ISSN 1644-0692
www.acta.media.pl

ACTA *Acta Sci. Pol. Hortorum Cultus, 15(2) 2016, 157-169*

EFFECT OF CLIMATE CHANGE ON SEASONAL FLIGHT ACTIVITY OF APHID MALES IN URBAN GREEN AREA

Barbara Wilkaniec, Beata Borowiak-Sobkowiak,
Agnieszka Wilkaniec, Paweł Trzciński, Maria Kozłowska
Poznan University of Life Science

Abstract. In temperate climate zones, where a continental climate prevails, the appearance of males in populations of most aphid species takes place only in the autumn. Holocyclic and heteroecious species typically have winged males obligatorily. In holocyclic and monoecious species, males are not always winged morphs. Photoperiod is the primary factor responsible for the change in the manner of reproduction, from parthenogenetic to sexual, during the growth season, and temperature is a modifying one. The paper presents the results of many years of research on the activity of aphid male flights in characterizing species diversity, phenology of appearance and their number in urban green areas, carried out employing the Moericke's yellow pan traps method. The research indicates a trend towards the decrease of male aphid species number over the course of the last decade, as a result of warmer weather conditions, in the years 2005–2014. The results of male catches of *Rhopalosiphum padi* (Linnaeus, 1761) – the most numerously represented species – prove that there is a relationship between their number in autumn and the number of days for which the average temperature exceeds 20ºC and rainfall occurs during the first decade of August. The very early appearance of *Brachycaudus divaricatae* Shaposhnikov, 1956 males in the season was an interesting phenomenon which is untypical for aphids in Poland.

Key words: aphid species composition, flight activity, temperature, urban greenery

INTRODUCTION

Many aphid species change their reproductive strategy from summer to autumn. In spring and summer females remain asexual for many viviparous parthenogenetic gen-

---

Corresponding author: Barbara Wilkaniec, Department of Entomology and Environmental Protection, Poznan University of Life Science, Dąbrowskiego 159, 60-594 Poznan, Poland, e-mail: wilk@up.poznan.pl

erations, before a single sexual generation of mating females and males appears near the end of the season [Hardie and Lees 1985].

The seasonal change from parthenogenesis to sexual reproduction is triggered by short day length, although temperature and nutrition also play a role [Lees 1966, Blackman 1971, Hardie 2010]. The timing of the change is adapted until the end of the season, ultimately to allow eggs to be produced before winter arrives [Smith and MacKay 1990, Austin et al. 1996, Halkett et al. 2004].

Although a local habitat always has the same day length on a particular date, the timing of the end of the season varies from year to year due to variation in autumn weather [Smith et al. 2011, 2013, Mackoś-Iwaszko et al. 2015]. Short days and decreasing temperatures promote the production of sexual forms in many aphid species. High temperatures in autumn tend to delay the production of sexual forms. The critical day length decreases with rising temperatures. At temperatures higher than 25ºC – with slight differences noted in various aphid species – the short-day effect is completely eliminated and only virginoparae are produced, even under short-day conditions [Brodel and Schaefers 1980].

This paper examines variation in species composition, abundance and phenology of aphid male occurrence in urban greenery. The paper assesses the contribution of different climatic factors like temperature and atmospheric precipitation on the dynamics of aphid males in autumn and tests the hypothesis that high temperatures in August just before the appearance of males influence their phenology and abundance during the season.

MATERIAL AND METHODS

The research was carried out in urban greenery in the Botanical Gardens of the Adam Mickiewicz University in Poznan in the years 2005–2014. The Gardens are situated in the western part of the city and its geographical location is delineated by coordinates $52^{o}25$'N and $16^{o}53$'E. The Gardens were established in 1930s and presently its area covers 22 ha, and its collections amount to approximately 7000 botanical taxa.

Aphids were caught using Moericke traps filled with a solution of aqueous ethylene glycol and detergent. Ten traps were used in each growth season, from May until October. The traps were placed at the height of 1.5 m. Every 10 days the traps were emptied. After the aphids were taken out of the traps, they were stored in tubes in 75% ethyl alcohol. The material was identified using the keys by Taylor [1984] and by Blackman and Eastop [1994].

