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WESTERN FLOWER THRIPS POPULATION DYNAMIC ON GREENHOUSE SWEET PEPPER

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KEYWORDS

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Growth rate of population
Ecological factors

ABSTRACT

Western flower thrips (*Frankliniella occidentalis*, WFT) is an important pest of sweet pepper in greenhouses in the Republic of Moldova. A greenhouse population of WFT on sweet peppers, which is difficult to control, has been studied. The high growth rate of the WFT population (333%) and its dominant position (56%) are largely dependent on ecological factors in greenhouses and the insecticides used. There is no interspecific competition between local thrips species and the invasive WFT due to the low abundance and species diversity of thrips. The prolonged and frequent use of insecticides without alternative control measures has resulted in 51.7±2.6%, 20.6±1.8% and 22.0±3.3% adults of the population being resistant to the active ingredients of the insecticides cypermethrin, thiamethoxam and abamectin, respectively. No resistance to spirotetramat has been detected in WFT larvae. The year-round cultivation of vegetable and ornamental crops in Ecoplantera's greenhouses contributes to the preservation of this pest population. To ensure sustainable control of WFT in greenhouses, it is recommended to apply an integrated pest management (IPM) approach, with the obligatory use of entomophages and entomopathogens.

INTRODUCTION

Currently, the western flower thrips (WFT), *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae**),** is a pest of global significance, affecting a wide range of agricultural crops in the field and protected cropping systems. The insects suck the contents of plant cells, reducing their photosynthetic activity. This leads to quantitative crop losses and diminishes the aesthetic value and quality of agricultural products (Reitz et al., 2020). Moreover, WFT spreads 11 viruses, including 8 representatives of the genus Orthotospovirus (https://gd.eppo.int/taxon/FRANOC/vectorof). WFT is considered the most active vector of tomato spotted wilt virus (*TSWV*) and impatiens necrotic spot virus (*INSV*), which cause significant damage of vegetable and ornamental plants (He et al., 2020).
The WFT invaded Europe in 1983. The pest was discovered in greenhouses in the Netherlands. It is now registered in almost all European countries (https://gd.eppo.int/taxon/FRANOC/distribution). In the Republic of Moldova, WFT was first detected on greenhouse roses in 1998 (Verderevskaya et al., 1996). Mass spread of thrips was observed between 2004 and 2010 on vegetable crops in greenhouses in Chisinau municipality (greenhouses of the state farm “Flori”) and in private greenhouses in the districts adjacent to Chisinau: Straseni (2007) and Ialoveni (2010). WFT infestation in the greenhouses of the “Flori” farm was accompanied by a 50% infection rate of tomatoes with the *TSWV* virus (Muntyan et al., 2014). In 2019, WFT was detected in the greenhouse of Institute of Horticulture and Food Technologies (Chisinau) (Muntyan et al., 2022). There is no data concerning the presence of *F. occidentalis* in greenhouses in the other regions of the country.
Use of virus-free planting material and pathogen-resistant plant varieties is recommended to protect vegetable crops against pathogens (Mouden et al., 2017). At the same time, the control of thrips vectors remains a key strategic task in protecting plants against viral infections. The insecticides application for preventive and therapeutic purposes is the main strategy of thrips management. But, WFT demonstrates a strong predisposition

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for developing resistance to a certain number of insecticides, especially in greenhouse conditions. The website of the Insecticide Resistance Management Committee (https://www.pesticideresistance.org) includes at least 30 active substances from several chemical classes to which the WFT resistance has been reported. The high resistance of thrips to chemical agents is maintained by the pest's high reproductive potential, short development time, the presence of haploid males, as well as the main route of their entry into greenhouses. As a rule, plant material infected with WFT from greenhouses where pests have already developed resistance to insecticides is the source of infection. The hidden lifestyle of pests and the development of a high degree of resistance to insecticides do not enable WFT effective control in the most cases.

The development of integrated approaches based on an understanding of the biology, behavior and ecology of thrips is the priority in WFT control. The discovery of thrips kairomones and pheromones has made detection, monitor and mass trapping of the pest much faster and easier using colored sticky traps with semiochemicals. In addition, the possibility of using plant extracts, essential oils or their ingredients with repellent and antifeedant properties against thrips both as independent protective agents and in combination with attractants in the "Push-Pull" technology is being studied (Kirk et al., 2021). In order to suppress the development of WFT resistance to insecticides and manage insecticide-resistant thrips populations in greenhouses, comprehensive control schemes that include the use of fungal pathogens, nematodes, parasitoids, predatory insects and mites, as well as biorational insecticides, are being developed (Mouden et al., 2017). The evaluation of the possibility of using specific bacteriophages against facultative or obligate endosymbionts of WFT that affect the life cycle parameters of these pests is a new area of the thrips management research (Krueger et al., 2024).

