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THE ABUNDANCE DYNAMICS AND SPECIES COMPOSITION OF THRIPS (THYSANOPTERA) ON SWEET PEPPERS IN GREENHOUSE

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INTRODUCTION

Thrips (Thysanoptera) belong to the group of key and the most dangerous pests of agricultural and ornamental crops. Insects damage the epidermis, suck the plant cells contents and encourage infection of plants with fungi, bacteria and viruses (Parker et al. 1995). For solanaceous crops *Tomato spotted wilt virus* (TSWV) from Bunyaviridae family, which main vectors are thrips, is of great danger (Pappu et al. 2009). TSWV causes significant tomatoes and peppers crops losses during outdoors and indoors cultivation (Sevik , Arli-Sokmen et al. 2012). The ability to transmit TSWV has been confirmed experimentally for eight thrips species Thysanoptera member, western flower thrips - *Frankliniella occidentalis* (Pergande), is of particular importance as the TSWV vector. This thrips are highly injurious to ornamental and vegetable crops indoors (Riley et al. 2010). Furthermore, the new viruses spread by thrips on tomatoes and peppers have been detected in the recent years (Keldysh et al. 2016).

Currently, there are no effective protection methods against plant viral infections. The use of virus-free planting material and pathogen-resistant varieties for the solanaceous crops protection in greenhouses is recommended (Mouden et al. 2017). However, thrips control remains the first priority in protecting plants against viral and other infections. The chemical method of thrips control is often ineffective because of the rapid development of resistance in greenhouse populations of phytophages to most of the pesticides used (www.pesticideresistance.org.). As a consequence, there is increasing interest in the alternative (non-chemical) control of harmful Thysanoptera in greenhouses. The possibility of applying individual substances and plant extracts with repellent, antifeedant effect on thrips as separate means of protection and together with attractants in "Push-Pull" technology is under investigation (Peneder et al. 2011; Allsopp et al. 2017; van Tol et al. 2007). Pest control schemes using parasitoids, predatory insects and mites as well as biorational insecticides are developed for the resistant Thysanoptera populations management in greenhouses (Mouden et al. 2017). Once the thrips' kairomones and pheromones have been found, colored sticky traps with these semiochemicals are used to monitor and catch the pests. Pyridine derivatives ethyl isonicotinate and methyl isonicotinate are the most effective kairomones of onion and western flower thrips (Koschier 2008; Teulon et al. 2017). High sensitivity and specificity of traps with semiochemicals allows timely detection of pests at low population levels and undertaking corrective actions to prevent mass reproduction of phytophages (Civelek et al. 2017).

For effective application of alternative and chemical thrips control, information on the seasonal abundance and species structure of greenhouse thrips populations is required. Although in the recent years the number of farms cultivating tomatoes and peppers in the greenhouses has increased in the Republic of Moldova, data on the species composition and abundance of harmful Thysanoptera on these vegetable crops are still lacking.

In this context, the aim of this work is to investigate the thrips abudance dynamics and species structure in the greenhouse sweet pepper cultivation.

MATERIAL AND METHODS

The study was conducted on sweet peppers (*Capsicum annuum*) in the greenhouse of the Institute of Fruit and Food Technology, Chisinau (Republic of Moldova) from May to September 2019. During the experiment sweet pepper crop was treated twice with the fungicide Sercadis Plus (75 g/l fluxapiroxad + 50 g/l difenoconazole, BASF, the application rate 0.8 l/ha). The insecticide Coragen (200 g chlorantraniliprole/l, FMC Corparation, 0.15 l/ha) was used in a single treatment against the cotton bollworm. No chemical treatments against thrips have been carried out in the greenhouse.

For thrips population and species composition monitoring yellow sticky traps were used, measuring 17.5 x 13 cm, in the centre of which a dispenser with thrips attractant (kairomone), 2 ml of 99% methyl isonicotinate (Sigma-Aldrich, China), was fixed. The eppendorf tubes with a cotton thread wick were used as dispensers. The dispensers released the attractant at a rate of 0.036±0.007 g/day at an average daily temperature of 27°C. Eight traps were placed on an area of 1.180 м^2 of pepper at 0.5-0.7 m from the ground, with a distance of 10 m in the longitudinal direction and 5 m in the transverse direction. The thrips average number per trap for three days was counted. The significance of differences was assessed by Student's t-test. A 5% significance level was adopted in all cases (Lakin 1980).

