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Population structure of *Ropalosiphum padi* (Linnaeus, 1758) /Hemiptera, Aphidoidea/ in Wielkopolska region in 2003-2008 in the context of winter cereals threat of BYDV expansion

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Abstract

Rhopalosiphum padi (Linnaeus, 1758) is a dominating species in the population of all cereal aphids in Poland, and its anholocyclic forms are major cereal virus vectors, especially BYDV. Global warming which stimulates the development of aphids-virus vectors is highly important in the spreading of anholocyclic forms of *R. padi* and cereal viruses. BYDV is of economic importance in regions with a warmer climate. The direction of territorial expansion of permanently parthenogenetic aphids are an indicator of this phenomenon.

In years 2003-2008 in the region of Wielkopolska all-year-long observations were carried out both on the primary host – *Prunus padus* L. trees and on winter cereals. Aphids were caught also using the Johnson's suction trap. Meanwhile, through the entire duration of the observation values of mean daily temperatures were registered.

R. padi is a dominating species in suction trap catches, especially in recent years it was most numerously caught in autumn. Anholocyclic forms of this species were recorded in Poznań for the first time in 1989. During the duration of the research temperatures conditioning the formation of these forms were registered. Also, during each year of the observation the presence of these forms in varying intensity was recorded.

The presented results of a six-year-long research are a continuation of many years of research concerning cereal aphids. Its aim is to signal the appea-

rance of new problems which should be taken into account when updating the methods of protection.

Introduction

Rhopalosiphum padi (Linnaeus, 1758) is often a species dominating in all cereal aphid populations in Poland, while its anholocyclic forms are major cereal virus vectors, especially BYDV (Mann & Harrington, 1996). Climate warming in Poland has a significant impact on the development of anholocyclic forms of *R. padi* and the cereal virus spreading, as it stimulates the development of aphids – virus vectors. Temperature of 25°C or above which continues for three days causes permanent parthenogenetic development of the entire aphid population (Ruszkowska, 1990b). The BYDV is important economically in regions with warmer climate when primary infection takes place on winter cereal sprouts. The territorial expansion of permanently parthenogenetic aphids is an indicator of these changes (Ruszkowska, 2002).

The problem of the virus disease which is Barley Yellow Dwarf is a relatively new topic of concern so far in the warmer regions of Poland. The presence of *R. padi* aphids as major virus vectors on winter cereals crops in autumn has become troublesome in recent years. In order to find out about a threat by the new forms of *R. padi* the research was conducted which aimed at a detailed analysis of population structure of this species in the region of Wielkopolska based on field studies as well as by the use of suction trap catches. The analysis of *R. padi* aphid population structure is a continuation of the research conducted since 1973 and thus allows one to follow changes within the population of this species: the number of holocyclic and anholocyclic forms as well as winged sexual morphs – males.

Virus analysis of plants settled in the autumn by aphids in the region of Wielkopolska and an attempt to confirm the presence of viruses directly in aphid bodies as caught in the suction trap allows one to assess a real threat. It also enables one to work out a precise program of forecasting of the growth of anholocyclic aphids number and to warn of the time of infected aphids flights. The designation of percentage of infected aphids in a population is important because not all anholocyclic forms are infected.

The presented research enables one to determine biodiversity changes dynamics and, apart from direct relevance for agriculture, reveals some of the consequences of climate warming in the environment to aphid development.

Material and methods

The research was carried out in years 2003-2008 in the Wielkopolska region. The number and time of aphid flights was registered using the Johnson's

suction trap, which was situated in the Institute of Plant Protection in Poznań. Samples were collected daily and designated under stereoscopic microscope. Anholocyclic forms of *R. padi* were selected due to the fact that in ethyl alcohol the embryos of these forms become dark brown, while of the holocyclic ones – light grey (LOWLES, 1995).

Meanwhile, all-year-long observations were carried out both on the primary host – *Prunus padus* L. and on winter cereals. Observations of eggs were carried out in spring of each year. The number of laid eggs was registered on bird cherry (eggs were collected from 100 of 50 cm long shoots from four parts of the tree, from lower twigs), the time of hatching and the development of consecutive morphs were observed. The collected shoots were placed in an incubator under control (Sanyo Incubator MIR – 153). Fundatrices, which hatched from the eggs, were reared on seedlings of *P. padus* in a climate chamber. In such conditions *R. padi* holocyclic forms tested biologically were treated as control for further aphid virus vectors analyses. Both in the incubator and in a climate chamber the temperature and light were determined on the basis of the level of natural conditions that occurred then.