Sweet peppers and tomatoes are the most common vegetable crops grown in greenhouses. In this study the invasive WFT population dynamics particularities on sweet pepper which have difficult to control in the greenhouse was examined. The sensitivity of WFT to certain insecticides was also assessed. These data can be used for more effective management WFT populations on sweet pepper using chemical and alternative control methods.

MATERIALS AND METHODS

The studies were conducted on sweet pepper (*Capsicum annuum*) in the greenhouse of the Limited Liability Company "Ecoplantera" from May to June 2021, Chisinau, and the Republic of Moldova. The Ecoplantera greenhouse is a multidisciplinary greenhouse for growing vegetable, flower and ornamental plants. In greenhouse, sweet pepper crops were treated twice with fungicide Ridomil Gold (Syngenta, 4 kg/ha). In 2021, chemical treatments against thrips were carried out with the insecticide Kestrel (200 g acetamiprid/L, Adama, 0.1 L/ha) on March 10 and March 23 and with the insecticide Movento (100 g spirotetramat/L, Bayer, 1.0 L/ha) on March 24.

Monitoring of thrips abundance and species composition

Thrips abundance and species composition were monitored using yellow sticky traps 17.5x13 cm in size, covered with polyethylene film, in the center of which a dispenser with thrips attractant (kairomone) - methyl isonicotinate (Sigma-Aldrich, China) was fixed. The solid-based dispensers were used in the Ecoplantera greenhouse. The dispensers released attractant at a rate of 53.2±6.7 mg/day, respectively, at an average daily temperature of 27°C. On sweet pepper, traps were placed at a height of 0.5-0.7 m from the ground surface. In the greenhouse, four traps were placed on an area of 810 m^2. The distance between traps was at least 10 m in longitudinal and transverse directions (Figure 1). The average number of thrips on the traps was counted for seven days.

Figure 1. Yellow sticky traps with methyl isonicotinate, installed on sweet pepper crop in a greenhouse

WFT (adults) population growth rate was calculated according to the formula:

$$G_r = (P^n - P^{n-1})/P^{n-1} \times 100 \quad (1)$$

where, G_r = Growth rate; P^n = Mean number of WFT on yellow sticky traps at the sampling date n; P^{n-1} = Mean number of WFT on yellow sticky traps at the sampling date n-1

The species identification of thrips captured on sticky traps was conducted. The thrips were cut from the polyethylene sheets and were washed of glue with benzene, and thrips preparations were prepared after a clarification procedure. Thrips were identified according to the keys of Moritz and Mound (2000). In order to describe the species structure of Thysanoptera, Kucharczyk's classification was employed. The classification system utilized is as follows: eudominant (>10%), dominant (5-10%), subdominant (2-5%), recessive (1-2%), and sub-recessive (less than 1%) (Kucharczyk et al., 2011).

Laboratory colony of the WFT

A laboratory colony of WFT to test the pest's sensitivity to insecticides was established from progeny of 20 females collected on weeds in the Ecoplantera greenhouse. In the laboratory, the colony was maintained in 5-litre desiccators on rooted bean leaves at 25 ± 1 °C, 60-70% relative humidity and a long (16-hour) daylight period (Figure 2). The 2nd instar larvae and adults were used for toxicological experiments**.**

