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SPECIES COMPOSITION AND POPULATION DYNAMICS OF THE HARMFUL INSECT FAUNA (HEMIPTERA: CICADOMORPHA, FULGOROMORPHA AND STERNORRHYNCHA) OF WINTER TRITICALE

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Abstract

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The aim of the present investigation was to identify the hemipteran pests of suborder Sternorrhyncha (family Aphididae) and suborders Cicadomorpha, and Fulgoromorpha, on winter triticale Vihren variety and examine the population dynamics of the dominant species during the spring/summer vegetation period in relation to the sowing date and the climatic conditions. The study was carried out during the period 2011–2013 on the experimental fields on four plots of 0.25 ha. Two plots were sown with triticale in September (early sowing) and October (late sowing) each year. A total of 3 species of family Aphididae, 10 species of Cicadomorpha and 1 species of Fulgoromorpha were found in the crop. *Sitobion avenae*, *Philaenus spumarius, Psammotettix provincialis, P. striatus* and *P. alienus* were the most abundant. The abundance of *Sitobion avenae* was statistically higher in the crop sown in September and can be forecasted using the percentage of attacked stems. The variations in the abundance of Cicadomorpha and Flugoromorpha during the spring vegetation period were more dependent on the climatic conditions than on the sowing date.
Key words: Winter triticale, Cicadomorpha, Fulgoromorpha, Aphididae, population dynamics, sowing date

Introduction

Triticale is a relatively new crop which was adopted by Bulgarian agriculture in 1980 and has been cultivated since then. In comparison to wheat, triticale is a lower risk cereal crop as regards losses caused by harmful insects. Triticale's economically important sap-sucking hemipteran pests belong to suborders Sternorrhyncha, Cicadomorpha and Fulgoromorpha. In particular years they are capable of reducing significantly the yield and quality of harvested grain (Prohorova et al., 2000; Smatas, 2006), even though specific data on the losses are lacking. In order to develop a system for Integrated Pest Management (IPM) on triticale, the identity and population dynamics of harmful insects in the crop need to be studied.

Aphids and hoppers are common pests on triticale. However, the dominant species may vary depending on the location. Their diversity has been studied in many European countries. *Sitobion avenae*, *Rhopalosiphum maidis, Metopolophium dirhodum, Schizaphis graminum, Macrosteles sexnotatus*, *Macrosteles laevis, Psammotettix* spp. and *Javesella pellucida* are major pests on triticale in Romania and the non-chernozem zone of Russia (Popov et al., 2007; Politiko et al., 2008). The most common insect pests on triticale in Germany, Poland, Belarus and Sweden are the aphids *S. avenae*, *R. padi* and *M. dirhodum* (Hinz, 1985, 1987; Kakol et al., 1996; Prohorova et al., 2000; Larson, 2005). In Bulgaria, the species composition and the dynamics of Aphididae, Aphrophoridae, Cicadellidae and Delphacidae on triticale has been studied during the autumn vegetation period. Cicadomorpha and Fulgoromorpha

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are represented by the highest number of species (12) and are more abundant in crops sown in the last ten days of September (Krusteva and Karadjova, 2011). During the spring/summer vegetation period, 11 species of Cicadomorpha and Fulgoromorpha and 3 species of aphids have been reported on triticale (Krasteva et al., 2013).

The abundance and distribution of pests in cereal crops may vary widely between years (Wiktelius and Ekbom, 1985). Generally, the most abundant permanent pests of winter and spring triticale from family Cicadellidae are *Psammotettix striatus* and *M. laevis* (Prohorova et al., 2000). According to Smatas (2005) the abundance of aphids in winter triticale in Lithuania was 4 times higher in 2002 than in 2004. Therefore warning and forecasting systems are essential for the purposes of IPM.