In the region of Wielkopolska in 2007 five localities were selected in which winter barley was cultivated with a 20 km distance from each other. They were analysed with respect to the BYDV-MAV and BYDV-PAV presence. In 2008 the samples were collected from one locality (Turek) and the analyses were broadened to include BYDV-RPV. Samples were collected in autumn crossing the fields diagonally, for 5 plants were picked up with aphids feeding on them. Each sample consisted of 10 plants. Winter cereals collected from the fields were brought to the Institute of Plant Protection in Poznań – National State Institute (Department of Entomology and Department of Virology and Bacteriology) to further rearing and to diagnose them for virus presence. From each location 25 insects were collected. Aphids caught in the Johnson's suction trap in 2007 also underwent virus analyses to determine the presence of BYDV-MAV and BYDV-PAV. For the purpose 5 dates were decided on during which two samples were analysed for the sake of prognosis (A and B – 10 aphids in a sample). In virus analyses serological tests were applied, including the Elisa test (CLARK & ADAMS, 1977; CROWTHER, 2001) and molecular tests – PCR.

During the whole period of the research the course of temperature values in Poznań was monitored using the Weatherscope application online (WeatherscopeSetup.exe) and satellite data from Rothamsted Research Station in Great Britain. The collected data was analysed with respect to mean daily temperatures (number of days in a year with average daily temperature $\geq 25^{o}C$).

Results

In 2003-2008 in total 146 494 aphids were collected by means of the Johnson's suction trap in Poznań. In all the years of the observation *R. padi* was the most often caught species as it constituted from 76.6% in 2003 to 44.1% in 2007 of all the collected aphid species. Until recently the greatest number of aphids of this species was recorded in summer. However, in recent years autumn has clearly dominated. When days were warmer in autumn and when winter was mild (2005-2007), aphids were caught even in December (Fig. 1).

In the first year of the observation a large increase in *R. padi* males was recorded (2112 – 37.2% of all the caught autumnal *R. padi*), and in the subsequent years a gradual decrease in their number was observed (Fig. 2). In 2008 1141 specimens were registered which amounted to 10.1% of all the caught autumnal *R. padi* specimens. During the research a parallel progressing delay in the times of appearance of the first *R. padi* males was also registered. They appeared the earliest in 2004 – 4 September (36^{th} week), and the latest in the last years, in 2007 – 8 October (41^{th} week) and in 2008 – 16 October (42^{nd} week) (Fig. 3).

The number of diversified autumnal morphs and forms of *R. padi* is presented in Table 1. During the past six years of the observation a percentage decrease in the number of males in relation to all the caught autumnal forms of *R. padi* was clearly observed. A reverse tendency was observed in relation to the number of anholocyclic forms of *R. padi*.

R. padi anholocyclic forms in Johnson's suction trap catches in the city of Poznań appeared the earliest in 2006 – on 26 August. The latest date when these morphs were observed was in year 2005 – on 22 September and in 2007 – on 24 September. The peak period of anholocyclic forms growth took place in the autumn of each year: from mid-September until mid-October. The ratio of holo- and anholocyclic *R. padi* forms number and the dates of their appearance are presented in Figures 4 – 9.

In spring, observations on bird cherry trees the eggs out of which aphids hatched constituted on average 89% of all the overwintered eggs. During the entire growth season observations concerning the appearance of particular morphs of *R. padi* were conducted (Tab. 2). Two final years of the observation are particularly relevant because fundatrices appeared very early, whereas males and oviparae were observed the latest.