The size of catches was analyzed in relation to the changing meteorological factors and measured (as was also the case in obtaining males) per a period of 10 days. The following parameters were taken into consideration: an average decade temperature and precipitation and a number of days in August with an average daily temperature above 20^{o}C. Meteorological data came from the station located in the Adam Mickiewicz University's Botanical Garden in Poznan.

The biocoenotic characteristics of the seasonal male communities were based on the following indicators: general species diversity by Shannon & Weaver (H') [Shannon and Weaver 1964], Pielou species evenness (J') [Pielou 1966] and Simpson's species diversity index (d) [Simpson 1949]. Hutcheson's [1970] test was used to assess the statistical significance of differences between values of index H’ for the compared groups.

In order to determine the prevalence of numerical relationships between observed variables, a correlation analysis was performed. Linear regression analysis was used to determine cause-effect relationships. Multiple regression analysis was applied using backward stepwise regression in order to match the simplest regression function. The significance level $\alpha = 0.05$ was applied.

RESULTS

The presence of 37 aphid male species or species groups was registered in the Adam Mickiewicz University’s Botanical Garden in Poznan in the years 2005–2014. Particular research seasons differed significantly in terms of species composition and the number of males. The greatest activity of aphid male flights was registered in the 2005 season when over 4 000 specimens, representing 21 species, were caught in traps, while the lowest activity was recorded in the seasons of 2010 and 2012, when only 10–100 specimens, representatives of single taxa were caught (tab. 1). The collected material proves that there is a correlation between the number of specimens and the number of species caught in a season (fig. 1).

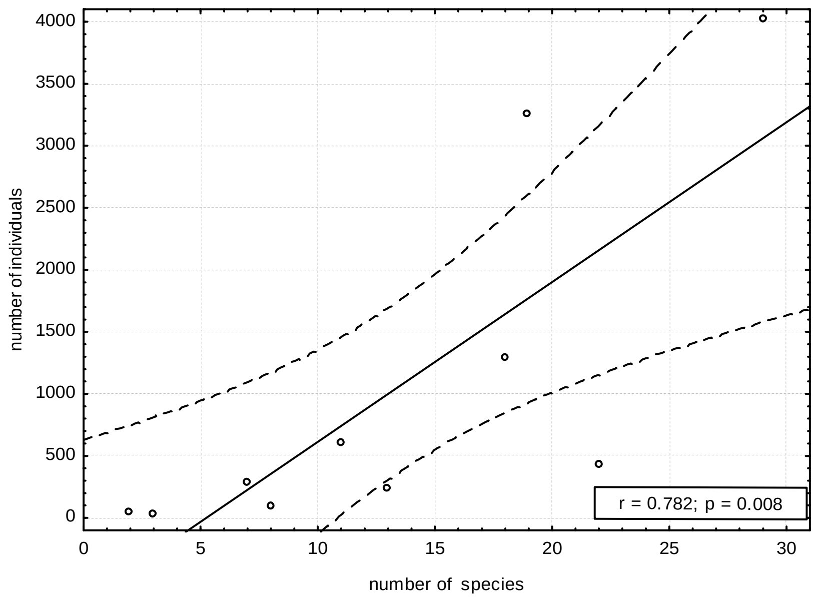

Fig. 1. Relationships between the number of aphid male species and the number of male individuals in Moericke traps in the years 2005–2014 in the Botanical Gardens of the Adam Mickiewicz University in Poznan with trend line indicated

Table 1. List of aphid male species and their number in the Botanical Garden of the Adam Mickiewicz University in 2005–2014