The Thysanoptera species diversity on peppers was studied by sampling pepper flowers. One fully opened pepper flower was randomly selected from five pepper plants in the vicinity of the set traps. In the laboratory, thrips were extracted from flowers by shaking them onto a white sheet of paper, killed with ether vapour, clarified with lactic acid and thrips preparations were made in Faure-Berlese liquid. In addition, species identification of thrips captured on sticky traps was carried out. For this purpose six 1.5 x 1.5 cm squares (equivalent to 6% of the total area of the sticky trap) with thrips were cut from trap, washed from the glue with organic solvents (benzene), and after the clarification procedure made preparations of thrips. The thrips were identified according to the keys of Moritz (Moritz 1994) and Moritz and Mound (Moritz and Mound 2000).

For the Thysanoptera species structure description we used Kuharchuk's classification based on abundance and frequency of thrips species: eudominant (> 10%), dominant (5.1-10%), subdominant (2.1-5%), recedents (1-2%) and subrecedents (below 1%) (Kucharczyk et al. 2011).

RESULTS AND DISCUSSIONS

Thrips population monitoring

The thrips population monitoring started 10 days after the peppers seedlings were planted in the greenhouse soil. The thrips population has been characterized by a number of stages in its development (Figure 1).

During the first stage (third decade of May-early June) the average number of adults on traps fluctuated, but did not exceed 146.2 individuals/trap. The relatively low Thysanoptera abundance on the traps reflected the invasion of young pepper plants by autochthonous thrips. The thrips population development was hampered by relatively low temperatures during this period (+22°C during the day and +16°C at night). Thysanoptera peak abundance (787.0 individuals/trap) in the sweet pepper crop occurred during mass flowering of plants and first fruits setting (mid-June). A chemical treatment with the insecticide Coragen was carried out at this time against the cotton bollworm, which also reduced the number of thrips. The thrips' numbers gradually decreased thereafter. The lowest thrips' average abundance on peppers was registered by attractant traps in September with only 63.7 individuals/trap.