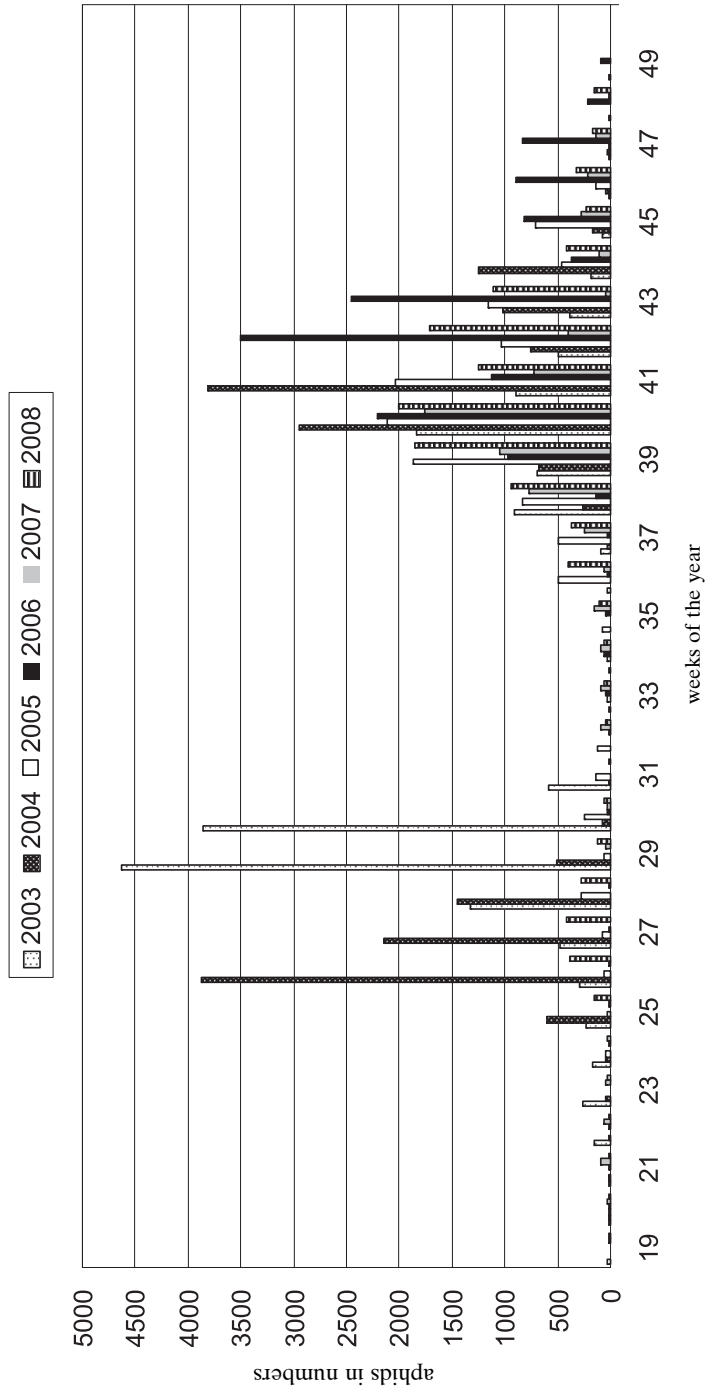

Figure 1. Dynamics of flights of *Rhopalosiphum padi* caught by suction trap in 2003-2008, Poznań

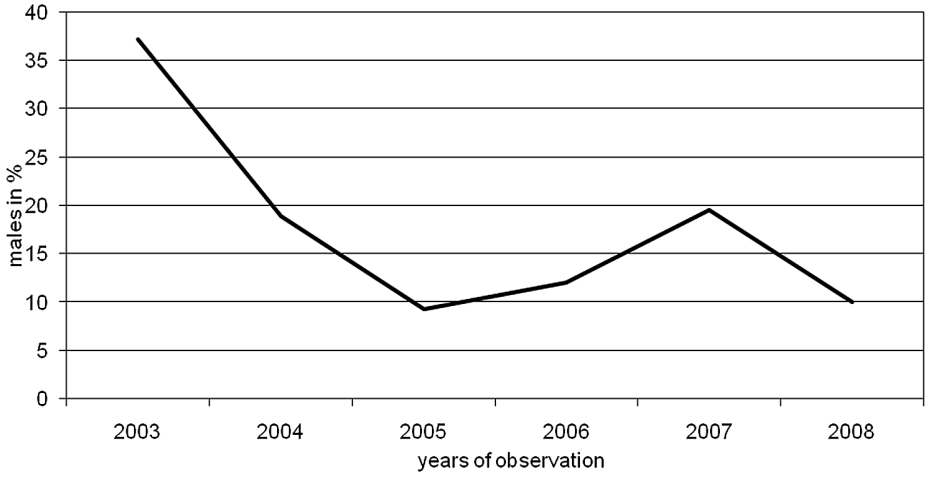

Figure 2. Percentage of *Rhopalosiphum padi* males in the population of this species in autumnal suction trap catches in 2003-2008