Species	Year										Total
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Amphorophora sp.	–	–	–	–	2	–	–	–	–	–	2
Aphis fabae Scop.	28	5	–	–	–	–	–	–	2	–	35
Aphis spp.	–	–	7	–	–	1	–	–	–	–	8
Aulacorthum solani (Kalt.)	–	–	–	–	–	–	1	–	–	–	1
Brachycaudus divaricatae Shap.	15	20	3	2	1	1	1	2	–	–	45
Brachycaudus helichrysi (Kalt.)	–	2	–	–	–	–	–	–	–	–	2
Calaphis betulicola (Kalt.)	7	1	16	–	11	–	–	–	1	–	36
Callipterinella calliptera (Hart.)	1	3	2	–	–	–	–	–	–	–	6
Capitophorus elaeagni (Del Gu.)	81	90	1	–	–	–	1	–	–	1	174
Ceruraphis eriophori (Walk.)	3	–	1	1	1	–	–	–	–	–	6
Chaitophorus sp.	–	–	–	–	1	–	–	–	–	–	1
Cryptomyzus ribis (L.)	1	–	–	–	–	–	2	–	–	–	3
Cryptomyzus galeopsidis (Kalt.)	3	–	2	–	–	–	–	–	–	–	5
Drepanosiphum aceris Koch	3	–	3	–	–	–	–	–	–	1	7
Drepanosiphum platanoidis (Schrk.)	97	364	69	4	1	–	15	–	–	1	551
Dysaphis plantaginea (Pass.)	8	1	1	–	–	–	1	–	–	–	11
Dysaphis spp.	1	1	1	–	–	–	–	–	2	1	6
Eucallipterus tiliae (L.)	–	1	–	–	–	–	–	–	–	–	1
Euceraphis betulae (Koch)	31	–	14	–	–	–	12	–	1	1	59
Hyperomyzus lactucae (L.)	28	4	1	–	–	–	1	–	1	2	37
Hyperomyzus picridis (Börn.)	2381	119	–	2	–	–	1	–	2	1	2506
Liosomaphis berberidis (Kalt.)	1	–	–	–	–	–	–	–	–	–	1
Metopolophium dirhodum (Walk.)	15	–	1	–	–	–	5	–	1	–	22
Myzus persicae(Sulz.)	23	7	–	2	–	–	9	–	3	–	44
Myzus cerasi (F.)	15	–	1	–	–	–	3	–	5	–	24
Myzus lythri (Schrk.)	3	1	–	–	–	–	–	–	–	–	4
Myzus ligustri (Mosl.)	1	–	–	–	–	–	–	–	–	–	1
Nasonovia ribisnigri (Mosl.)	1	–	–	–	–	–	–	–	1	–	2
Periphyllus aceris (L.)	–	–	1	–	–	–	7	–	–	1	9
Periphyllus hirticornis (Walk.)	1	–	3	–	–	–	–	–	–	–	4
Periphyllus testudinaceus (Fern.)	13	4	24	–	–	–	3	–	1	1	46
Phorodon humuli (Schrk.)	38	10	49	2	2	–	9	–	1	2	113
Rhopalomyzus lonicerae (Sieb.)	56	1	6	–	–	–	12	–	–	–	75
Rhopalosiphu insertum (Walk.)	2	–	–	–	–	–	–	–	–	–	2
Rhopalosiphus nymphaeae (L.)	1	–	1	–	–	–	2	–	–	–	4
Rhopalosiphum padi (L.)	1159	2619	223	265	67	21	1199	37	218	598	6406
Trichosiphonaphis corticis (Aizenb.)	–	1	–	–	–	–	–	–	–	–	1
Number of individuals	4017	3254	430	278	86	23	1284	39	239	610	10260
Number of species	29	19	22	7	8	3	18	2	13	11	37

Rhopalosiphum padi (Linnaeus 1761) was the only species whose males were caught in all the seasons of the research. Only in the first year of the research, were the males of *Hyperomyzus picridis* (Börner & Blunck 1916) more numerous than males of *R. padi*. The males of the latter species dominated in all the remaining research seasons. Out of over 10000 males collected during the ten years of research as much as 62.4% were from the same taxon. *Phorodon humuli* (Shrank 1801), *Brachycaudus divaricatae* Shaposhnikov, 1956 and *Drepanosiphum platanoidis* (Schrank 1801) followed in terms of frequency of occurrence as they were recorded in seasonal catches in 7–8 of the ten years of research.