The rate at which the pest population increases depends on the weather conditions, plant quality, plant resistance and the activity of natural enemies (Dixon, 1989). Temperature and precipitation are important factors for the diversity of the insect fauna of triticale. For example, crop yield correlates with a warm autumn, rain and warm weather in May (Larson, 2005). An investigation in Scotland has shown that cooler weather leads to later arrival of *S. avenae* to the fields in the spring (Walters and Dewar, 1986).

The sowing date is also important, as it can influence significantly the phytosanitary condition of the sowings by altering the distribution and abundanceof the above mentioned groups of phytophagous insects, hence the associated degree of damage. Data with respect to triticale are scarce, however, there are studies on wheat to illustrate this correlation. Early sowing of winter wheat in warm autumns may lead to earlier egglaying and emergence of *S. avenae* (Larsson, 2005).

Avoidance of early sowing, selection of varieties, either resistant or exhibiting good compensatory mechanisms, and mineral fertilization are recommended to decrease the crop damage from pests (Popov et al., 2007; Politiko et al., 2008). However, the fluctuations in their abundance relative to the term of sowing have not been investigated.

Globally, the research in this field is scarce. The presented data from the literature show that Aphididae, Cicadomorpha and Fulgoromorpha have the potential to reduce the quality and quantity of triticale yield. The crop damages result from their feeding and, to a greater extent from infection with the viruses they transmit (Lindsten and Vacke, 1991; Kennedy and Connery, 2005; Manurung et al., 2005). The knowledge on the diversity of these sap-sucking insect pests, the dynamics of their development and their harmful effect, as well as the respective underlying factors, is a necessary precondition for the development of programs for monitoring and control in triticale.

The aim of the present study was to investigate the harmful hemipteran insect fauna of Aphididae, Aphrophoridae, Cicadellidae and Delphacidae during the spring/summer vegetation period on triticale fields with different sowing dates. For this purpose, the diversity of the pests and the fluctuations in the population dynamics of the dominant pest species were studied with respect to the climatic conditions and the sowing date of the crop.

Materials and Methods

The study on the species composition and population dynamics of Aphididae, Cicadomorpha and Fulgoromorpha was carried out on the experimental fields of the Institute of Soil Science, Agrotechnology and Plant Protection at the town of Kostinbrod located in the valley of Sofia, Bulgaria (42°48′,113″ N , 23°11′, 127″ E, 454 m above sea level).

The trials were conducted with winter triticale variety Vihren during the period 2011–2013. The early and late sowing dates of the variants (0.25 ha each) were as follows: September 26 and October 21, 2011; September 28 and October 16, 2012.

The population dynamics of aphids were monitored by counting insects on 100 stems/ears (10 locations x 10 stems/ears per variant; 1 sample = 10 stems/ears) at 5–6 day intervals during the phenophases of ear emergence and milk development (DC 50-77 on the Zadoks growth scale) (Zadoks et al., 1974) in the field and the laboratory. The number of aphids per stem/ear and the percentage of infested stems/ears were calculated.

The dynamics of spittlebugs, leafhoppers, and plant hoppers were monitored using a 30 cm wide sweep-net (5 locations × 20 sweeps) in each surveyed field from March-April until harvest. Samples were collected at 5–7 day intervals depending on the weather conditions. The rule of “5 sweeps = 1 m^2” was used to calculate the individuals per square meter (Mihailova et al., 1982).

The normal values of the temperature and precipitation for the region of Sofia basin (calculated for the period 1961–1990) and the average daily, per decades and monthly temperature and precipitation for the period of the study (2011–2013) were obtained from the Bulgarian National Institute of Meteorology and Hydrology (NIMH).

The species identification was performed as follows: for Aphididae after Blackman and Eastop (1989); for Cicadomorpha and Fulgoromorpha after Kopaneva (1980) and using a collection, identified by Viola Bayryamova (Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Science, Sofia) and Venelin Pelov (Institute of Soil Science, Agrotechnology and Plant Protection, Agricultural Academy, Sofia).

