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Biodiversity of *Rhopalosiphum padi* (Linnaeus, 1758) /Hemiptera, Aphidoidea/ and BYDV expansion in Poland

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Introduction

What does biodiversity between aphids mean? This group of insects determines forms which depend on environmental factors. The photoperiod, the age of the host plant or the temperature are the factors which condition aphid's life cycle. In the formation of anholocyclic forms in the regions, where in natural conditions the aphids develop holocyclically, it is the high temperature that plays the dominating role and hence eliminates the effect of photoperiodism. In temperature above 25C (daily mean), with little variation for different aphid species, the short day effect does not count, and under the conditions of adequately high temperature only virginoparae develop. So far the mechanism of high temperature impact has not been studied. In such developmental processes it is assumed that certain enzymes play a role (SHIBATA, 1952; ZHOU XILONG, 1995).

Out of all the insect species temperature has the greatest influence on aphids. With a 2°C warming a year five more aphid generations develop, while in case of other insects, e.g. Homoptera, only one, and Diptera, two. Moreover, viviparous aphids have the lowest developmental temperature threshold (-6°) and the shortest period of one generation development (YAMAMURA *et al.*, 1998).

In Poland's natural conditions, until recently most aphid species developed only holocyclically, i.e. having a full cycle in case of gynoparae and sexual morphs, males and oviparous females. Aphids which developed holocyclically overwinter as eggs, and in this case the parthenogenesis is cyclic (SZELEGIEWICZ, 1968; 1978a).

The formation of gynoparae and sexual forms in host-alternating Aphididae, is regulated by means of day length and temperature. Gynoparae give birth on their primary host to only one kind of sexual partner, namely the oviparous females. Sexuparae which occur in the evolutionarily less developed species, give birth to oviparous females and males (SZELEGIEWICZ, 1978a). Gynoparae occur in most species in autumn before the males appear. Temperature significantly affects the length of time of their birth, when a warmer autumn months make it longer. Males, who share their mother with them, develop more slowly, because their differentiation at the embryo stage is caused by adequately low temperatures. Such a type of heteroecy is the youngest in phylogeny and provides aphids with great capabilities to evolve. Precisely, it ensures aphids such superb diversity of morphs and forms.

In regions with a warmer climate most populations of species that develop holocyclically in their native areas with moderate temperature can develop leaving out the sexual forms which become permanently viviparous. The parthenogenesis which takes place then in these anholocyclic forms becomes obligatory and permanent (DIXON, 1998; SIMON *et al.*, 1996a and 1996b).

Most studies on the formation of sexual morphs relate to the functions of a shortening photoperiodism and were carried out in the areas where holo-, anholocyclic, and androcyclic forms have co-existed for a long time. Anholocyclic forms and the possibilities of their return to the holocyclic form was studied previously (WĘGOREK & DEDRYVER, 1987; HARRINGTON *et al.*, 1995).

Perennial observations on cereal aphids in the region of Wielkpolska, Poland, which confirmed the domination of *Rhopalosiphum padi* (Linnaeus, 1758) over other species, also showed changes in its biology. The changes are concerned with different time of their mass occurrence, a different way of plant colonizing, varied proportions of sexual morph occurrence, and the settling of winter cereals in autumn (RUSZKOWSKA, 1987; 1990b; 1993; 1997; 1998; STACHERSKA *et al.*, 1978a; 1978b).

All the new elements in *R. padi* biology, by revealing the so far unknown developmental mechanisms have a practical and theoretical significance. In practice they are relevant for agriculture because of greater harmfulness of the differently developing aphids, especially as virus-vectors. Developmental changes require an updating of the cereal protection program. Rigid requirements as to temperature necessary for the formation of different morphs and forms allow to use aphids as indicators of the climate change. Biological diversity of *R. padi*, the capability to quickly adapt to the environment and, at the same time, its economic importance as a pest on cereals have all made the species become an object of frequent research on genetics and evolution (LOX-

DALE & BROOKS, 1987; HALES & BROOKS, 1990; WIKTELIUS *et al.*, 1990; LESZCZYŃSKI, 1993; BENNETTS, 1995; HARRINGTON *et al.*, 1995; 1998; MARTINEZ TORREZ *et al.*, 1997b; SIMON *et al.*, 1995; 1996a; 1996b; 1998).