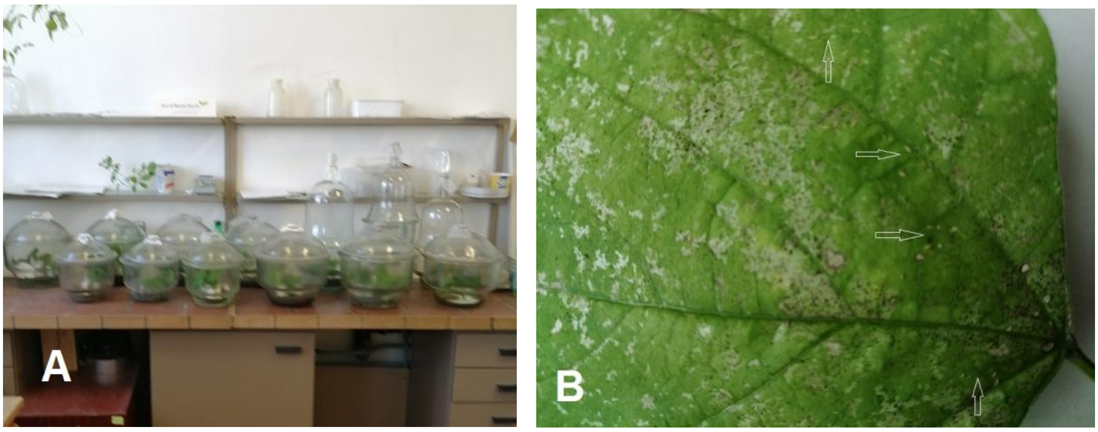

Figure 2. Rearing of WFT on bean leaves in glass desiccators (A); bean leaf infested with WFT larvae (B)

Determination of WFT susceptibility to insecticides

To assess the sensitivity of thrips to insecticides, the method of placing the pest on a feed substrate pre-treated with poison was used. The sensitivity of thrips was assessed to the pyrethriod: Arrivo (250 g cypermethrin/L EC, FMC, USA); neonicotinoid: Actara (250 g thiamethoxam/L, WG, Syngenta, Switzerland); avermectin: Vetrimec (1.8 g abamectin/L, EC, Syngenta, Switzerland) and an insecticide based on tetronic and tetramic acid derivatives: Movento (100 g spirotetramat/L SC, Bayer Crop Science, Germany). In the experiments, diagnostic concentrations of insecticides were used for sensitive WFT population (Herron & James, 2007). When testing spirotetramat, the concentration of the insecticide was used - 0.1 g a.i./L. The sensitivity of adult thrips to cypermethrin, thiamethoxam and abamectin was assessed according to the method described in work (Muntyan et al., 2014). The toxicity of spirotetramat to thrips larvae was assessed in Petri dishes containing slightly moistened cotton wool and bean leaf cuttings. For treating with pesticide, the bean leaf was immersed for 30 seconds on both sides, dried in a fume hood. In the control, the bean leaves were treated with water. Thrips larvae were transferred to the spirotetramat-treated food substrate using a soft brush.

All tests were carried out with 20-25 adult and 20 larvae of thrips 2nd instar at least 4 times at a temperature of 25 ± 1 °C in a 16:8 L:D regime. The pest's mortality was recorded for pyrethroid insecticide after 24 hours, for neonicotinoid and avermectin - after 72 hours, for spirotetramat - after 6 days. Thrips were considered dead if individuals did not respond to the touch of a thin brush. When assessing the larvae mortality after the application of spirotetramat, only individuals that developed to the pupal stage were considered to be living. Mortality in the control groups did not exceed 1% in the all experiments.

RESULTS AND DISCUSSION

In 2017, mass reproduction of WFT was noted on tomatoes, peppers and Chinese cabbage in the Ecoplantera greenhouse. There has been a persistent combat against WFT for many years. The pyrethroid, neonicotinoid and avermectin insecticides have been used to destroy thrips. The monitoring of thrips abundance using yellow sticky traps with methyl isonicotinate in the third decade of March (23-30/03/21) revealed a low abundance of WFT on pepper crops, with an average of 1.25 ± 0.48 individuals per trap (Figure 3). Chemical treatments apparently had a restraining effect on the pest numbers. In early April, there was no increase in the numbers of adult thrips on peppers, G was -40.5% (Figure 3). However, the infestation of plants with thrips then gradually increased. In April, a high growth rate of the pest population was noted with a maximum value of 333% (Figure 3). During this period, from 3.25 ± 0.48 to 13.25 ± 1.44 WFT individuals were caught per trap. Then, there was a slight increase in the number of thrips adults on sweet pepper, and the average pest catch was 15.75 ± 5.04 individuals per trap.

