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Comparison of *Sitobion avenae* (Fabricius, 1775) and *Rhopalosiphum padi* (Linnaeus, 1758) /Hemiptera, Aphidoidea/ performance on winter triticale

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Abstract

The aim of our study was to compare of abundance, development, fecundity and feeding behaviour of grain aphid (*Sitobion avenae*) and cherry bird-oat aphid (*Rhopalosiphum padi*) on winter triticale.

It was stated that Tornado cv was characterized by higher susceptibility to both aphid species than Witon cv, and that these differences were connected mainly with antibiosis mechanism. Peak of population density of the grain aphid on both triticales and the cherry-oat aphid on Lamberto cv was found during early milk, while *R. padi* on Witon cv was most numerous during half-way anthesis. Larvae dominated in the structure of populations of both aphids species, as exemplified by *R. padi* on Witon cv, where winged females was most numerous in the developmental period. The grain aphid settled both studied cultivars while the cherry-oat aphid on Witon cv preferred ears as a feeding place. Greater part of *R. padi* population on Tornado cv settled bottom leaves and stem. Individuals of *R. padi* developed on seedlings of both triticales and showed a shorter prereproductive period and higher values of daily fecundity and intrinsic rate of natural increase than *S. avenae*. Higher number of EPG patterns of non-probing and total pathways was observed during penetration of plant tissues by females of the cherry-oat aphid. However, *S. avenae* females penetrated phloem tissue longer. Different strategies of adaptation of both aphid species to winter triticale are discussed.

Introduction

Three aphid species dominate on cereals cultivated in Poland, but the grain aphid (*Sitobion avenae* F.) and the bird cherry bird-oat aphid (*Rhopalosiphum padi* L.) are especially important, in view of their abundance and harmfulness (Korbas, 2007). Earlier studies showed that these cereal aphid species preferred different plant organs on winter wheat and triticale as a feeding site and had slightly different population dynamics (Leszczynski *et al.*, 1990; Ciepiela *et al.*, 2006). However, there is still little information on the growth and development, fecundity and feeding behaviour of the aphid species on winter triticale, one of the major cereal crops in central-eastern part of Poland. The aim of the study was to determine the *S. avenae* and *R. padi* abundance on winter triticale and compare their development, fecundity and feeding behaviour.

Material and methods

Two cultivars of winter triticale (*Triticosecale*, Wittm. ex A.Camus): Tornado and Witon were used in the experiments. Seeds of both cultivars were obtained from Plant Breeding and Acclimatization Institute (IHAR) in Strzelce near Łódź (Poland). Population parameters of *S. avenae* and *R. padi* on the triticale cultivars were estimated in natural field conditions at Agricultural Experimental Station in Zawady near Siedlce (central eastern Poland). Detailed growth, development, fecundity and feeding behaviour were tested on seven-day-old seedlings, in a climatic chamber at 24°C at day and 18°C at night, 70% r. h. and photoperiod 16L:8D. The seedlings were grown in a medium nutrient fine structure compost with sand (UMEX), in 8.0 x 9.5 cm plastic pots, and were regularly watered.

Abundance of aphids on winter triticale

Grain aphid and bird cherry-oat aphid density on the studied triticales was estimated, according to the method described earlier by Wratten *et al.* (1979) and Lykouressis (1984). The observations were carried out from the aphid arrival on cereals, until its disappearance (G.S. 52-88) Tottman & Broad (1987), in one-week intervals. Technique of counting the aphids on 25 randomly selected plants, diagonally across the field was applied. The plots' area were 2 m x 9 m, and the distances between plots amounted to 3 m. The aphid number on plants and the percentage of infested plants were estimated. In addition, the number of aphids on ear, flag leaf and bottom leaves with stem as well as dynamics and structure of their populations on the studied cultivars were performed. The values of estimated parameters were calculated as arithmetical means from three independent replications, conducted on three different experimental plots for the each studied triticale cv.