Great sensitivity of *R. padi* to climate conditions is reflected in its biology. As a host-alternating species, i.e. such that cyclically changes its host, it develops morphologically diversified generations, the formation of which is determined by precise environmental conditions. *R. padi*'s heteroecy is dimorphic, i.e. its autumnal flight over to the primary host is conducted by two types of migrants: winged gynoparae females and males. Males fertilize wingless females born by the gynoparae already on the primary host (*Prunus padus* L., cherry bird tree) and after the flight from cereals and grass. This type of heteroecy ensures perfect amphimixis which provides the opportunity of a quick adjustment to new conditions (SZELEGIEWICZ, 1978a; TOMIUK, 1987; BLACKMAN & EASTOP, 1994).

Significance of anholocyclics of *R. padi* for agriculture

Anholocyclic forms of *R. padi* are important for agriculture in countries with a warmer climate. These forms are considered to be the most important vectors of diseases caused by the barley yellow dwarf virus (BYDV). It causes a serious economic problem and makes aphids still the object of numerous researches (TATCHELL *et al.*, 1998; MANN & HARRINGTON, 1996).

When *R. padi* develops anholocyclically on secondary host?

A widespread and more extensive presence of *R. padi's* anholocyclic forms in western Europe (DEDRYVER & GELLE, 1982; DEDRYVER, 1983; HARRINGTON *et al.*, 1995; Simon *et al.*, 1995) suggests that these populations may develop in Poland, where they find favourable temperature, which changes their development from holocyclic to anholocyclic and enables them to settle autumnal cereal seedlings. The threshold value of temperature which changes *R. padi* biology in 100% of population is ≥ 25°C during 3 days. This data was obtained in the research conducted in a growth chamber. The presence of anholocyclic forms on winter cereals was first registered in Poland in 1989 (RUSZKOWSKA, 1990b). Since then their populations have been successively observed to increase in number and frequency. They are present on winter cereals only for a few generations until first critical temperature for these species appears (-6°) (RUSZKOWSKA, 1997; 1998). For the first time they overwintered on crops in warmer regions of Poland during the whole winter in 2007 (RUSZKOWSKA, 2007). It caused a potential threat of an infection with viral diseases, and in particular the BYDV.

The confirmation of a global temperature rise is presented in Figure 1.

★ First anholocyclic of *Rhopalosiphum padi* in Poland on winter cereals, first BYDV infection (1989)

Figure 1. Global temperatures in 1860-2006 (http://data.giss.nasa.gov./gistemp/graphs/)

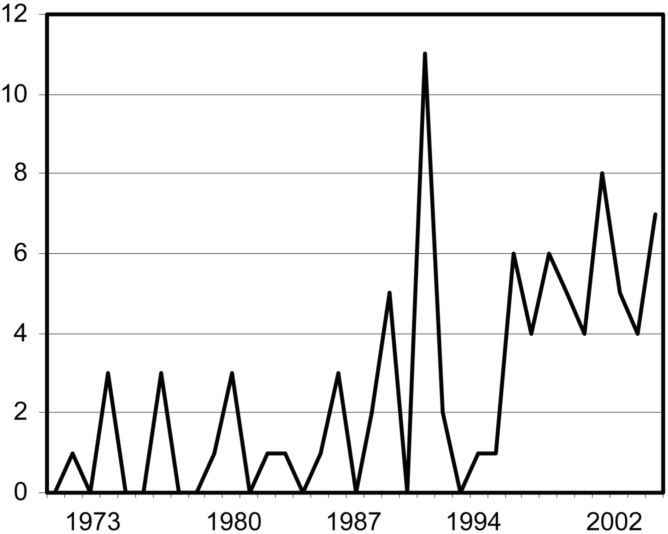


Figure 2. Number of days per year with temperature which altered the life cycle of *Rhopalosiphum padi*: daily mean ≥25°C, Poznań, Wielkopolska

The population structure of *R. padi* autumnal morphs during the last 32 years of observation show changes in their differentiation (Fig. 3).