The collected data were analyzed with correlation, regression and one- way ANOVA methods using the statistical software SPSS-16 at $P \leq 0.05$.

Results and Discussion

The climatic characteristics of the investigated vegetation periods are presented on Figures 1 and 2. The average temperatures for April – July, 2012 and 2013 were, with minor exceptions, above the 30-years norm (Figure 1). Small deviations under the norm were observed only during the first decade of March (2012), the third decade of March and the first decades of June and July (2013). The precipitations were irregularly distributed. The monthly sums were above the normal in April and May 2012, and June and July, 2013 (Figure 2).

The species composition of the pests of family Aphididae and suborders Cicadomorpha and Fulgoromorpha on triticale during the vegetation periods of 2012 and 2013 is presented in Table 1. Three species of aphids were recorded, of which the English grain aphid (*Sitobion avenae*) was most abundant. Suborder Cicadomorpha was represented by one species of family Aphrophoridae and 10 species of family Cicadellidae, while suborder Fulgoromorpha was represented by a single species of family Delphacidae. *Psammotettix* spp. was most abundant, followed by *Philaenus spumarius*, *Empoasca pteridis* and *Hardya anatolica*.

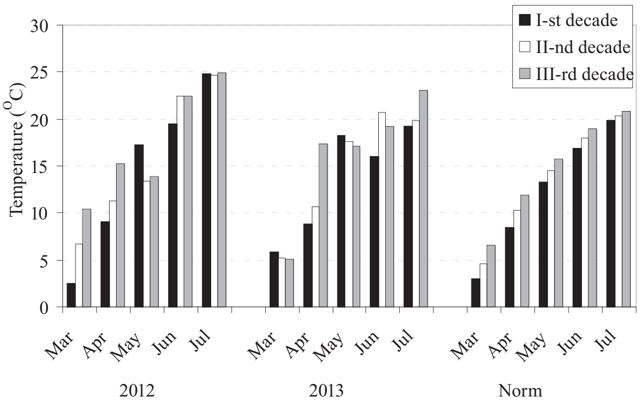

Fig. 1. Average temperatures per decade during the period of the investigation and normal temperatures for the region of Sofia basin

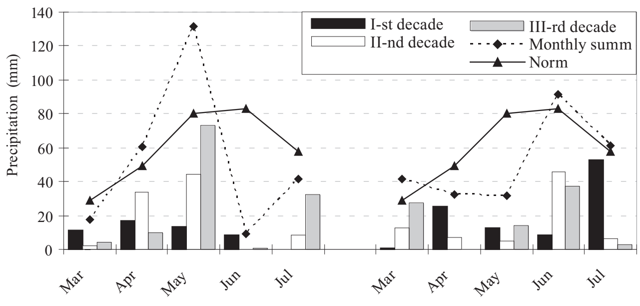

Fig. 2. Average decade and monthly sum of precipitation during the period of the investigation and normal monthly sum of precipitation for the region of Sofia basin

S. avenae is the most common, abundant and harmful species in cereal crops in Bulgaria. It damages wheat, oats, barley, triticale, rye, spelt and many other true grasses (Grigorov, 1980; Krusteva, 2008). It is a non-migrating, heterocyclic species. The English grain aphid completes all stages of its life cycle on cereal plants and overwinters as an egg on autumn sowings and wild poaceous grasses. It develops 10–15 generations per year.

The spittlebug *Philaenus spumarius* is highly polyphagous. In Bulgaria, it develops one generation per year and overwinters as an egg (Pelov and Krusteva, 1993; Krusteva, 1995). Leafhoppers of the genus *Psammotettix* are oligophagous and specialized in feeding on cereal crops: wheat, barley, oats, rye and triticale. Depending on the climatic conditions they develop 2 – 4 generations per year in Bulgaria. They overwinter as eggs in the leaves of autumn cereal sowings and perennial poaceous grasses and as adults under plant debris (Pelov and Krusteva, 1993; Krusteva, 1995; Krusteva and Pelov, 1995).