Population tests

Chosen population parameters of both studied aphid species were estimated in control conditions according to LESZCZYŃSKI (1996). The adult apterous females were placed individually on abaxial surface of seven-day-old seedlings of the triticale cultivars. Seedlings with aphids were isolated with Plexiglas cages with a cheese cloth cover (10 cm x 30 cm). After 24 h, one nymph remained on each single plant while other offspring and adults were removed. The experiment was ran in 25 independent replicates for each studied triticale cv. The aphids' pre-reproductive period (time from birth until maturity of female) and daily fecundity were estimated. An intrinsic rate of natural increase (r_m) was calculated using the following equations, after WYATT & WHITE (1977):

$$r_m = 0.738 \frac{\ln Md}{d}$$

were:

0.738 correction coefficient

d – the length of the prereproductive period (days)

Md – the number of larvae born during reproductive period equal d period.

Feeding behaviour

Feeding behaviour of the grain aphid and the bird cherry-oat aphid on the studied triticale cultivars was monitored by an electrical penetration graphs (EPG) technique after LESZCZYŃSKI & TJALLINGII (1994). Duration of the following EPG patterns was determined: Np – non-probing, ABC – penetration of peripheral tissues (epidermis and mesophyll), E1 – sieve element salivation, E2 – ingestion of phloem sap, G – xylem sap ingestion. Experiments were ran for 10 h on ten different plants for each studied triticale.

Statistics

The obtained results were subjected to a one-way analysis of variance (ANOVA), differences between arithmetical means were analyzed with Tukey's test.

Results

The obtained results showed that the first appearance of grain aphid on the tested cultivars occurred during triticale heading (G.S. 52) (Fig. 1 and 2). Aphid number and percentage of infested plants increased while the development of triticale, and peak density of *S. avenae* population was reached at early milk ripe stage (G.S. 73). The grain aphid population was strongly reduced during the late milk rape stage (G.S. 78) and at early waxy ripe stage (G.S. 82), and finally disappeared at late waxy ripe stage (G.S. 88). The dynamics of *R. padi* population on Tornado cv was pretty similar, instead on Witon cv the bird cherry-oat aphid reached the peak density at half-way anthesis (G.S. 65) and disappeared at milk ripe (Fig. 1 and 2). Both aphid species were characterized by higher population and percentage of infested plants on blades of Tornado cv in comparison with Witon one (Tab. 1 and 2). Moreover, Witon cv was more frequently settled by *S. avenae* than *R. padi*, while the density of both aphid species on Tornado cv. was similar.

Larval stadium dominated in population structure of the grain aphid on both triticale cultivars and bird cherry-oat aphid on Tornado cv, stating about 80% of the total aphid number (Fig. 3). The second stadium were wingless adults (*apterae*), about 10-20% of the population, instead the winged adults (*alatae*) only in 2% participated in the total aphid number. In case of the *R. padi* population on Witon cv, winged females (about 60%) dominated, wingless females constituted about 38%, and larvae about 2% (Fig. 3).

Most of the *S. avenae* population (about 90%) occurred on ears of both triticale cultivars (Fig. 4). The rest of the individuals settled aboveground vegetative parts of triticale plants, occurring in a similar number on flag leaves and bottom leaves with stem. The bird cherry-oat aphid showed different preferences in relation to plant organs on Tornado cv and occurred mainly on the bottom leaves and stem (about 60%) and on flag leaf (about 40%), while on Witon plants about 90% of population settled ears, and the remaining individuals occurred on aboveground vegetative organs (Fig. 4).

Population tests showed that individuals of *R. padi*, which occurred on seedlings of both triticale cultivars, were characterized by a shorter pre-reproductive period and mean time of the population development, and by higher values of daily fecundity and intrinsic rate of natural increase (r_m), than *S. avenae* individuals (Tab. 3). Moreover, the grain aphid apterous adults which fed on Tornado cv. showed a significantly higher value of daily fecundity and an intrinsic rate of natural increase (r_m), than on Witon cv. Similar differences were noted for the bird cherry-oat aphid, but not statistically confirmed.