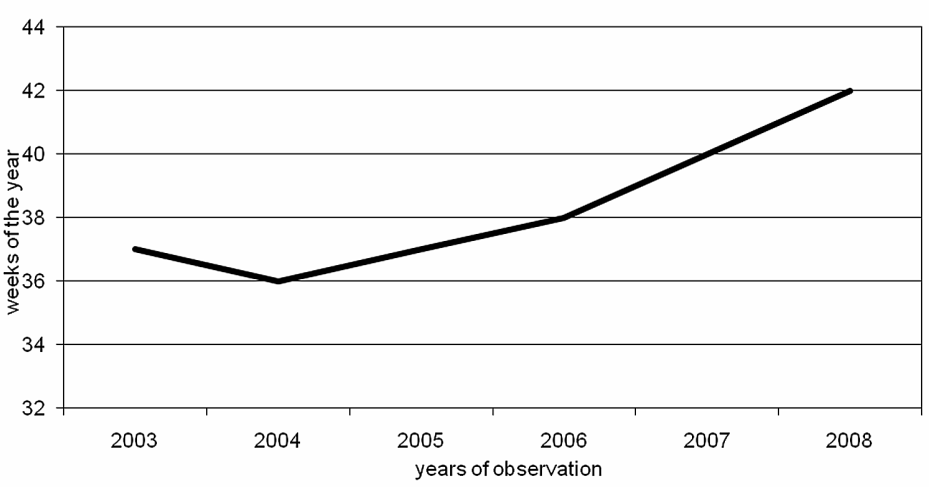

Figure 3. Time of first appearance of *Rhopalosiphum padi* males in suction trap in 2003-2008

Table 1. Population structure of autumnal morphs and forms of *Rhopalosiphum padi* in suction trap catches, in 2003-2008

Year	*Gynoparae*, mothers of sexual morphs	Males in numbers (% of population)	Pernament virginiopare forms (anholocyclic)	Holo- / anholocyclic forms	Autumnal morphs and forms
2003	3473	2112 (37.2%)	89 (1.5%)	39.0	5674
2004	8236	2087 (18.9%)	603 (5.4%)	13.6	11026
2005	8600	965 (9.3%)	704 (6.8%)	12.2	10269
2006	10134	1654 (12.1%)	1 852 (13.5%)	5.4	13640
2007	4702	1163 (19.6%)	49 (0.8%)	77.9	5914
2008	9233	1141 (10.0%)	972 (8.5%)	9.4	11342

Table 2. Several morphs of *Rholpalosiphum padi* observed in natural environment, time of first occurrence in Poznań, in 2003-2008

Year	Number of eggs	Fundatrices	Migrantes	Gynoparae	Males	Oviparae
2003	104	29.03	26.05	19.09	2.10	28.09
2004	59	11.04	3.06	30.08	4.09	3.09
2005	121	8.04	28.05	8.09	3.10	19.09
2006	132	2.04	19.05	16.09	4.10	21.09
2007	125	16.03	14.05	25.09	8.10	1.10
2008	116	25.03	20.05	24.09	16.10	4.10

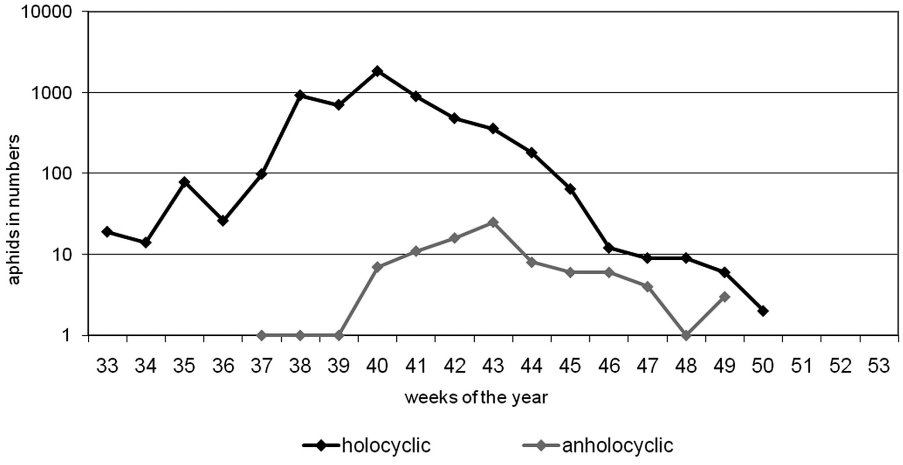

Figure 4. Dynamics of holo- and anholocyclic forms of *Rhopalosiphum padi* in numbers. Time of occurrence in suction trap in 2003