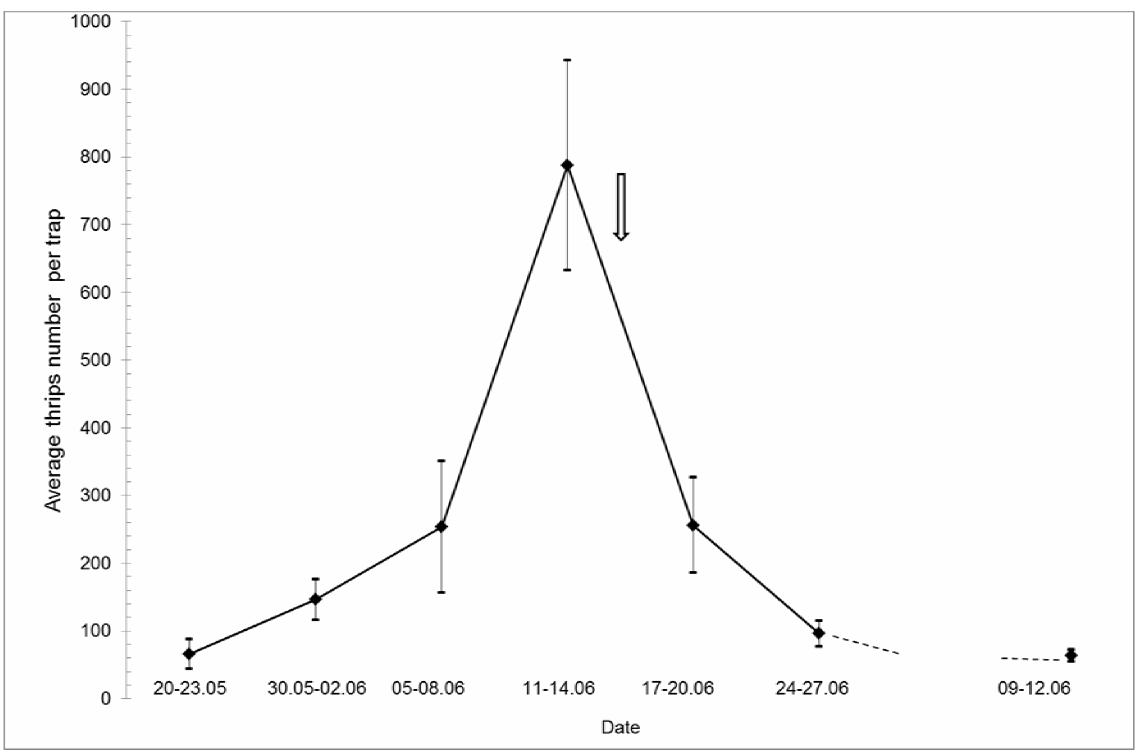

Figure 1. Thrips monitoring using yellow sticky traps with methyl isonicotinate in greenhouse sweet pepper cultivation. Arrow indicates Coragen treatment.

Thrips species composition on sweet peppers

Table 1 shows the species structure of the Thysanoptera population on sweet peppers obtained during the period of maximum pest abundance (11-14.06.19). Members of the order Thysanoptera belonging to 3 families, 5 genera and 10 species were found in pepper flowers and on yellow sticky traps.

Six species of thrips were found in pepper flowers (Table 1). The largest thrips' proportion belonged to the genus Thrips, which accounted for 56.8 % of the total number of identified individuals. The genus Frankliniella accounted for 38.6% (*F. occidentalis* predominated in the samples) and the genus Aeolothrips for 4.5 %. According to Kukharchuk's classification (Kucharczyk et al. 2011), eudominant species were *T. tabaci* , *F. occidentalis, F. intonsa* and *T. physapus*; subdominant species : Thrips atratus and *A. intermedius.* Onion thrips (84.7% of all thrips) was the eudominant species on the yellow sticky traps (Table 1). *F. intonsa and F. occidentalis* comprised 2.4% to 2.6 %; the *Frankliniella* species complex was subdominant in the structure of the Thysanoptera population studied. Furthermore, *Aeolothripis intermedius* (4.7%) also belonged to the subdominant group at the growth peak of the thrips population. The minor thrips species: *T. atratus* , *T. physapus* , *T. angusticeps*, formed the recedents group. The predatory thrips *Haplothrips subtilissimus* , phytophagous thrips: *T. fuscipennis, Limothrips* spp. - a subrecedent group, were extremely rare on the traps. The presence in greenhouses on vegetable crops of the Thysanoptera species listed in Table 1 has been noted previously by several authors (Tommasini and Maini 1995; Orosz et al. 2017; Dolzhenko and Klishina 2009).

Notably, among the thrips identified on pepper, the species to cause epiphytotics are in the first three places according to the frequency of occurrence in the samples analyzed. In addition, two species of predatory thrips, *A. intermedius* and *H. subtilissimus*, known as natural regulators of herbivorous thrips, were identified in the greenhouse. The rest of the identified Thysaportera species are polyphagous and are rather typical of the open ground fauna. However, some species (*T. fuscipennis, T. angusticeps* , *F. intonsa, T. atratus*) are found in greenhouses in summer and, under favorable conditions, are able to reproduce on greenhouse plants to relatively high numbers (Velikan and Ivanova 2005).

Thrips species monitoring

Figure 2-4 shows the number of some thrips species as a percentage of the total Thysanoptera captured on yellow sticky traps with attractant in sweet pepper cultivation. *T. tabaci* is a cosmopolitan, feeding and breeding on the leaves and flowers of outdoor and indoor plants. *T. tabaci* population monitoring has shown that this thrips species is constantly present on peppers (Figure 2). It was detected on the traps immediately after planting the pepper seedlings in the ground. On average, the proportion of *T. tabaci* in the total catch of thrips on traps ranged from 81.6% in pepper seedlings to 86.6% during the beginning of plant blossoming and fruiting phases. In early autumn, its share in the total catch did not decline lower than 73.2%.