Wingless females of *S. avenae* were characterized by a higher number of activities connected with the ingestion of phloem sap (E2) and xylem sap (G) and lower number of non-probing pattern (Np) and peripheral tissues penetration (ABC) than *R. padi* individuals (Tab. 4). Longer duration of phloem sap ingestion and total phloem penetration (E1 + E2), and a shorter time of non-probing and phloem salivation (E1) was stated in the case of *S. avenae* (Tab. 5). Statistical analyses confirmed significant differences in the number of Np and ABC activities, and in the duration of total phloem penetration for individuals of *R. padi* and *S. avenae* on Tornado cv as well as in the duration of E2 activity on both studied cultivars. On the Tornado cv the bird cherry-oat grain aphid showed a higher number of Np and ABC activities and lower of E1, E2 and G patterns, while the grain aphid was characterized by a higher number of E1 and E2 activities and a lower number of the remaining EPG patterns than on Witon triticale (Tab. 4). Moreover, both aphid species on Tornado cv. penetrated phloem tissue for a longer period of time (E2 and E1 + E2 patterns) and showed a shorter duration of Np and G activities in comparison to Witon cv. The duration of ABC activity on Tornado triticale was longer in case of *R. padi* and shorter for *S. avenae*. Differences in the feeding behaviour of the both aphid species on the triticale cultivar were not statistically confirmed.