During the early developmental stages of the host plant, aphids, spittlebugs, leafhoppers and plant hoppers suck sap from the leaves and stems. After ear formation they start feeding exclusively on the ears. The damages lead to stunted plant growth and formation of a reduced number of malnourished grains. *S. avenae* is also a vector of the most harmful virus on barley, Barley yellow dwarf virus (BYDV) (Kennedy and Connery, 2001) which causes more severe infections in early sowings (Mc Grath and Bale, 1990; Wangai et al., 2000). *Ph. spumarius* is the only confirmed vector of *Xylella fastidiosa*, a regulated harmful bacterial plant pathogen which started causing severe damages to olive plantations in Apulia region in 2013 (Saponari et al., 2014).

The data on the species diversity and the relative density of Cicadomorpha and Fulgoromorpha during the spring/summer vegetation periods of 2012 and 2013 did not show significant differences with respect to the sowing date.

In 2012, nine species from two families were identified: Aphrophoridae (1 species) and Cicadellidae (8 species) (Table 1). Among them, *Ph. spumarius* and *Psammotettix* spp. (*P. provincialis, P. striatus* and *P. alienus*) were most abundant (Figures 3, 4). They represented 95.88% and 96.77% of the total number of spittlebugs and leafhoppers in the triticale sowings of the two sowing date variants, respectively, determining the peaks in the density of the whole group. The first peak was observed at the beginning of the second decade of June during the phenophase of milk development (DC 75-79) with population density of 2.8 individuals/m^2 and 2.4 individuals/m^2 in the variants of the early (Figure 3) and the late (Figure 4) sowing date, respectively. The second peak was observed in the first decade of July during dough development (DC 85 – 87). In contrast to

Table 1
Species composition of aphids (Aphididae) and hoppers (Cicadomorpha and Fulgoromorpha) in winter triticale during the spring/summer vegetation period , 2012–2013, Kostinbrod

S uborder/Superfamily / Family	Species	2012	2013
APHIDOIDEA			
Aphididae	*Rhopalosiphum padi* (Linnaeus 1758)	–	+
(Aphids)	*Schizaphis graminum* (Rondani 1852)	–	+
	Sitobion avenae (Fabricius 1775)	+	+
CICADOMORPHA			
Aphrophoridae	*Philaenus spumarius* (Linnaeus 1758)	+	+
(Spittlebugs)			
Cicadellidae	*Balclutha punctata* (Fabricius 1775)	+	+
(Leafhoppers)	*B. rhenana* Wagner 1939	+	+
	Cicadula placida (Horvath 1897)	–	+
	Empoasca pteridis (Dahlbom 1850)	+	+
	Hardya anatolica Zachvatkin 1946	+	+
	Macrosteles laevis (Ribaut 1927)	–	+
	Psammotettix alienus (Dahlbom 1850)	+	+
	P. provincialis (Ribaut 1925)	+	+
	P. striatus (Linnaeus 1758)	+	+
	Zyginidia pullula	+	–
FULGOROMORPHA			
Delphacidae	*Laodelphax striatellus* (Fallen1826)	–	+
(Planthoppers)			

+/– presence or absence of the species in the respective year

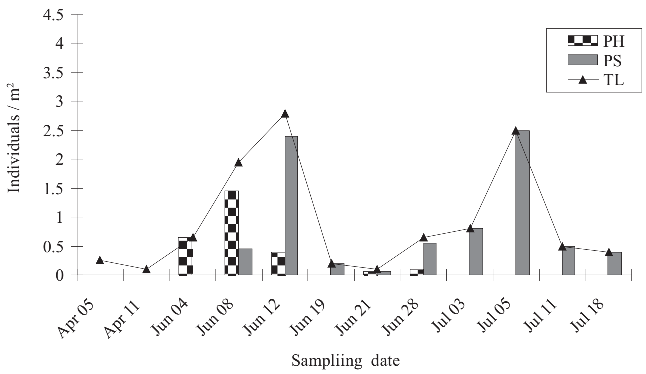

Fig. 3. Population dynamics of *P. spumarius* (PH), *Psammotettix* spp. (PS) and the total Cicadomorpha (TL) in spring/summer, 2012 in the triticale crop sown on September 26, 2011