Apart from the dominating *R. padi*, which constituted over 90% of all collected specimens in as many as six seasons, thus forming a group of very active species in autumnal migrations, collected specimens also included the following: *D. platanoidis*, *Capitophorus elaeagni* (del Guercio 1894) and *P. humuli*. Their number in the entire period of time reached several hundred specimens. Averagely active groups comprised *Rhopalomyzus lonicerae* (Siebold 1839), *Euceraphis betulae* (Koch 1855), *Periphyllus testudinaceus* (Fernie 1852), M*yzus persicae* (Sulzer 1776), *Metopolophium dirhodum* (Walker 1849), *Calaphis betulicola* (Kaltenbach 1843) and *Aphis fabae* (Scopoli 1763) of which several dozen or so specimens were collected.

Analyzing the male diversity in groups during the last decade, a trend indicating a decline in numbers was recorded in the years 2005–2014 (fig. 2). Analysis of the number of specimens caught during the following seasons indicates that their number initially dropped but started to increase after 2012 (fig. 3).

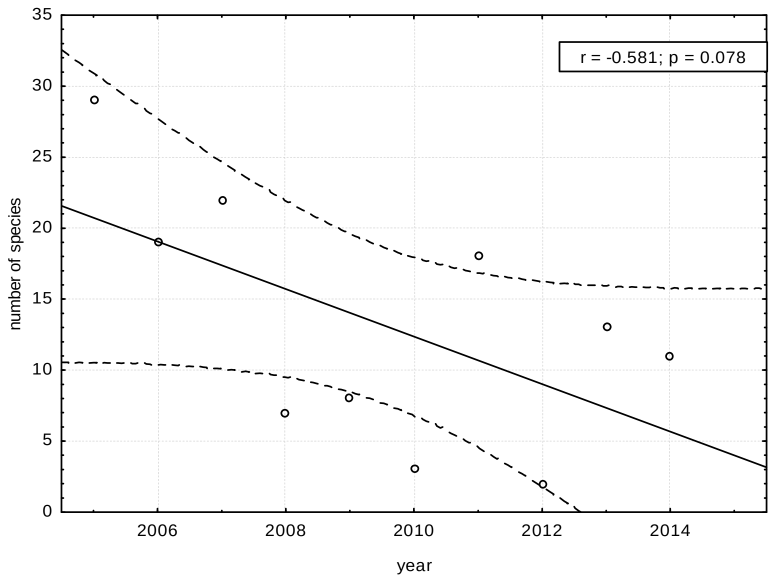

Fig. 2. Number of aphid male species in Moericke traps in the years 2005–2014 in the Botanical Gardens of the Adam Mickiewicz University in Poznan with trend line indicated

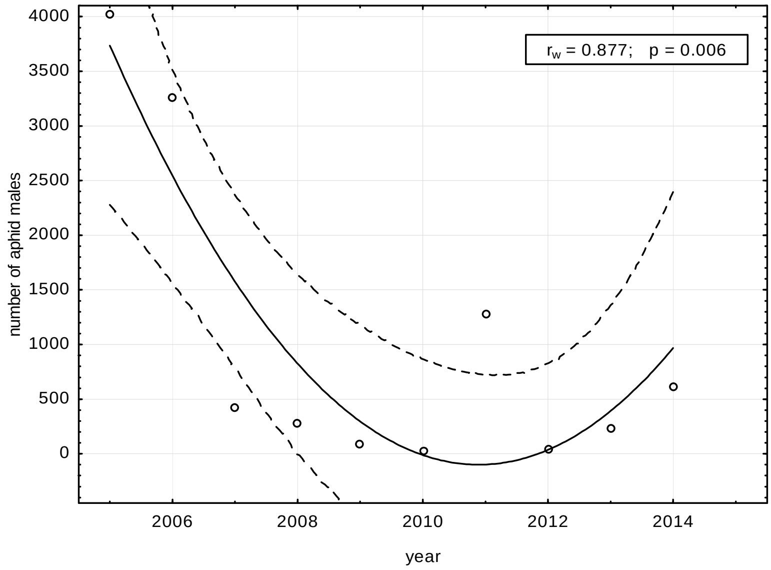

Fig. 3. Aphid males abundance in Moericke traps in 2005–2014 in the Botanical Gardens of the Adam Mickiewicz University in Poznan with trend line indicated