Two thrips belonging to the genus *Frankliniella*: *F. intonsa* and *F. occidentalis* were detected in the sticky traps with attractant (Figure 3). On peppers the proportion of *Frankliniella* species complex compared with onion thrips was insignificant reaching 2.5% at the beginning of plant vegetation and did not exceed 3.1% at the maximum number of Thysanoptera. The proportion of thrips of the genus *Frankliniella* on sticky traps with methyl isonicotinate increased to 7.6% by September. The increase of genus *Frankliniella* thrips in the structure of the greenhouse population has shifted these pests from a subdominant to a dominant position. This is presumably because of the increasing abundance of *F. occidentalis* in the population. *F. occidentalis* is known to have a high biotic potential and can quickly outcompete other thrips in greenhouses (Gao et al. 2012). In September 2020, on peppers the thrips catch was carried out on yellow sticky traps with methyl isonicotinate. It showed that the *Frankliniella* species complex, compared to 2019, increased slightly to 12.05% (6.4÷17.5) in the greenhouse.

Table 1. Thrips species composition on sweet peppers in the greenhouse

Species / Family	Pepper flowers		Yellow sticky traps with methyl isonicotinate	
	Number of specimens	Percentage	Number of specimens	Percentage
Aeolothripis intermedius Bagnall, 1934, Aeolothripidae	2	4.5	18	4.7
Frankliniella intonsa Trybom, 1895 , Thripidae	7	15.9	9	2.4
F. occidentalis Pergande, 1895, Thripidae	10	22.7	10	2.6
Limothrips spp., Thripidae	-	-	1	0.3
Thrips (Taeniothrips) atratus Haliday, 1836, Thripidae	2	4.5	5	1.3
T. angusticeps Uzel, 1895 Thripidae,	-	-	5	1.3
T. fuscipennis Haliday, 1836, Thripidae	-	-	1	0.3
T. physapus Linnaeus, 1758,Thripidae	5	11.4	6	1.6
T. tabaci Lindeman, 1779, Thripidae	18	40.9	322	84.7
Haplothrips subtilissimus, Haliday,1852, Phlaeothripidae	-	-	3	0.8
Total	44		380	

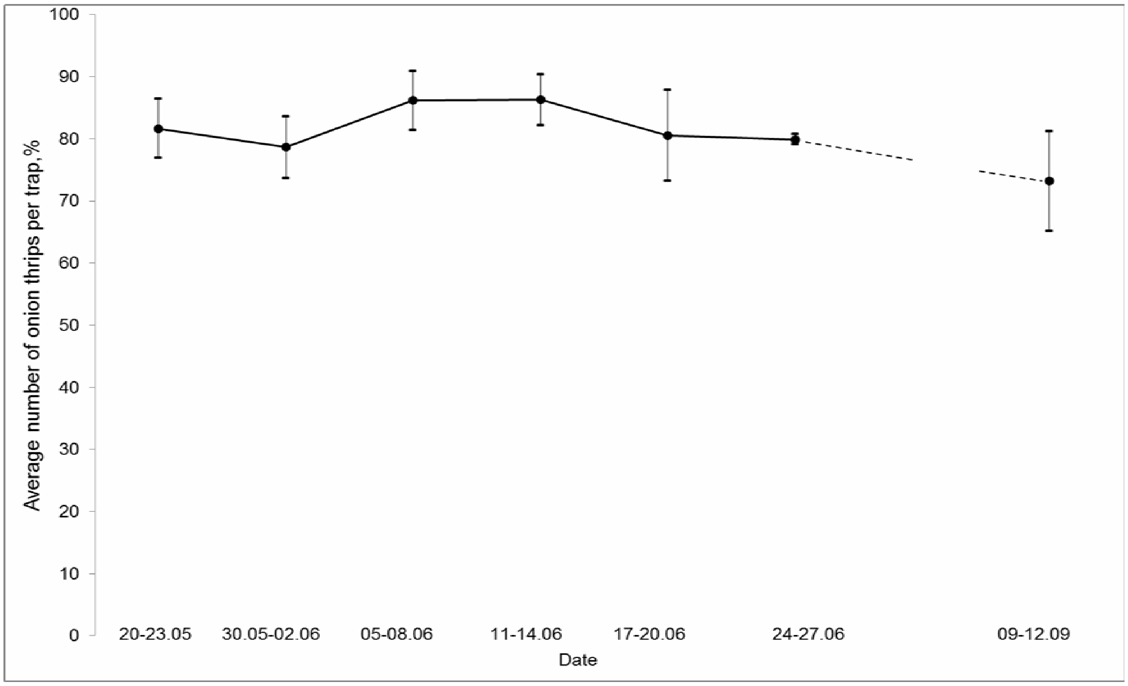

Figure 2. The average number of onion thrips per yellow sticky trap with methyl isonicotinate (%) in greenhouse sweet pepper cultivation