number of individuals / 1 m^2 = 5 sweeps with an entomological sweep net

the first peak, the density of spittlebugs and leafhoppers during the summer peak was higher in the field sown in October (3.8 individuals/m^2) (Figure 4) in comparison to the field sown in September (2.5 individuals/m^2) (Figure 3). A possible explanation for this observation is the softer texture of the grains in the second variant during this period.

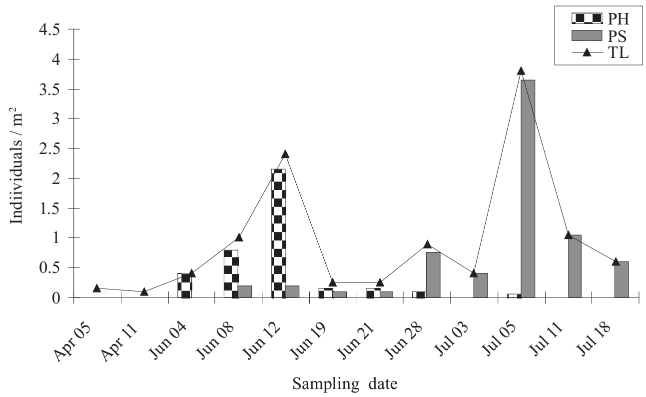

Fig. 4. Population dynamics of *P. spumarius* (PH), *Psammotettix* spp. (PS) and the total Cicadomorpha (TL) in spring/summer 2012 in the triticale crop sown on October 21, 2011

number of individuals / 1 m^2 = 5 sweeps with an entomological sweep net

The results from the processing of the collected samples showed that the population of *Ph. spumarius* consisted exclusively of adult individuals. This fact and the presence of the species in the sowings only until the beginning of milk development leads to the conclusion that triticale is not a main but rather an intermediate host of *Ph. spumarius,* which

Table 2
Relative density (%) of the species of suborders Cicadomorpha and Fulgoromorpha in winter triticale during the spring/summer vegetation period, 2012–2013, Kostinbrod

Family/species	Species densities (%)			
	2012 Sowing date		2013 Sowing date	
	26.09.2011	21.10.2011	28.09.2012	16.10.2012
Aphrophoridae				
Philaenus spumarius	44.50*	33.70	0.63	0.85
Cicadellidae				
Balclutha punctata	0.90	0.90	4.43	5.93
B. rhenana	0.46	–	0.63	–
Cicadula placida	–	–	–	0.42
Empoasca pteridis	2,20	0.90	4.43	3.81
Hardya anatolica	0.46	0.90	6.96	5.93
Macrosteles laevis	–	–	0.64	-
Psammotettix alienus	6.68	21.78	–	3,40
P. provincialis	4.13	8.40	32.22	33.05
P. striatus	40.37	32.89	48.10	46.61
Zyginidia pullula	–	0.45	–	–
Delphacidae				
Laodelphax striatellus	–	–	0.64	–