This phenomenon is confirmed by biocoenotic factors which characterize male groups caught in the following years of the research (tab. 2). Hutcheson's test carried out on the basis of Shannon-Weaver's species diversity indicator shows that every year its value changed significantly and only in the years 2010–2012 was there no difference between groups.

Table 2. Biocenotic indices from 2005–2014, characterizing aphid male communities in the Botanical Garden of the Adam Mickiewicz University in Poznań

Year	Number of species	Number of individuals	H'	J'	d
2005	29	4.017	1.77*	0.36	7.77
2006	19	3.254	1.09*	0.26	5.13
2007	22	430	2.43*	0.55	7.97
2008	7	278	0.39*	0.14	2.46
2009	8	86	1.21*	0.40	3.62
2010	3	23	0.51	0.32	1.47
2011	18	1.284	0.58	0.14	5.47
2012	2	39	0.29	0.29	0.63
2013	13	239	0.72*	0.20	5.05
2014	11	610	0.20*	0.06	3.59

Significance level of difference between values (t-test) $\alpha = 0.05$, H' – Shannon Weaver index; J' – Pielou' index; d – Simpson index

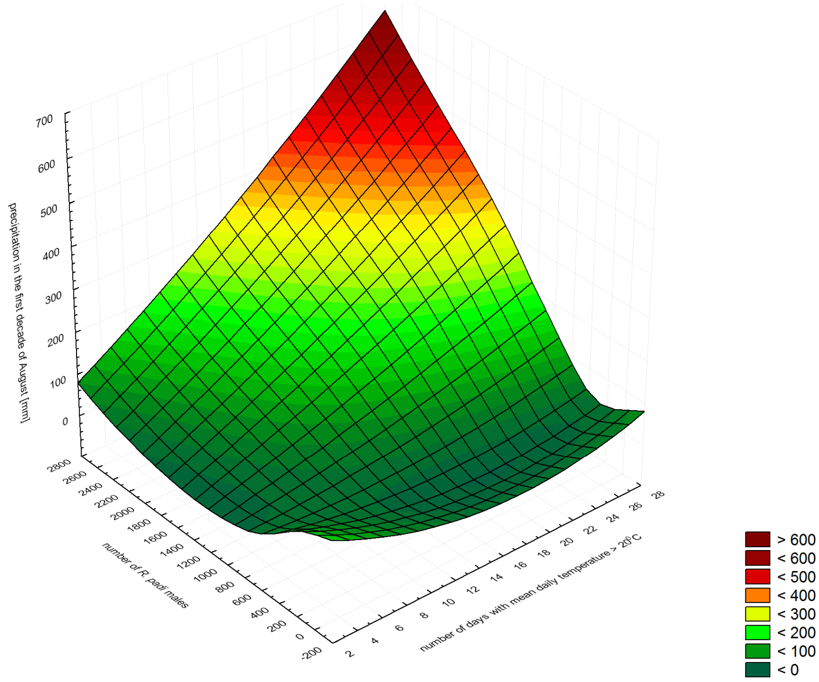

Fig. 4. Model of multiple regression with relationships between the number of *Rhopalosiphum padi* males (y) and the number of days with average daily temperature > 20°C (x_1) and the precipitation in the first decade of August (X_2) (F = 22.25; p = 0.002; R^2 = 94.7%)

Table 3. Abundance of *Rhopalosiphum padi* males in Moericke traps in the Botanic Garden of the Adam Mickiewicz University in Poznań in 2005–2014