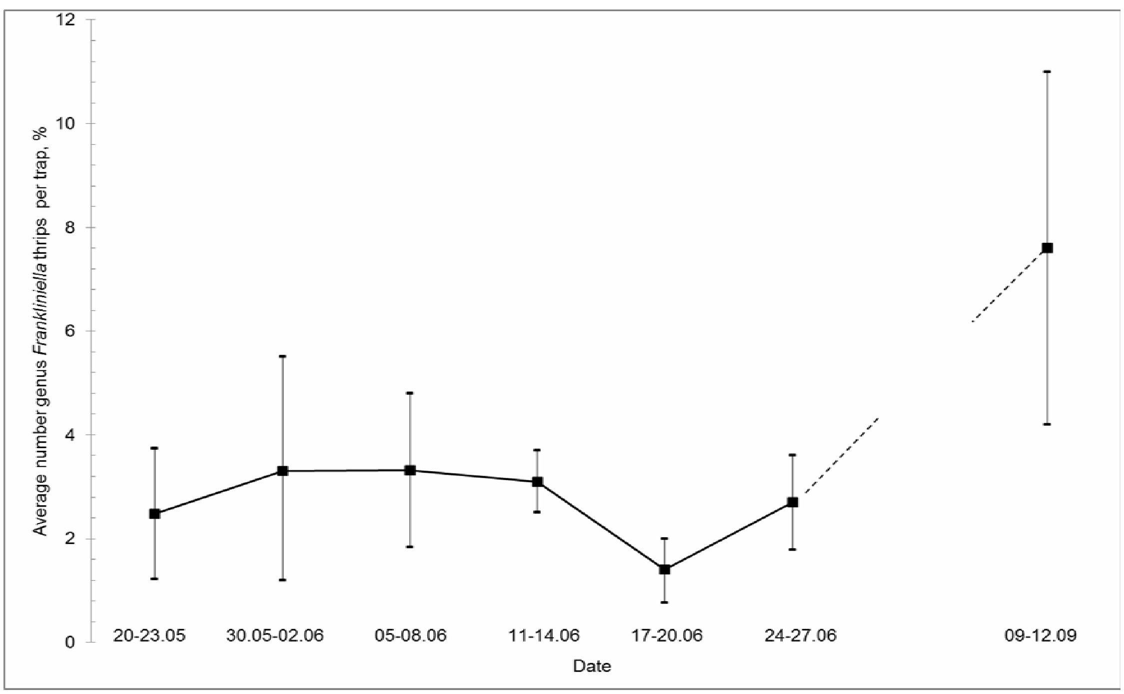

Figure 3 The average number of genus *Frankliniella* thrips per yellow sticky trap with methyl isonicotinate (%) in greenhouse sweet pepper cultivation.

F. intonsa is a common species of Thysanoptera for the Republic of Moldova entomofauna. *F. occidentalis* is an invasive thrips species. Thrips has spread widely throughout the world greenhouses, including Europe. *F. occidentalis* was first identified on roses in greenhouses in the Republic of Moldova in 1998 (Verderevskaya et al. 1996), and the thrips mass reproduction on cucumbers and tomatoes was observed in 2004-2010 (Muntyan et al. 2014).

The economic injury level (EIL) for *F. occidentalis*, varies widely depending on the season of sweet pepper production in the greenhouse and market prices. Thus, Ban et al., 2012 defines an EIL for *F. occidentalis* on peppers as 1 adult per flower (Bán et al. 2012). The number of captured *F. occidentalis* was 0.23 adult per flower during our experiment. This does not exceed the EIL for that pest on the sweet pepper greenhouse crop.