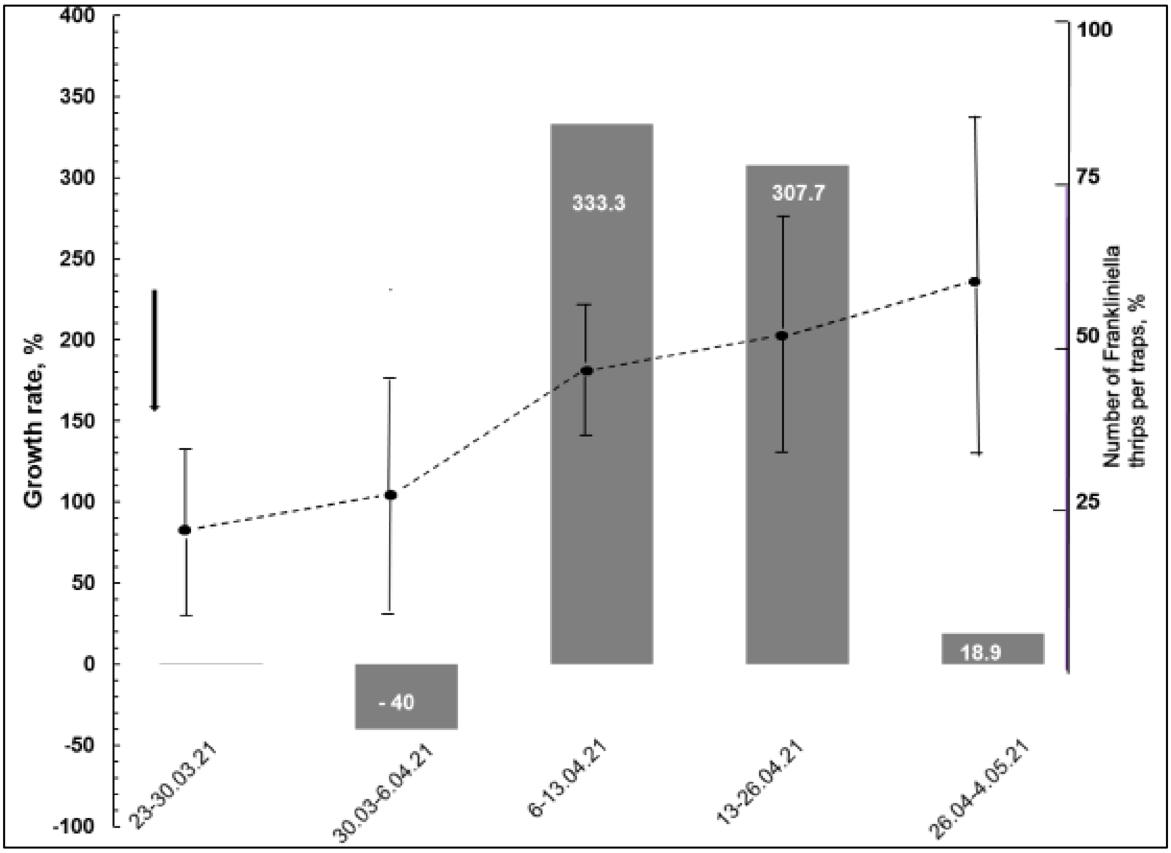

Figure 3. **WFT population growth rate and the mean number of WFT specimens per trap (%) on sweet pepper in Ecoplantera greenhouse. Confidence interval for probability P=95%. Arrow indicates chemical treatments**

WFT is an invasive species of thrips. The abundance and position of the pest in the overall structure of Thysanoptera varies and largely depends on specific ecological factors in greenhouses and the insecticides used. Ecoplantera farm operate year-round and produces not only vegetables but also ornamental flowers, which undoubtedly contributes to the preservation, maintenance, and development of this pest's population. The development of the WFT population is limited by competition for food resources and egg-laying sites between females of native thrips species and the invasive species, the WFT. The development of the phytophagous population is limited by competition for food resources and egg-laying sites between females of native and alien pest species. This is especially true for the invasive thrips species such as the WFT. This is supported by reports of a number of authors who note that interspecific competition on the part of native thrips species limits the survival of western flower thrips larvae (Reitz et al., 2003).

However, the interspecific competition as restraining factors is absent in the greenhouses of the Ecoplantera farm. Currently, the greenhouse has extremely low abundance and species diversity of Thysanoptera and other sucking pests. Moreover, an assessment of thrips species composition on sweet pepper showed that the WFT has actually displaced most of the herbivorous thrips. Total number thrips species was 4. Only 2 species - *T. tabaci* and *Chirothrips manicatus* (Figure 4) - out of 7-8 species of phytophagous thrips, which are usually present in most greenhouses growing vegetable crops, were found (Tommasini and Maini, 1995; Orosz S. et al., 2017). The WFT on sweet peppers occupies a high, eudominant position (25-56% of the total number of thrips species) during the entire observation period (Figure 4).