Year	Decade of September			Decade of October			Total
	1	2	3	1	2	3	
2005	2	28	158	281	286	404	1159
2006	0	1	163	1324	516	615	2619
2007	0	1	0	20	83	119	223
2008	0	0	3	10	153	99	265
2009	0	0	10	5	38	14	67
2010	0	2	11	0	0	8	21
2011	1	180	23	606	132	257	1199
2012	0	3	1	10	19	4	37
2013	0	0	4	5	19	190	218
2014	0	11	182	273	99	33	598

The onset of autumnal male flight was registered in September, although depending on the season it was either in the first, second or third decade of the month. The earliest that single males of the most numerously represented species – *R. padi* – were caught in traps was during the first decade of September in seasons 2005 and 2011, and the latest was in the third decade of September in 2008, 2009 and 2013 (tab. 3). The peak number of occurrences during those years in which *R. padi* were observed in numerous quantities occurred in the first ten days of October. The males of the remaining aphid species usually appeared in the catches later – in the first ten days of October – and their number gradually rose as the season progressed.

Table 4. Number of days with mean daily temperature > 20ºC in August and September in the Botanical Garden of the Adam Mickiewicz University in Poznań in 2005–2014

Year	Decade of August			Total	Decade of September			Total
	1	2	3		1	2	3	
2005	0	2	3	5	4	1	0	5
2006	1	2	0	3	1	0		1
2007	5	4	4	13	0	0	0	0
2008	4	4	0	8	2	0	0	2
2009	6	3	5	14	1	0	0	1
2010	2	4	3	9	0	0	0	0
2011	1	1	2	4	2	1	0	3
2012	8	6	8	22	5	2	1	8
2013	10	6	10	26	0	0	0	0
2014	9	1	0	10	0	1	0	1

The results of *R. padi* male catches prove that there is a relationship between the number of males and the temperature and precipitation in August. The greatest and the most significant impact on recorded numbers was observed given precipitation during the first decade of August and according to the number of days during this period of time when an average temperature exceeded 20ºC (tab. 4). No such relationship was observed between the number of *R. padi* males and precipitation and temperature in September and October.

Very early appearance in the season of *B. divaricatae* males was an interesting phenomenon. In the years 2005–2012, forty-five specimens from this species were collected in an untypical period for Poland's climate: during June and July.

DISCUSSION

The obtained results prove migrant activity of 37 species or species groups of male aphids in urban green areas. This enriches our knowledge in comparison with the results of earlier research carried out in that habitat [Wilkaniec 2005, Wilkaniec et al. 2007]. Male species composition, similar in terms of quantity, was found in midfield thickets in the agricultural landscape of Wielkopolska [Wilkaniec 2003] where the activity of 32 taxa was registered. Present results confirm a clear domination of *R. padi* males in the catches in some seasons, amounting to over 90% of all the specimens collected in autumn.

The results reveal a large degree of variability in male flights between seasons which is expressed both in species composition as well as in the number of taxa. A set of environmental factors determines this. In accordance with previous research of many authors, photophase, the critical value for which ranges from 14 to 15 h for many species, is the main factor determining the change in the way aphids reproduce – from parthenogenesis to the sexual one. Moreover, aphids might be adapted to use temperature to modulate their photoperiodic response [Lamb and Pointing 1972, Ward et al. 1984, Austin et al. 1996, Smith et al. 2011].

Lees [1966] elucidated that in *Megoura viciae* at a temperature of 15.0ºC, the critical day-length for determination of sexual forms appeared to be between 14.5 and 15.0 h. The critical day-length tends to become shorter with rising temperatures, at a rate of 15 min per increase of 5ºC. When aphids are kept at 23ºC or higher, the effect of day-length disappears completely and, as a result, even under short-day conditions only virginoparae are produced.