A. intermedius is a facultative predator that feeds on pollen, thrips and small arthropods. The species is widespread throughout Europe, the Middle East and Palearctic Asia. A. *intermedius* is found in many wild and cultivated plant biocenoses, including indoor ground (Orosz et al. 2017; Riudavets 1995). *H. subtilissimus* (Haliday, 1852) is a predatory thrips species that feeds on mites, lepidopterans eggs as well as the scale insects and whiteflies immature stages. The species is widespread throughout the Eurasian continent (Mound 1997).

Predatory thrips were found in relatively high numbers at the beginning of the pepper vegetation (Fig. 4). The total proportion of predatory thrips in catches was up to 10%. *A. intermedius* dominated on the traps. However, predator numbers then decreased markedly and the predator's relative abundance did not exceed 2.73% and 1.27% in July and early September, respectively. *H. subtilissimus* was not observed on the traps in September. The relatively high abundance of *A. intermedius* (16.3%) in the greenhouse on peppers was previously recorded by Orosz. But the following year the proportion of this entomophage in the thrips greenhouse population was very low and amounted to only 0.7% (Orosz et al. 2017). Hence, Orosz's observations and our *A. intermedius* monitoring data probably indicate that this thrips species has a low reproductive potential in greenhouses on peppers. Despite the availability of food resources, the predator is not able to maintain its population at a high level under greenhouse conditions. Our findings on the dynamics of *A. intermedius* trapping in the greenhouse are in complete agreement and repeat the characteristics of predator abundance dynamics in the open ground, from where it penetrates into the greenhouse. Surveys carried out in Central Italy using yellow sticky traps showed an abundance of *A. intermedius* in May and a drastic decrease in abundance in late summer (Conti 2009). The weeds surrounding the greenhouse are reservoirs for these predators. Moreover, attempts to colonize *Aeolothrips* in greenhouses to control herbivorous thrips have been unsuccessful. Experiments by Elimem and Chermiti on sweet peppers showed that no predators were found in the greenhouse after three releases of *Aeolothrips tenuicornis* and *A. fasciatus* against western flower thrips (Elimem and Chermiti 2012). In our opinion, this is most probably not directly related to the food factor, as a relatively high number of its prey, the onion thrips, was recorded throughout the pepper vegetation period. The *T. tabaci* : *A. intermedius* adult ratios ranged from 11 to 16 in May and June. At the same time, it should be noted that *A. intermedius* apparently slowed down the development of the phytophagous thrips population at the beginning of the pepper vegetation.