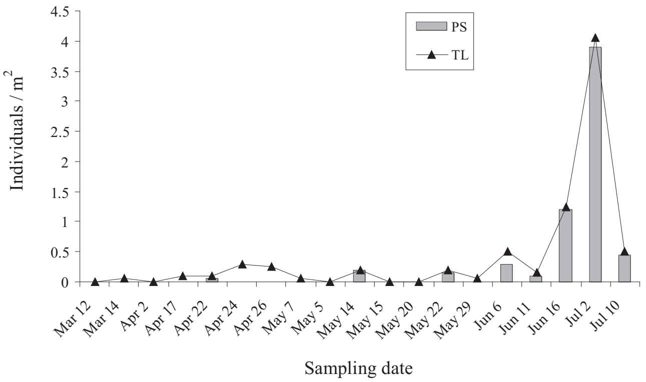

Fig. 5. Population dynamics of *P. spumarius* (PH), *Psammotettix* spp. (PS) and the total Cicadomorpha and Fulgoromorpha (TL) in spring/summer 2013 in the triticale crop sown on September 28, 2012
number of individuals / 1 m^2 = 5 sweeps with an entomological sweep net

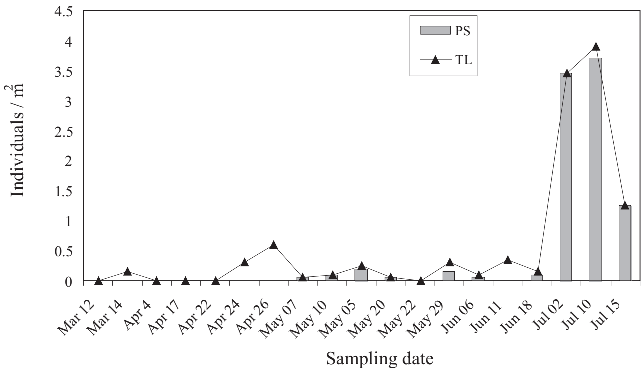

Fig. 6. Population dynamics of *P. spumarius* (PH), *Psammotettix* spp. (PS) and the total Cicadomorpha and Fulgoromorpha (TL) in spring/summer 2013 in the triticale crop sown on October 16, 2012
number of individuals / 1 m^2 = 5 sweeps with an entomological sweep net

does not regularly attack the crop in the area of Kostinbrod.

In the spring/summer of 2013, suborders Cicadomorpha and Fulgoromorpha were represented by 11 species of three families: Aphrophoridae (1 species), Cicadellidae (9 species) and Delphacidae (1 species) (Table 1) with one peak in the density during their development (Figure 5; Figure 6). The dominant species belonged to the genus *Psammotettix* and represented 80.38% and 83.06% of the collective population of Cicadomorpha and Fulgoromorpha in the fields of the early and the late sowing date variant, respectively. The peaks in the overall density of the groups, 4.05 (Figure 5) and 3.45–3.90 (Figure 6) individuals/m^2 in the September and October sowings, respectively, were observed during dough development (DC 85-87) in the first decade of July. Regarding the relative abundance of the species within family Cicadellidae, the dominant *Psammotettix* spp. was followed by *Hardya anatolica*, *Balclutha punctata* and *Empoasca pteridis* (Table 2).

The data presented on Figures 3 – 6 show that the fluctuations in the density of Cicadomorpha and Fulgoromorpha during the spring/summer vegetation period are more linked to

Table 3

Characteristics of the overall population of Cicadomorpha and Fulgoromorpha in periods of mass development during the spring/ summer vegetation period of winter triticale sown on different dates

Collection date	Early sowing date		Late sowing date		df	F	P
	m±SE	RV%	m±SE	RV%			
4, 8 and 12 June 2012	7.2±1.00	13.89	5.06±0.92	18.18	1,28	2.44	0.13
3, 5 and 11 July 2012	5.06±1.00	19.76	7.00±1.65	23.57	1,28	0.97	0.33
2, 10 and 15 July 2013	7.73±1.69	21.86	11.46±1.31	11.43	1,28	3.05	0.09

m – mean density of the the overall population of Cicadomorpha and Fulgoromorpha, number of individuals/20 sweeps with an entomological sweep net; SE – mean error; RV% - relative variance; df – degree of freedom; F – ratio; P – significance