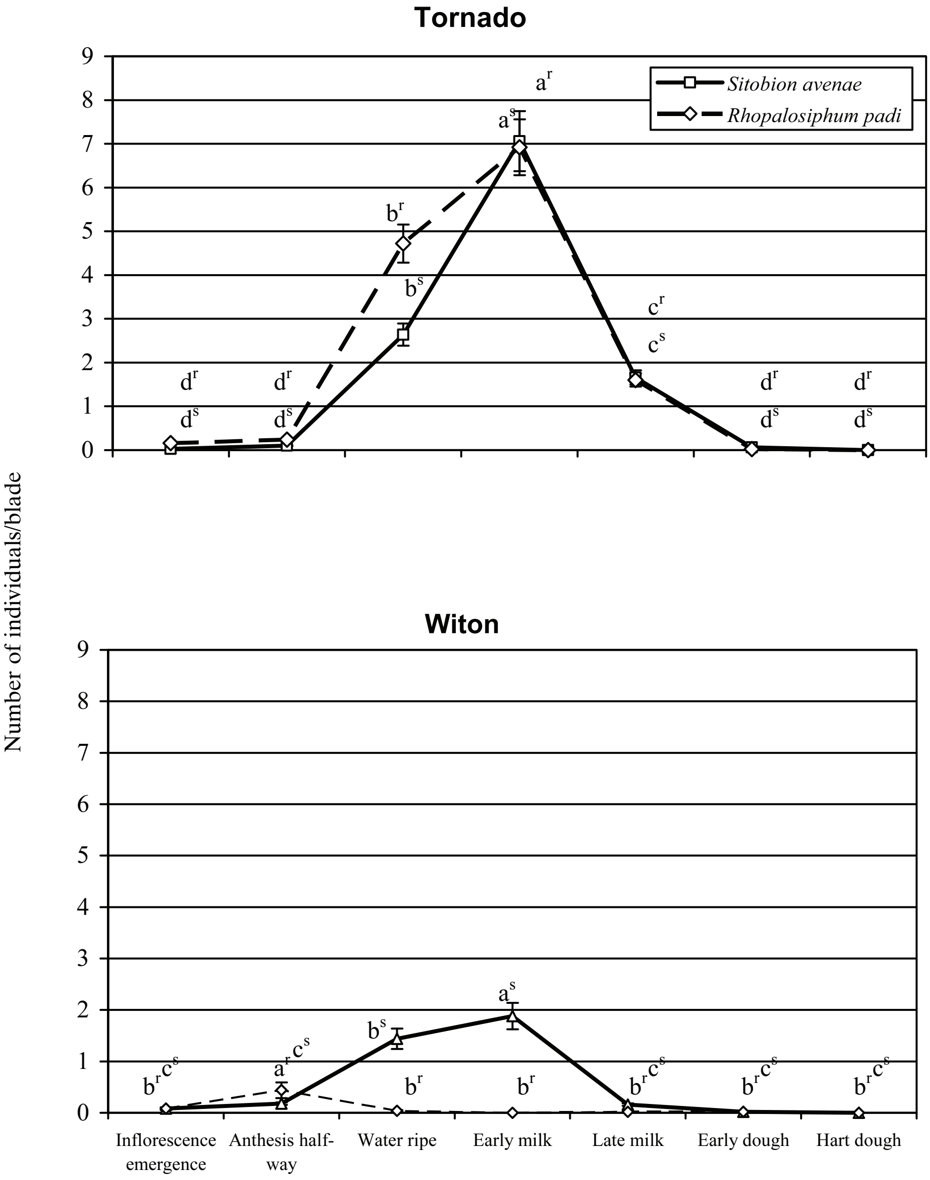

Figure 1. Dynamics of the grain aphid and the bird cherry-oat aphid population on the triticale /growth stages after Tottman and Broad (1987)/.
Values signed by various letters are significantly different at $P \leq 0,05$ (Tukey's test).
Signs "r" and "s" concern *R. padi* and *S. avenae*.