The number of threshold value of temperature which altered aphid life cycle is presented in Figure 2. The anholocyclic form of *R. padi* occurs only in the warmer regions of Poland, where their geographical distribution is increasing (Fig. 4).

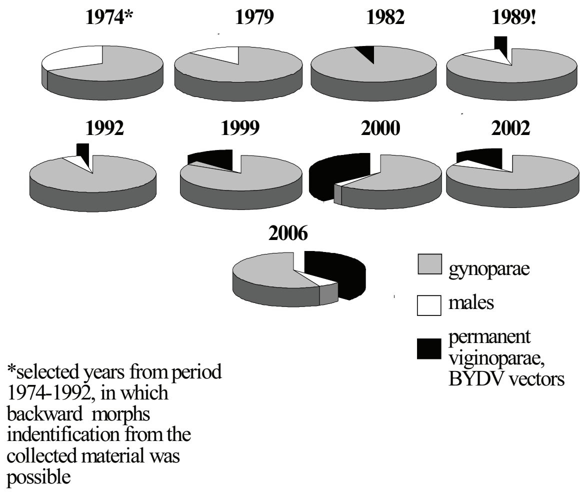
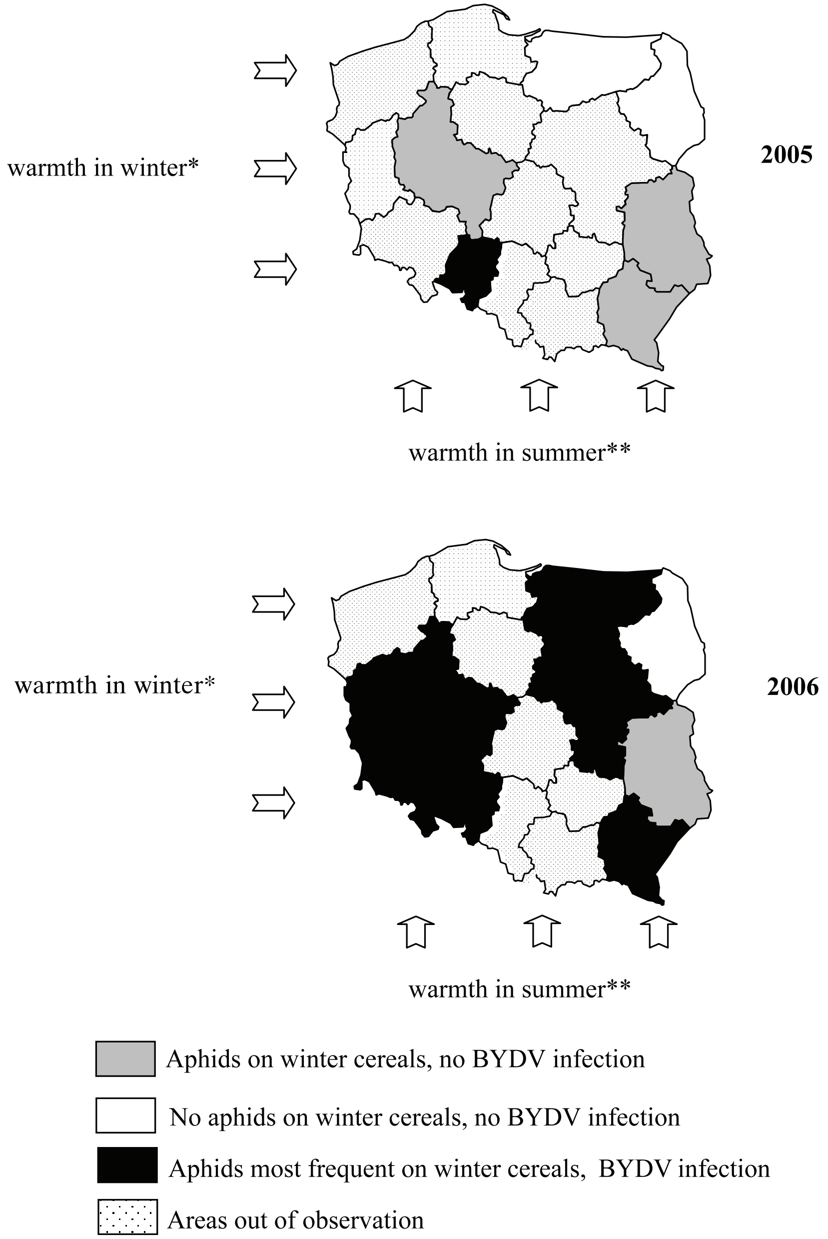