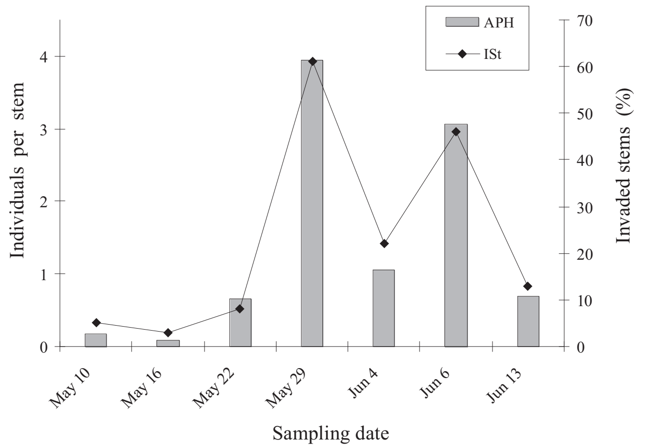

Fig. 7. Population dynamics of aphids in the vegetation period of 2013 in the triticale crop sown on September 28, 2012

APH – individuals per stem, ISt – percentage of invaded stems

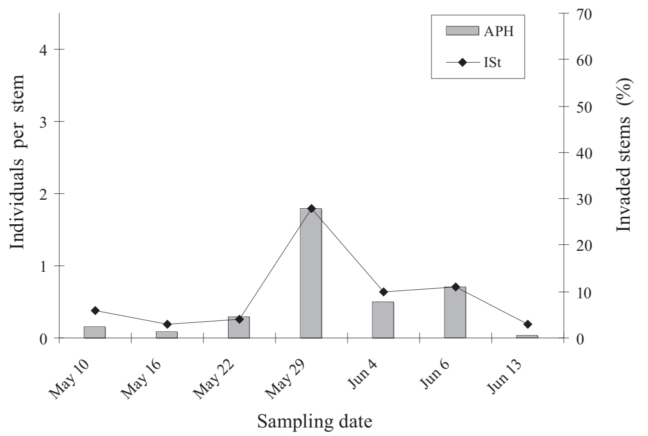

Fig. 8. Population dynamics of aphids in the vegetation period of 2013 in the triticale crop sown on October 16, 2012

APH – individuals per stem, ISt – percentage of invaded stems

the climatic conditions during the separate years as compared to the sowing date. The analysis of the data on the density of *Psammotettix* spp., the mean daily temperatures and the sum of precipitation during the investigated period showed that 2013 was more favourable for the development of hoppers. It was characterized by above normal mean daily temperatures (only the first decades of June and July deviated slightly below the norm) and precipitation under or close to the norm during the phenophases of milk development – dough development (DC 75 – 85) when the outbreak of *Psammotettix* spp. was observed. The climatic conditions during the period June 1 – July 10, 2012 were characterized by lack of precipitations and above normal temperatures (Figure 1; Figure 2). This contributed to the fast completion of the critical crop phenophases resulting in lower densities of leafhoppers.

The lack of significant difference in the mean total densities of the populations of Cicadomorpha and Fugoromorpha in the different variants was confirmed with ANOVA. The periods of mass development of the populations were identified as follows: for 2012, first peak period – June 4, 8 and 12, second peak period – July 3, 6 and 11; for 2013 – a single peak period – July 2, 10 and 15. The data are presented in Table 3. The different species were considered as one population based on the following assumptions: spittlebugs, leafhoppers and plant hoppers cause similar damages, they are simultaneously present in the field and no economic threshold of damage has been established for either species. The comparison of the relative standard error (RV, %) in the different variants showed that accuracy of the assessments within the limits of the maximum permissible value of RV = 25% (Southwood and Henderson, 2000) can be achieved by collecting samples with 5 repetitions of 20 sweeps with a sweep net.