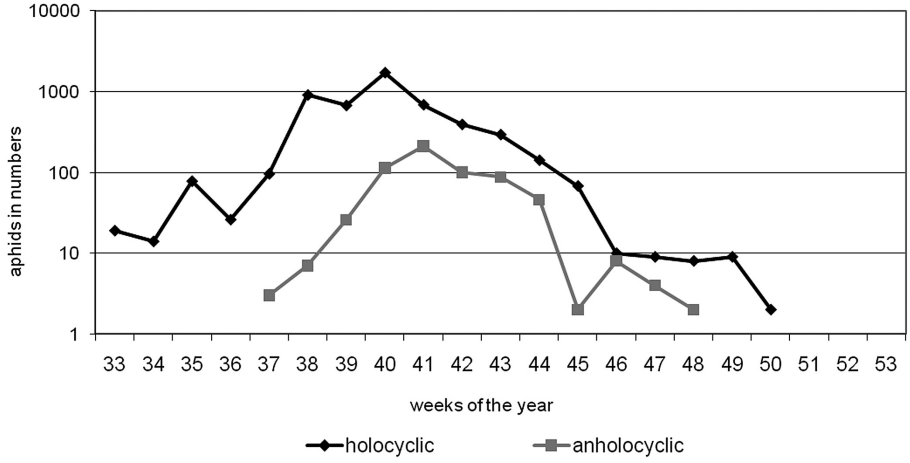

Figure 5. Dynamics of holo- and anholocyclic forms of *Rhopalosiphum padi* in numbers. Time of occurrence in suction trap in 2004

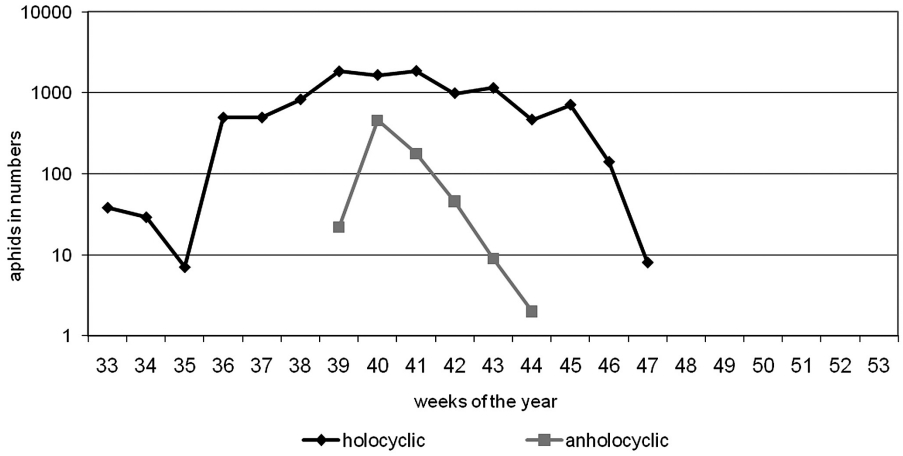

Figure 6. Dynamics of holo- and anholocyclic forms of *Rhopalosiphum padi* in numbers. Time of occurrence in suction trap in 2005

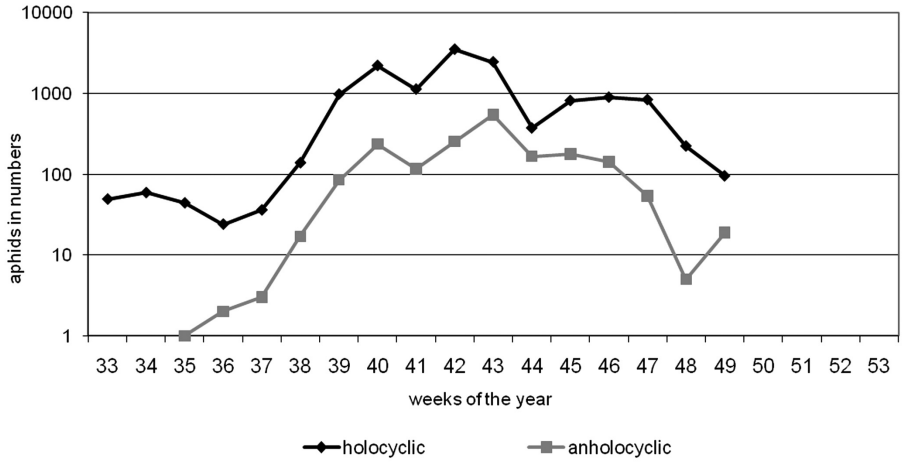

Figure 7. Dynamics of holo- and anholocyclic forms of *Rhopalosiphum padi* in numbers. Time of occurrence in suction trap in 2006

