can significantly reduce population densities of *T. urticae* in the following season** as it was confirmed in our experimental hop gardens. Other research aimed at the improvement of over-wintering conditions therefore is not necessary. Harvested hop bines are transported to a stationary picking machine on the contrary to orchards, where this species is commonly used to keep spider mites under the economic threshold. But we must realize that together with them leave also plenty of spider mites (if present). In this way the balance between *T. pyri* and native acarophagous predators on one hand and two-spotted spider mites on the other one is not significantly changed.

4. **This species of predatory mite can be efficiently used not only in organic but in other commercial hop gardens as well within IPM systems.** If *T. pyri* is used within IPM systems applications of **a selective insecticide (flonicamide)** is necessary to save not only Phytoseiids but all the complex of acarophagous and aphidophagous predators as well.

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1. Two-spotted spider mite (*Tetranychus urticae*) is the most dangerous pest of hop plants in Žatec hop growing region nowadays. It ensues from weather conditions, which have become still warmer and in this way very good conditions are created for this pest. Females are 0.5 mm long and 0.3 mm wide with oval body and four pairs of legs.

2. The first symptoms of damage caused by two-spotted spider mites are usually visible at the turn of May and June on lower leaves. If weather conditions are optimal these spots quickly grow and number of spider mites increase.

3. Predatory mite *Typhlodromus pyri* is our native species even though it is not common in hop gardens and therefore it is necessary to relase it. Very important is the fact that it can over-winter in hop gardens and therefore it is not necessary to release it every year but only if economic threshold (5 mobile stages of *T. urticae* /leaf) is reached. It may be used to help to control spider mites not only in organic hop growing but in IPM as well.

4. Tiny lady bird *Stethorus punctillum* is the most important native acarophagous predator in hop gardens in Žatec hop growing region. Both adults and larvae feed on spider mites.

5. Larvae of *S. puctillum* are very mobile and they are able to destroy several tens of spider mites a day and in this way to help to control this dangerous pest.

6. Larvae of predatory bug *Orius minutus* from the family of Anthocoridae may also be an important predator. It usually becomes more abundant later in the season.

7. Rove beetles *Oligota flavicornis* also belong among the natural enemies of *T. urticae*. Tiny black beetles reach the length of mere 2.0 mm. Both larvae and adults are acarophagous.