In comparison to hoppers, the population dynamics of aphids was influenced to a greater extent both by the climatic conditions and the sowing date. In 2012 the only representative of family Aphididae recorded in the triticale sowings was *S. avenae.* The population density of the pest was reduced by frequent intensive precipitations in May (131.4 mm compared to norm of 80 mm for the same period) and below normal temperatures during the second and third decade of the month (Figure 1; Figure 2). Due to the unfavourable climatic conditions, the aphids were not surveyed this month. The first of the five surveys was carried out on June 7 and the last one, on June 29. No aphids were observed in the sowings in July, since the conditions for their feeding had deteriorated. *S. avenae* developed more intensively in the early sowing (September) with average density of 0.34 (June 7) to 1 (June 19) individuals/stem. The population density in the late sowing (October) varied from 0.1 to 0.22 individuals/stem. The statistical analysis of the numbers of individuals per sample (1 sample = 10 stems/ears) during the period of mass development (June 16 and 19, 2012) confirmed greater density of *S. avenae* in the early sowing (df 1,38; F = 36.46; P = 0.000).

S. avenae was more abundant in 2013 due to the more favourable climatic conditions during the period of mass development (May 20 – June 10, average daily temperature of 16–17°C and 22.6 mm precipitation) as compared to 2012. The first individuals were observed during the last decade of April, while mass development occurred at the end of May – beginning of June during the phenophases of flowering – milk development (DC 65–79) with maximum densities of 3.94 and 1.8 individuals/ear, and 61% and 28% attacked stems in the early and the late sowing, respectively (Figures 7 and 8).

The greater density of *S. avenae* in the field sown in September in comparison with the field sown in October can be explained by the more advanced phenological development of the earlier crop. The results from the ANOVA of the numbers of individuals per sample during the period of mass development of the *S. avenae* (May 29, June 4 and June 6, 2013) confirmed that the density of the pest in the field sown in September is significantly higher (df 1, 58; F = 41.85; P = 0.000). The data on the development of *S. avenae* in the fields with different sowing dates presented on Figure 7 and Figure 8 show that there is a strong correlation between the density of the pest (individuals/stem) and the percentage of attacked stems. The significance of this correlation was proven with statistical analysis. Thus, the following equation was worked out to calculate the density of the pest with high statistical significance for the purposes of forecasting:

$$Y = -0.117 \pm 0.049X \ (r = 0.994; P = 0.000),$$

where Y is the expected number of aphids per stem and X is the percentage of attacked stems.

Based on the established correlation, an increase in the density of aphids can be expected in the period May 20 – June 10, during the phenophases DC 65 – 75 (flowering halfway complete – milk development halfway complete) if the following conditions are met during DC 65: 60% attacked stems, moderate precipitation (20–23 mm) and mean daily temperature 16–17°C. The relative quantity of attacked stems should be calculated using 10 samples x 10 stems each.

Conclusions

During the spring/summer vegetation periods of 2012 and 2013, three species of family Aphididae were identified in winter triticale sowings, of which *Sitobion avenae* was most abundant. The density of aphids was greater in the crops sown earlier in the autumn of the previous year.

For *S. avenae,* a strong correlation was established between the number of individuals per stem and the percentage of attacked stems. This correlation was presented as an equation with high statistical significance which can be used for the purposes of forecasting.

Suborder Cicadomorpha was represented by 1 species of family Aphrophoridae and 10 species of family Cicadellidae. Suborder Fulgoromorpha was represented by 1 species of family Delphacidae. *Philaenus spumarius, Psammotettix provincialis, P. striatus* and *P. alienus* were most abundant, followed by *Philaenus spumarius*, *Empoasca pteridis* and *Hardya anatolica*.

The population dynamics of Cicadomorpha and Fulgoromorpha during the spring/summer vegetation period fluctuates in a wider range depending on the climatic conditions. Their development is favoured by above normal daily temperatures and precipitation under or close to the norm during the phenophases of milk and dough development when outbreaks occur.

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