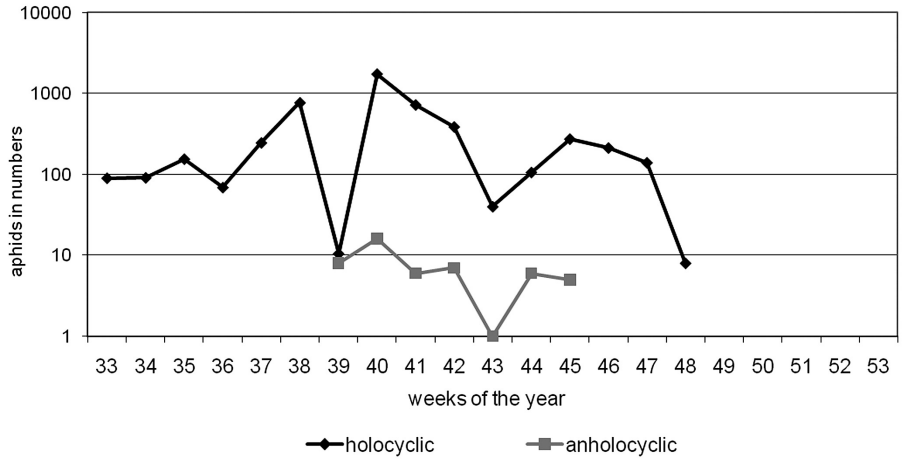

Figure 8. Dynamics of holo- and anholocyclic forms of *Rhopalosiphum padi* in numbers. Time of occurrence in suction trap in 2007

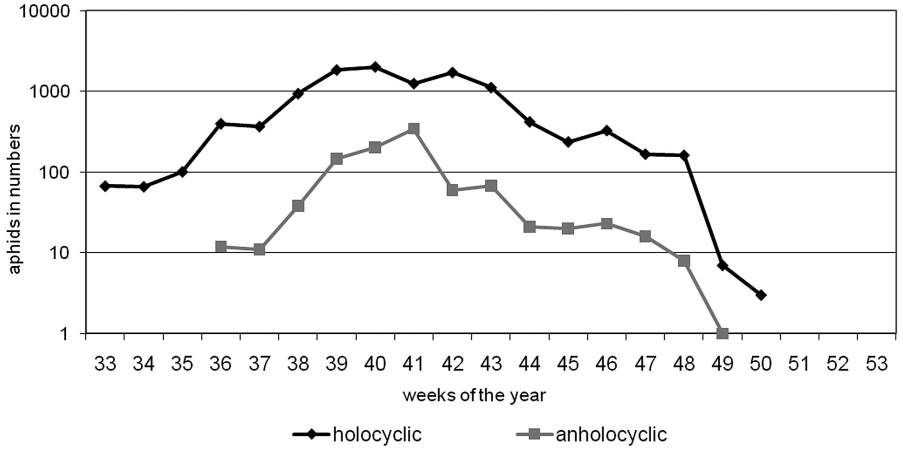

Figure 9. Dynamics of holo- and anholocyclic forms of *Rhopalosiphum padi* in numbers. Time of occurrence in suction trap in 2008

Plants which did not show clear signs of virus infection in autumn were collected for virus analyses. In 2007 winter barley samples were collected on 12 December. As a result of the analyses only BYDV-PAV infection was confirmed on three of them. In 2008 plants were collected on 20 October and likewise BYDV-PAV infection was confirmed (Tab. 3). The analyses of samples of aphids caught in autumn of 2007 using the Johnson's suction trap in Poznań revealed BYDV-MAV and BYDV-PAV infections in aphid bodies only since the second half of September (Tab. 4).