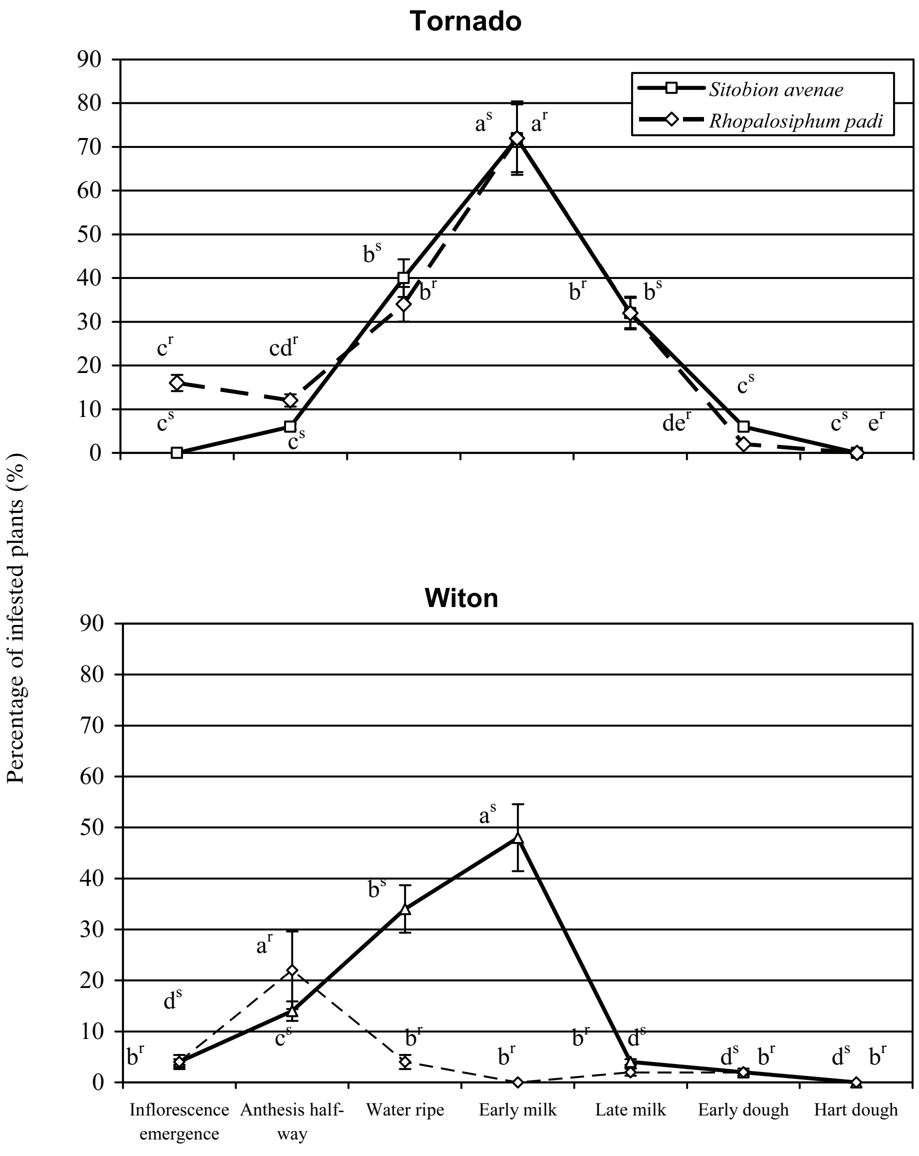

Figure 2. Percentage of infested plants by the grain aphid and the bird cherry-oat aphid during triticale vegetation /growth stages after Tottman and Broad (1987)/
Values signed by various letters are significantly different at P≤0,05 (Tukey's test).
Signs "r" and "s" concern *R. padi* and *S. avenae*.

Table 1. Density of the grain aphid and the bird cherry-oat aphid on the triticale

Cultivar	Number of individuals/blade	
	At peak density $\bar{x} \pm SE$	An average during vegetation season $\bar{x} \pm SE$
Rhopalosiphum padi		
Tornado	6.92 ± 0.58a	1.95 ± 0.18a
Witon	0.44 ± 0.06c	0.09 ± 0.06c
Sitobion avenae		
Tornado	7.06 ± 0.29a	1.65 ± 0.16a
Witon	1.88 ± 0.19b	0.54 ± 0.08b
$F_{3,6}$	257.92	125.54
NIR	1.06	0.38

Values in the same columns signed by various letters are significantly different at P ≤ 0.05 (Tukey's test).

Table 2. Percentage of infested plants by the grain aphid and the bird cherry-oat aphid on the triticale

Cultivar	Number of individuals/blade	
	At peak density $\bar{x} \pm SE$	An average during vegetation season $\bar{x} \pm SE$
Rhopalosiphum padi		
Tornado	72.00 ± 5.77a	24.00 ± 2.80a
Witon	22.00 ± 5.25b	4.8 ± 61.68c
Sitobion avenae		
Tornado	72.00 ± 6.93a	22.29 ± 2.40a
Witon	48.00 ± 4.62ab	15.14 ± 2.07b
$F_{3,6}$	6.63	139.13
NIR	28.67	3.61

Values in the same columns signed by various letters are significantly different at P ≤ 0.05 (Tukey's test).

Table 3. Values of the population parameters of the grain aphid and the bird cherry-oat aphid on seedlings of the triticale

Aphid species	Triticale cultivars	Parameters		
		Prereproductive period (days) $\bar{x} \pm SE$	Daily fecundity/female $\bar{x} \pm SE$	Intrinsic rate of natural increase (r_m) $\bar{x} \pm SE$
Rhopalosiphum padi	Tornado	6.92 ± 0.10b	5.49 ± 0.23a	0.3853 ± 0.0030a
	Witon	7.08 ± 0.13b	4.87 ± 0.22a	0.3657 ± 0.0030a
Sitobion avenae	Tornado	7.84 ± 0.32ab	3.97 ± 0.34b	0.3129 ± 0.0033b
	Witon	8.32 ± 0.40a	2.50 ± 0.32c	0.2508 ± 0.0040c
$F_{3.86}$		5.99	43.31	72.60
NIR		0.99	0.79	0.01

Values in the same columns signed by various letters are significantly different at P ≤ 0.05 (Tukey's test)