This is consistent with the observations of a number of authors. Studies on thrips population dynamics have shown that native species are often displaced by the invasive species when they are in the same ecological environment (Cao et al., 2018; Hu et al., 2018).

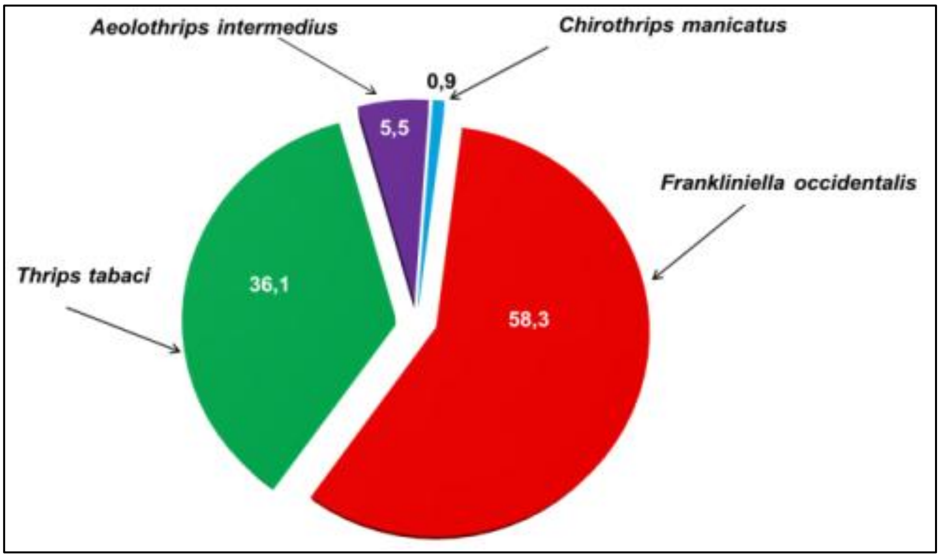

Figure 4. Thrips species composition on sweet pepper in the Ecoplantera greenhouse. In brackets is given the number of thrips as a percentage of the total Thysanoptera on yellow sticky traps with methyl isonicotinate

It is known that WFT has a high biotic potential, greater physiological tolerance and broader ecological adaptability compared to its related local thrips species *F. intonsa* (Baez et al., 2011; Gao et al., 2012; Zhang et al., 2020). For example, *F. occidentalis* displaced *F. gemina* in Argentina on *Lycopersicon esculentum* (De Borbón et al., 2006), and *Thrips hawaiiensis* was displaced by *F. occidentalis* on *Rosa chinensis* and *Gardenia jasminoides* (Cao et al., 2018).

Finally, predatory thrips (*Aeolothrips intermedius*) could have contributed to the WFT population control. They accumulate on plants surrounding greenhouses. These species of thrips are present in greenhouses in rather large numbers (5.5% of all thrips) throughout the entire growing season of peppers. However, as shown by the research of Orosz's, *A. intermedius* monitoring data indicated that this thrips species has a low reproductive potential in greenhouses on peppers (Orosz et al., 2017).

In addition, as noted by a number of researchers, insecticides can be an important factor that increases competition between WFT and other thrips species. It has been shown, that WFT emerges as a winner in the competition for survival, when avermectin, beta-cypermethrin or imidacloprid are used (Zhao et al., 2017; Hu et al., 2018, Zhang et al., 2020). These results allow to assume that the treatment of peppers with acetamiprid, and earlier with abamectin and cypermethrin, which were used in the Ecoplantera greenhouse to suppress WFT, contributed to an increase in the demographic indicators of the WFT population and the displacement of other thrips species.

It should be noted that three-time application of the neonicotinoid Kestrel and a single application of Movento at the beginning of the plant growing season did not fully protect pepper crops from WFT in the Ecoplantera greenhouse. Moreover, a significant and consistent increase in the WFT population was observed after the chemical treatments. This result indicated the presence of resistant thrips in the population, which required an assessment of the pest's sensitivity to insecticides. Table 1 summarizes the toxicity of some insecticides to WFT adults from the Ecoplantera greenhouse.