Table 3. Percentage of winter barley plants collected from different localizations infected by different viruses of BYD, in 2007-2008

Year and localization		MAV	PAV	RPV
2007	Kowalewo	0	20	-
	Kiełczewo	0	0	-
	Prochy	0	60	-
	Batorówko	0	0	-
	Myślęcin	0	20	-
2008	Turek	0	68	0

Table 4. Aphids of *Rhopalosiphum padi* infected by BYDV in 2007 (aphids caught by suction trap)

Date	MAV		PAV	
	A*	B*	A*	B*
7-11.09	+	-	-	-
18-22.09	+	+	+	+
29.09-1.10	+	+	+	+
6-8.10	+	+	+	+
18-19.10	+	+	+	+

* two samples consisting of 10 aphids each

In the region of Wielkopolska during each year of the observation temperatures conditioning the formation of *R. padi* anholocyclic forms were registered. In that region temperatures inducing anholocyclic development of *R. padi* have been lasting unremittingly since 1999 (Ruszkow-

SKA, 2006; RUSZKOWSKA & STRAŻYŃSKI, 2007) (Fig. 10). In year 2003 – 8 June these temperatures were recorded the earliest. Aphids on winter cereals developed the longest in 2007 – until 22 December, and in 2008 – until 28 December.

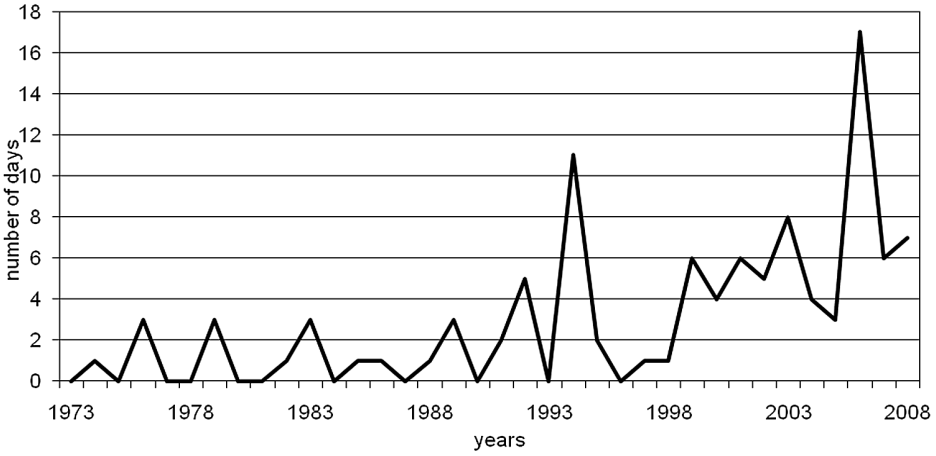

Figure 10. Number of days a year with mean daily air temperature ≥25°C in Poznań, in 1973-2008

Discussion

The results of the Johnson's suction trap catches carried out between 2003-2008 in Poznań showed that in all the years of the observations *R. padi* was a decisive dominant. Earlier research by STACHERSKA & RUSZKOWSKA (1978) carried out between 1973-1975 in the Institute of Plant Protection in Poznań showed that *R. padi* is the most numerously caught species in the suction trap. In 2003-2008 two periods of intensified insect flight activity were observed: period of summer dispersion and autumnal re-emigration on *P. padus*. Until recently *R. padi* aphids were caught in the greatest number during summer (RUSZKOWSKA, 1987; RUSZKOWSKA & ZŁOTOWSKI, 1977; STACHERSKA & RUSZKOWSKA, 1978). However, in recent years of observations autumnal catches are more numerous and aphids are still caught in the beginning of December (2005-2007) (RUSZKOWSKA , 1990a; 1990b; STRAŻYŃSKI, 2005; 2006). The smallest number of aphids was caught in 2007. This can suggest a smaller share of winged forms in the population as a result of unfavourable developmental conditions, or as a result of mass development on corn the crop area of which has increased in recent years. Aphids, having access to large storage of phy-

siologically younger host plants and in favourable conditions do not make winged forms (DIXON, 1998). Different times of appearance of particular morphs in given years were observed on the primary host of *R. padi*. Spring migration of winged forms of *R. padi* females from *P. padus* on cereals and grasses usually took place in the third decade of May (except for 2004, when it took place on 3 June). One may draw a conclusion that an earlier development of the primary host in spring stimulates an earlier flight of migrants onto cereals and grasses.