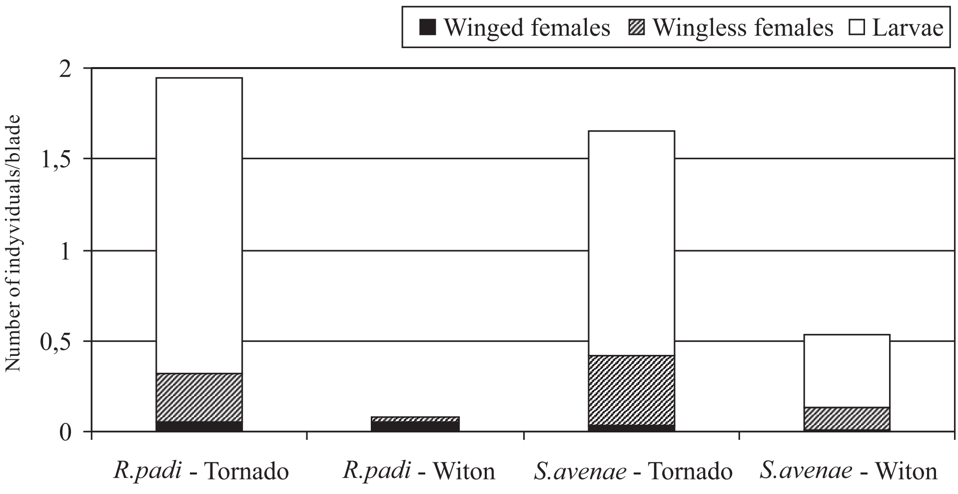

Figure 3. Population structure of the grain aphid and the bird cherry-oat aphid on the triticale

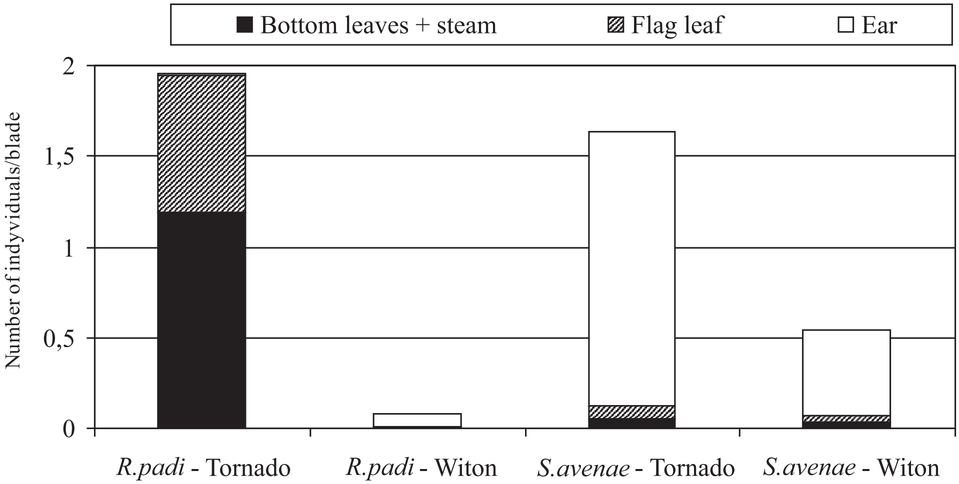

Figure 4. Location of the grain aphid and the bird cherry-oat aphid on selected organs of the triticale

Discussion

The comparison of population of the aphid species on the triticale cultivars at the peak of density and during the entire vegetation season proved that tested cultivars differed in susceptibility to *S. avenae* and *R. padi*. Our studies as well as earlier work showed that grain aphid on winter wheat and triticale achieved peak of population at early milk ripe (Kakol & Mietkiewski, 2001; Ciepiela *et al.*, 2006). Leszczyński *et al.* (1990) stated, that the bird cherry-oat aphid population achieved the highest density on winter wheat at anthesis. However, Ciepiela *et al.* (2006) stated that on triticale, this species, occurred was most numerous at early milk ripe. These differences may be the result of significant changes in *R. padi* biology, which followed over the last years, such as various time of mass abundance, different way of the colonization of plants, various share of sexual morphs in the population, and colonization of winter crops during autumn (Ruszkowska, 2002). Low level of acceptance of the Witon cv. resulted from antibiosis, especially in relation to grain aphid. Thus a significant increase of the prereproductive period, and a decrease of daily fecundity and intrinsic rate of natural increase (r_m) were observed. This data corresponds with the results of Ciepiela *et al.* (1999), who stated, that such antibiotic properties, as the ability of host plants to reduce growth and development of the aphid population, are an important mechanism of triticale