Table 1. Toxicity of some insecticides to WFT adults from the Ecoplantera greenhouse

Insecticides, a.i.	[1]N	Concentration, mg a.i./L	[2]The resistant thrips, %
Cypermethrin	99	10.0*	51.7±2.6
Thiamethoxam	93	300.0*	20.6±1.8
Spirotetramat	75	100.0**	0
Abamectin	86	10.0**	22.0±3.3

[1]N is the total number of insects used in the experiments; [2]The average number of thrips ± SEM; *Diagnostic concentrations of insecticides, i.e. concentrations that kill all susceptible individuals (Herron & James, 2007); ** Insecticide application rate recommended for greenhouse conditions.

Movento with the active ingredient spirotetramat, which affects insect growth and development (inhibitor of acetyl-CoA carboxylase) was the most toxic insecticide for thrips (larvae) (Table 1). It killed all thrips larvae. The share of adult thrips resistant to neonicotinoid insecticides Actara with the active ingredient thiamethoxam did not exceed 20.6%. The microbiological insecticide Vertimec based on abamectin also did not show 100% toxicity against WFT. When treating adult individuals with this chemical, 22.0% of resistant thrips were detected. 51.7% of thrips exhibited insensitivity to the cypermethrin in the studied population, which is undoubtedly due to the widespread and frequent use of pyrethroids in greenhouse**.**

Thus, the long-term use of insecticides without control measures against resistance has become a factor that has provoked the formation of a resistant WFT population in this greenhouse, which makes it impossible to effectively control the pest with chemicals. In this regard, it is necessary to eliminate the use of pyrethroids, as well as the frequent use of insecticides containing thiamethoxam and abamectin, in order to prevent the further development of WFT resistance to insecticides. In this context only insecticide Movento with a strong larvicidal activity is highly effective against WFT. However, there are already known cases of developing resistance to spirotetramat by sucking pests. Resistance to spirotetramat has been reported in tobacco whitefly, *Liriomyza huidobrensis*, thrips, and aphids (Yükselbaba et al., 2022; Umina et al., 2022; Nguyen et al., 2024).

The obtained characteristics of the WFT population from the Ecoplantera greenhouse clearly confirmed the long-known thesis that the sole use of insecticides against WFT is not a sustainable strategy. Successful control programs against WFT integrate chemical and alternative methods for the pests control (biological, physical and others). Both of these strategies will result in diminished insecticide application, thereby reducing selection pressure on WFT populations and reducing insecticide resistance (Gao et al., 2012). Phytoseiid mites (*Amblyseius* spp.) and pirate bugs (*Orius* spp.) stand out among the numerous natural enemies that attack WFT. *A. swirskii* has been the main predator used for biological control of WFT and whiteflies on vegetable and ornamental plants worldwide since its commercial introduction in 2005 (Van Houten et al., 2005). The most notable results on biological control of WFT on peppers were obtained by Funderburk (Funderburk et al., 2000). The authors showed that the predatory bug *Orius insidiosus* (Say) colonized peppers and was able to effectively suppress thrips populations. It is important to note that the use of entomophages in greenhouses is closely correlated with the development of insecticides that are at the lowest possible level of toxicity for biological control agents. Therefore, maintaining high activity of Movento in the greenhouses surveyed is a priority, as this insecticide is characterized as a biocompatible chemical agent.

CONCLUSION

Almost 30 years have passed since the discovery of WFT in the Republic of Moldova. During this time the outbreaks of the pest mass reproduction as well as the *Tomato spotted wilt virus* disease mass spread in greenhouses were recorded periodically. Currently, WFT is limitedly distributed in greenhouses of the Chisinau municipality. Based on the obtained results, in order to prevent the spread of the especially highly dangerous invasive species of WFT in greenhouses of the Republic of Moldova, it is recommended to introduce mandatory and regular monitoring of the species composition of thrips using highly sensitive sticky traps with methyl isonicotinate in the protection system of vegetable crops, in particular sweet peppers. Such traps detect pests on plant seedlings during periods of low the thrips numbers. When invasive and quarantine thrips species *F. occidentalis* and *T. palmi* are detected, it is strongly recommended to control the sensitivity of the pests to insecticides. As part of the anti-resistance control, non-chemical methods of thrips management should be widely applied, using microbiological preparations and entomophages.

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