Figure 3. Population structure of *R. padi* autumnal morphs and forms: gynoparae, males and anholocyclic forms separated in suction trap catches in 1974-2006 (selected years)

Autumnal *R. padi* occurrence across different climate regions shows how quick were the changes in geographical distribution of this aphid forms and the resulting BYDV infection (Fig. 4).

Aphid dilemma: holo- and anholocyclic development

Anholocyclic development of *R. padi* can be stimulated by means of tree factors: light, temperature and nutrition quality reactions. The presence of anolocyclic forms in areas where so far they have been developing only holocyclically may suggest an increased reach of migration of these forms from areas in which they have been developing anholocyclically for a long time. It may also be the result of higher temperature's impact on developmental changes in the environment. The knowledge of their values lets one conclude that the anholocyclic forms of *R. padi*, which occur in Poland, may derive from domestic populations in the years when at least for three days the daily mean temperature was 25°C or above. One may thus state that aphids which appear on winter cereals in autumn come from mixed populations, from migrations



* isotherms of January run meridionally and they decrease from west (-1°C) to east (-5°C)

** isotherms of July run evenly with the parallel of latitude and they decrease from south(>18,5°C) to north

Figure 4. *Rhopalosiphum padi* autmnal infestation on winter cereals across different climate regions and BYDV infection in 2005 and 2006

and from domestic clones which develop differently. In the climate conditions of the Wielkopolska region temperatures which enable aphids a change in development have recently been registered. For example, in 1992 there were 5 days with daily mean temperature of 25°C or above, in 1994 there were as many as 11 such days, and in 2000 – 4 (Fig. 2).

The anholocyclic development of *R. padi* conditions permanent parthenogenesis, both on the secondary host as well on the primary host. The permanent parthenogenesis of *R. padi* on *Prunus padus* L. can occur on young plant's seedlings, suckers and offshoots. Therefore, one has to distinguish between anholocyclics on primary- and secondary host in the case of host alternating species (heteroecious).

Rhopalosiphum padi is holocyclic (cyclic appearance ♀♂)
At least 3 days with temperature ≥25 holocycle is switched, a parts start to be anholocyclic, permanent virginopare