The number of diversified autumnal morphs and forms of *R. padi* aphids in the Johnson's suction trap catches in 2003-2008 shows yearly occurrence of anholocyclic forms. The regular appearance of males is a characteristic feature of aphids which undergo a holocyclic development. The duration of day but most of all temperature, both of which are changeable factors, influence the formation of sexual morphs of host alternated (heteroecious) aphids. RUSZKOWSKA (2002) concludes that a lowering of male number is the result of higher temperatures in the period of morph differentiation which stimulates gynoparae and which prolongs the period of summer generations presence. There are also delays in gynoparae delivery. Consistently male delivery is delayed and thus they do not come in time to fertilize females. Finally, one may find fewer and fewer eggs. Such dependencies were shown also in field experiments.

The registration of temperature course confirms the appearance of threshold value, determined in climate chamber, which induces changes in the developmental cycle of *R. padi*. Directions of warmth and cold flow to Poland's territory make the south-western and western regions the warmest. There the anholocyclic forms of *R. padi* as well as winter cereals affected with BYDV were registered for the first time and, so far have occurred in the greatest intensity (RUSZKOWSKA, 2006). Since 1973 the number of days with temperature changing *R. padi* life cycle in Poznań clearly shows increasing tendencies. Further increase of temperatures lets one assume that the problem of infections to autumnal crops of cereals will have more significance. Warmer autumns may cause the formation of more numerous winged morphs which will increase the number of secondary infections with BYDV.

One should keep in mind that the presence of aphids on crops does not mean that they are infected with viruses, since it is aphids which have to be infected first. In some localities aphids were found on winter cereals and plants on which they fed were virus-free (STRAŻYŃSKI & TRZMIEL, 2008). Expansion of BYDV results from the extension of aphids-virus vectors presence the development of which is enabled by climate warming. Therefore, keeping in mind this progressing process and in particular the frequency of higher temperatures during summer one may foresee further changes in the structures of all aphid species populations. Crop lustration and monitoring by means of the Johnson's suction trap along with registration of data on the course of temperature are the

most effective methods of signaling the times and increase of virus vectors flights (RUSZKOWSKA, 1998; 2003; 2004; RUSZKOWSKA & STRAŻYŃSKI, 2007).

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Struktura populacji mszyc *Rhopalosiphum padi* (L.) /Hemiptera, Aphidoidea/ w Wielkopolsce w latach 2003-2008 w aspekcie zagrożenia zbóż ozimych ekspansją wirusów żółtej karłowatości jęczmienia

Streszczenie

Mszyca czeremchowo-zbożowa (*Rhopalosiphum padi* L.) jest gatunkiem dominującym w populacji wszystkich mszyc zbożowych w Polsce, a jej anholocykliczne formy są głównymi wektorami wirusów zbóż, szczególnie żółtej karłowatości jęczmienia. Istotne znaczenie w rozprzestrzenianiu się anholocyklicznych form *R. padi* oraz wirusów zbóż ma ocieplanie się klimatu, stymulujące rozwój mszyc-wektorów. Żółta karłowatość jęczmienia ma znaczenie ekonomiczne w regionach o cieplejszym klimacie. Kierunki ekspansji terytorialna permanentnie dzieworodnych mszyc są wskaźnikiem tego zjawiska.

W latach 2003 – 2008 prowadzono w Wielkopolsce całoroczne obserwacje zarówno na żywicielu pierwotnym – drzewach czeremchy zwyczajnej (*Prunus padus* L.), jak i na oziminach. Mszyce odławiano również za pomocą aspiratora ssącego Johnsona. Równocześnie przez cały okres obserwacji rejestrowane były wartości średnich dobowych temperatur.

R. padi to dominujący w odłowach aspiratorem gatunek, szczególnie w ostatnich latach najliczniej odławiany jesienią. Anholocykliczne formy tego gatunku zostały stwierdzone w Poznaniu po raz pierwszy w 1989 roku. W okresie prowadzonych obserwacji odnotowano temperatury warunkujące powstawanie tych form. Również każdego roku notowano obecność tych form w różnym nasileniu.

Prezentowane wyniki sześcioletnich badań są kontynuacją wieloletnich obserwacji dotyczących mszyc zbożowych. Mają one zasygnalizować wystąpienie nowych problemów, które powinny być uwzględnione w aktualizacji metod ochrony.