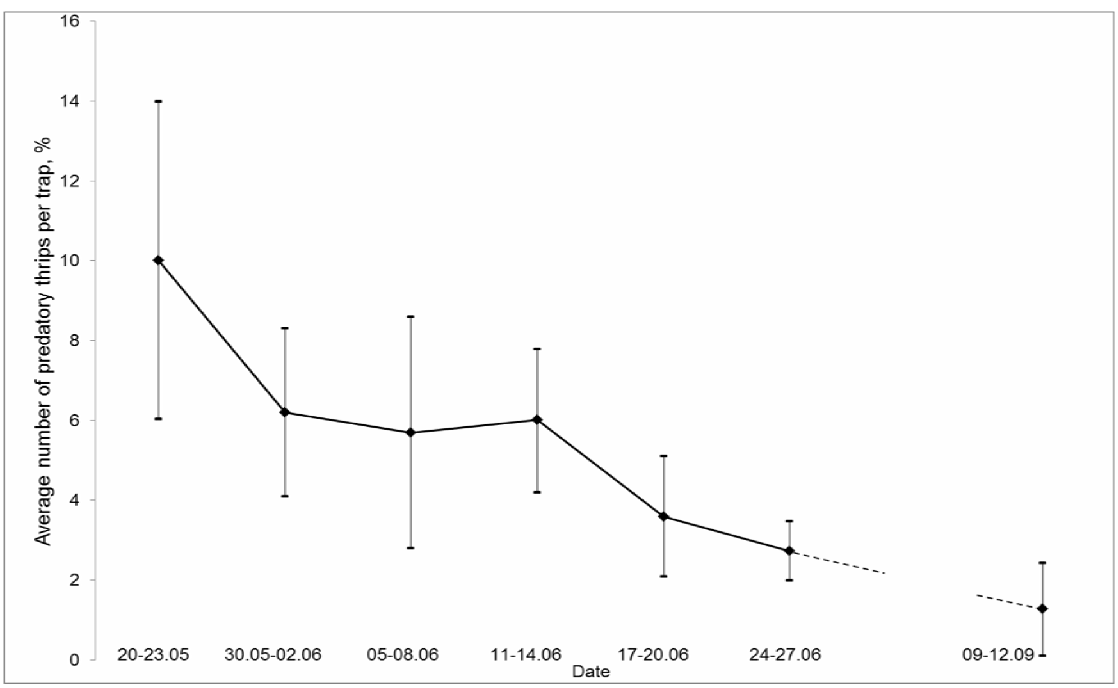

Figure 4. The average number of predatory thrips per yellow sticky trap with methyl isonicotinate (%) in greenhouse sweet pepper cultivation

CONCLUSION

Thus, during thrips monitoring on sweet pepper using yellow sticky traps with methyl isonicotinate and by visual pest counts in pepper flowers, 10 thrips species from three families were identified: Thripidae - 8 species, Aeolothripidae - 1 species and Phlaeothripidae - 1 species. Two of these species are zoophagous and the rest are phytophagous. In general, the thrips' species composition does not differ from that of the Thysanoptera of most greenhouses specialised in vegetable cultivation.Four thrips species (*T. tabaci, F. intonsa, F. occidentalis, T. atratus*) are economically important Thysanoptera species that can spread viral infections and cause epiphytotics.Onion thrips dominated throughout the whole pepper cultivation period. The *Frankliniella* species complex abundance was small, not exceeding 3.3% on average. Nevertheless, *F. occidentalis*, poses a serious danger. This is evidenced by the *Frankliniella* thrips rapid increase (by a factor of 2) towards the end of the pepper growing season. At present, this thrips species' development is probably inhibited by the death of some individuals during the winter, as the greenhouse is not heated. The number of *Frankliniella* species complex did not reach the EIL established for *F. occidentalis.* Cases of adaptation of *F. occidentalis* in the open field at the latitude of the Republic of Moldova Central part are not described in the literature. In mild winters, however, there is a definite risk that a large proportion of the pest population will overwinter on weeds and in unheated greenhouses during the winter. This could cause serious problems in the future when growing vegetables in this greenhouse. Moreover, an increasing number of peppers and tomatoes showing signs of viral infections in recent years may be related to the entry of *F. occidentalis* into the greenhouse.

It should be mentioned that the use of chemical protection agents in the greenhouse has been moderate over the past years. The reduced use of insecticides in pepper cultivation allows entomophages to move into the greenhouse from weeds surrounding the greenhouse and participate in thrips suppression. When inspecting peppers, we repeatedly noted the presence of predatory bugs: *Orius niger*, *Orius majusculus* and *Dicyphus hesperus*, in addition to predatory thrips. The number of *Orius* bugs was as high as 0.8 individuals/flower on peppers in September 2019. It can be assumed that relatively low overall numbers of thrips on peppers that we observed in early September may be attributed to these entomophagous insects.

ABSTRACT

Thrips species composition and seasonal abundance was studied on greenhouse sweet pepper crops in Rebublic of Moldova. Ten thrips species have been identified using yellow sticky traps with methyl isonicotinate and by visual pest counts in pepper flowers. The economically important Thysanoptera species (*T. tabaci , F.intonsa, F. occidentalis , T. atratus*) that can spread viral infections and cause epiphytotics have been detected among them. Onion thrips was the eudominant species on pepper flowers (40.9%) and on the yellow sticky traps (84.7%). In May and July the Frankliniella species complex (*F. intonsa* and *F. occidentalis*) abundance on sticky traps with methyl isonicotinate was low, not exceeding 3.3% on average of the total thrips. The proportion of thrips of the genus Frankliniella increased to 7.6% by September. Predatory thrips *Aeolothrips intermedius* were detected on traps in relatively high numbers (10%) at the beginning of the pepper vegetation. The role of *A. intermedius* in the suppression of the phytophagous thrips number during the cultivation of sweet pepper in a greenhouse is discussed.

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