Table 4. Number of analyzed EPG patterns, registered during feeding of the grain aphid and the bird cherry-oat aphid on seedlings of the triticale

Aphid species	Triticale cultivars	Number of patterns				
		Np $\bar{x} \pm SE$	ABC $\bar{x} \pm SE$	E1 $\bar{x} \pm SE$	E2 $\bar{x} \pm SE$	G $\bar{x} \pm SE$
Rhopalosiphum padi	Tornado	10.00 ± 1.51a	11.00 ± 1.31a	1.10 ± 0.38a	1.10 ± 0.38a	0.30 ± 0.22a
	Witon	9.90 ± 0.62a	10.70 ± 0.50ab	1.30 ± 0.30a	1.20 ± 0.33a	0.60 ± 0.22a
Sitobion avenae	Tornado	5.90 ± 1.21b	7.30 ± 1.24b	2.10 ± 0.41a	2.00 ± 0.37a	0.70 ± 0.26a
	Witon	7.60 ± 0.89ab	8.70 ± 1.45ab	1.30 ± 0.41a	1.40 ± 0.36a	0.80 ± 0.26a
$F_{3,27}$		7.04	4.89	1.65	**2.38**	**0.66**
NIR		2.84	3.61	1.67	1.24	1.01

Np non-probing, ABC penetration of peripheral tissues (epidermis and mesophyll), E1 salivation into sieve elements, E2 phloem sap ingestion, G xylem sap ingestion.
Values in the same columns signed by various letters are significantly different at P ≤ 0.05 (Tykey's test)

Table 5. Total duration (min) of the analyzed EPG patterns, registered during feeding of the grain aphid and the bird cherry-oat aphid on seedlings of the triticale

Aphid species	Triticale cultivars	Duration of patterns (min)					
		Np $\bar{x} \pm SE$	ABC $\bar{x} \pm SE$	E1 $\bar{x} \pm SE$	E2 $\bar{x} \pm SE$	E1+E2 $\bar{x} \pm SE$	G $\bar{x} \pm SE$
Rhopalosiphum padi	Tornado	5.54 ± 1.52a	13.94 ± 1.90a	4.69 ± 2.16a	35.69 ± 13.74b	40.34 ± 14.76b	6.95 ± 4.65a
	Witon	5.81 ± 1.66a	11.35 ± 2.13a	8.67 ± 3.16a	24.82 ± 8.06b	33.49 ± 7.87b	22.30 ± 8.69a
Sitobion avenae	Tornado	3.80 ± 1.37a	10.99 ± 2.99a	4.28 ± 1.17a	83.38 ± 14.79a	88.56 ± 15.57a	13.14 ± 5.80a
	Witon	6.78 ± 1.46a	11.00 ± 1.72a	6.59 ± 1.93a	61.54 ± 8.20a	66.34 ± 7.96ab	18.44 ± 11.88a
$F_{3,27}$		0.69	0.37	0.63	15.15	5.57	0.58
NIR		5.73	9.05	9.71	28.27	40.88	33.57

Np non-probing, ABC penetration of peripheral tissues (epidermis and mesophyll), E1 salivation into sieve elements, E2 phloem sap ingestion, G xylem sap ingestion, E1 + E2 duration of total phloem activity.
Values in the same columns signed by various letters are significantly different at P ≤ 0.05 (Tykey's test)