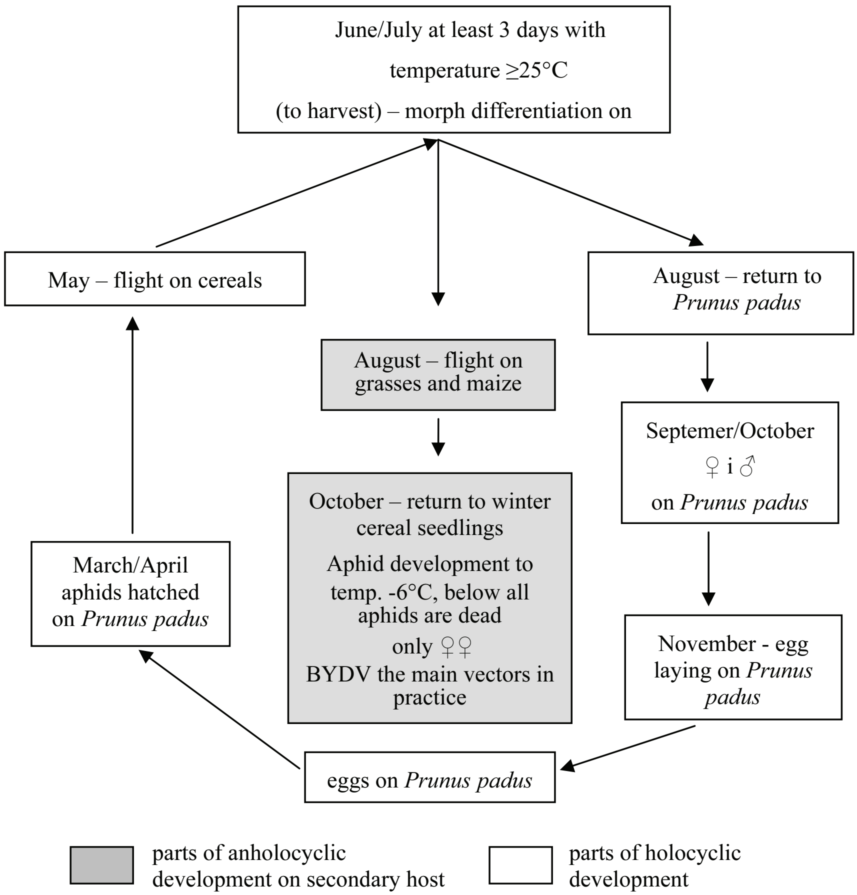


Figure 5. Life-cycle of Polish strains of *Rhopalosiphum padi*

The life history (life cycle) is not a constant feature for the species as it depends on the changes in the environment, such as e.g. temperature or food quality. Figure 5 shows the life cycle of *R. padi* in a higher temperature in spring/summer seasons which took place in some regions of Poland.

Conclusions

Thirty three years (1973-2006) of detailed research on ecology and biology of *R. padi* allowed one to observe diversified examples of environmental adaptation in the life cycle of this aphid in natural conditions of the warmer regions of Poland. The changes in *R. padi* life cycle is an important element of environmental adaptation. The new forms of *R. padi* that are found in Poland are the main vector, and in practice the only one, of BYDV. The new virus disease is a new problem of important economic significance in winter cereal protection.

An increase in the occurrence of anholocyclic forms on secondary host and their following geographical expansion testify to an accelerated pace of global warming which is a natural evolutionary trend. An increase of geographical distribution of anholocyclic forms of *R. padi* along with virus diseases as an effect of higher temperature in some warmer regions of Poland and, therefore, it could be an indicator of global warming.

Host alternating aphids (*R. padi*) are equipped with an adaptation mechanism to become anholocyclic both on primary and secondary hosts.

Unusual specialization and morphological diversity of aphids, an ability to migrate and adapt environmentally by means of fast reactions to all changes in the environment, including biodiversity, ensure aphids a possibility to become leaders of the organisms which are evolutionarily modernized.

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http://data.giss.nasa.gov./gistemp/graphs

Rola bioróżnorodności *Rhopalosiphum padi* (Linnaeus, 1758) /Hemiptera, Aphidoidea/ w rozprzestrzenianiu żółtej karłowatości jęczmienia – groźnej choroby wirusowej zbóż

Streszczenie

Ekspansja terytorialna form anholocyklicznych mszyc *Rhopalosiphum padi* w Polsce jest wskaźnikiem postępującego ocieplenia w zróżnicowanych klimatycznie regionach. Formy anholocykliczne na żywicielu wtórnym rozwijają się tylko w warunkach wyższych temperatur w okresie wiosny i lata. Formy anholocykliczne na żywicielu pierwotnym powstają w efekcie innych wartości pokarmowych.

Unikalna specjalizacja, różnorodność morfologiczna, zdolność do migracji i adaptacji środowiskowej wynikającej z szybkich reakcji na wszelkie zmiany najliczniejszego gatunku reprezentującego wszystkie mszyce powoduje, że owady te należą do najbardziej ewolucyjnie udoskonalonych organizmów.

Występowanie nowych form rozwojowych mszyc w Polsce ma znaczenie dla ochrony roślin ponieważ są one głównymi wektorami BYDV.