resistance to grain aphid. Both aphid species on the triticale cultivars were characterized also by a different duration of the ingestion of phloem sap and total phloem penetration. According to LESZCZYŃSKI & Tjallingii (1994), the duration of activities connected with the penetration of phloem tissue signified a sensitive indicator of plants resistance to aphids. Moreover, the unfavourable effect of Witon cv. had various character for different aphid species, the grain aphid was less numerous on its plants, and infested a lower number of blades than on Tornado cv. However, this species was characterized by strong domination of larvae in population structure and by preference of ears as a feeding place of both studied cultivars. In the case of *R. padi*, a higher number of larvae than imago was found only in population which developed on Tornado cv., rather than on Witon domination of winged females was observed. It may suggest that these cultivars limited the growth and development of aphids and induced its migration on other host plants. Besides, the bird cherry-oat aphid showed various preferences in relation to plant organs chosen as feeding sites. On more accepted Tornado cv. *R. padi* individuals fed on bottom parts of plants, while on Witon cv. they moved onto the ears.

A shorter prereproductive period, and higher daily fecundity and values of intrinsic rate of natural increase of *R. padi* population in relation to *S. avenae* on the both cultivars suggest a higher reproductive potential of the bird cherry-oat aphid on the triticale seedlings. On the other hand, it may be also connected with higher adaptation of this species to feeding on triticale leaves. Various levels of preference of the triticale organs by the aphid species may be also the result of different ways of penetration of the host tissues. Since the bird cherry-oat aphid more often penetrated peripheral tissues than *S. avenae*. It may result in better adaptation of feeding within leaf parenchyma tissue, than in stem and ear axle (URBAŃSKA & NIRAZ, 1990). The grain aphid is probably more adapted to the penetration of phloem tissue, and thus, it is more directly harmful to the triticale plants, because it collects higher quantities of assimilates transported via phloem from vegetative parts of plants to ears. A higher indirect harmfulness of *S. avenae* may be the result of intense secretion of honeydew, favorable fungal pathogens development and/or infection by viruses.

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Porównanie występowania mszycy zbożowej (*Sitobion avenae* (Fabricius, 1775)) i mszycy czeremchowo-zbożowej (*Rhopalosiphum padi* (Linnaeus, 1758)) /Hemiptera, Aphidoidea/ na pszenżycie ozimym

Streszczenie

Celem podjętych badań było porównanie występowania, tępma rozwoju osobniczego i rozmnażania oraz przebiegu penetracji tkanek roślinnych przez *S. avenae* i *R. padi* na pszenżzycie ozimym. Stwierdzono, iż odmiana Tornado odznaczała wyższsa podatnością na oba badane gatunki mszyc niż pszenżyto Witon, a różnice te w znacznym stopniu warunkowane byłly mechanizmem antybiozy. Maksimum liczebności populacji badanych gatunków mszyc zbożowych występowało w okresie wczesnej dojrzałości mlecznej pszenżyta, za wyjątkiem *R. padi*, która na odmianie Witon występowała najliczniej w stadium kwitnienia.

W strukturze populacji mszycy zbożowej, na obu badanych odmianach pszenżyta i mszycy czeremchowo-zbożowej na odmianie Tornado dominowały larwy, natomiast w przypadku *R. padi* na odmianie Witon dominującym stadium rozwojowym były samice uskrzydlone. Stwierdzono ponadto, iż *S. avenae* na obu badanych odmianach i *R. padi* na pszenżycie Witon preferowały klosy jako miejsce zerowania, podczas gdy na odmianie Tornado przeważająca cześć populacji mszycy czeremchowo-zbożowej występowała na liściach dolnych i łodydze. Osobniki *R. padi*, rozwijające się na siewkach badanych odmian pszenżyta szybciej osiągały dojrzałość płciową oraz odznaczały się wyższą płodnością i wyższym wskaźnikiem wrodzonego tempa wzrostu populacji (r_m) niż *S. avenae*. Podczas penetracji tkanek badanych roślin samice mszycy czeremchowo-zbożowej częściej nie nakłuwały tkanek badanych odmian, lub nakłuwały tkanki peryferyjne, natomiast bezskrzydłe samice *S. avenae* dłużej żerowały w elementach floemu. W pracy omówiono różne aspekty adaptacji obu badanych gatunków mszyc zbożowych do pszenżyta ozimego.