According to Lamb and Pointing [1972] both males and oviparae of *Acyrthosiphon pisum* can be induced by less than 13.0–14.0 h light per day, but the critical photoperiod needed to produce males is about an hour longer than that required for the production of oviparae. In many species of aphids more males tend to appear during the latter half of the reproductive period. Matsuka and Mittler [1979] stated that in *M. persicae* the critical day length needed for the production of males is 14.5 h. Short-day treatment given only once may moderately increase the production of males, when given twice, it will considerably increase it. It has also been shown that parents are most sensitive to photoperiod immediately before they are born.

The study of Smith et al. [2013] shows that although photoperiod is generally thought to be the cue used to time the transition from parthenogenesis to sexual reproduction, temperature also plays an important role for *A. pisum.* This study shows a similar modulation of its response to day length by temperature, responding to longer day lengths earlier in the season in years when August temperature is lower than in years when temperature is high.

In most holocyclic aphid species, the morph of the offspring is determined largely prenatally via the effect of day-length on the mother [Hales et al. 1989]. Dixon and Dewar [1974] found that *R. padi* mothers are only sensitive to short days during the first half of their nymphal development. In Poland's climate conditions, the period in which photoperiod acquires critical value takes place at the beginning of August. The large number of days with high temperatures during this period in recent years explain the changes taking place in male fauna. Ruszkowska and Strażyński [2011] reached similar conclusions when studying the changes in bionomy of aphids living on trees in urban areas. Their many years of research using Johnson's suction trap indicate a later time of appearance of males in recent years, a decrease in their total number and in species composition in the urban environment.

Our study showed that there are statistically significant differences in the degree of the differentiation of the number of species in the communities of aphid males occurring in the urban greenery and the number of days in August with an average daily temperature above 20^{o}C. Climatic change has been one of the most important environmental issues in recent years. Such changes have the potential to affect many animal species in numerous ways. In particular, a very strong influence is expected on temperature-dependent insects, like aphids, with their short generation times and high reproductive rates [Menéndez 2007], which facilitate adaptations to long-term climatic fluctuations.

Herbivorous insects respond to global warming with more rapid development [Williams et al. 2003], higher overwintering survival [Harrington et al. 2001] increased reproduction [Bale et al. 2002] and migration [Harrington et al. 1995]. The changes not always are benefit to the insects. Aphids are the model species in studying the association of insect biology with large-scale climate fluctuations because they multiply only within a certain range of temperatures, and their rate of development directly depends on temperature [Harrington et al. 1995]. Our study demonstrated that environmental conditions significantly affected the species composition, abundance and phenology of aphid males in urban greenery. The emergence of the males in the warmer seasons resulted in later emergence and fewer abundance and composition of communities of males. The studies showed an negative effect of climate warming on diversity of aphid in urban greenery.

Durak et al. [2015] found that in the warmer years in Poland, the autumn sexual generation of *Cinara juniperi* was accompanied by parthenogenetic individuals, which shows that the part of the population did not switch to sexual reproduction. Such process may lead to the appearance and development of anholocyclic generations in Poland, where the species was described as holocyclic to date. Anholocyclic generations which accompany holocyclic ones may occur in some aphid species [e.g. *R. padi*: Ruszkowska 2007], but in Poland this is not typical due to poor survival of parthenogenetic individuals during winter.

Early appearance of *B. divaricatae* males in the season was a very interesting phenomenon. Their presence was recorded in June and July. The phenomenon of "early males" appearance is well known in academic literature but it mainly concerns geographical regions which have much milder winters than Poland, for example Great Britain. There, over 30 aphid species were recorded with their males appearing in spring or early summer. Taylor et al. [1998] explain that early males may be produced by androcyclic clones which, unlike holocyclic clones, may have no "interval timer" mechanism preventing a response to critical night lengths in spring. It seems that in Poland's climate, with severe winters, such an explanation is not adequate. *B. divaricatae* has been registered here since 2002 and since then it has quickly spread around the country. The results of research conducted in Poland by Wilkaniec and Wilkaniec [2013] indicate that the species develops only on cherry plum without migration onto the summer host plant *Melandrium album* as is the case in the Middle East, where it originates from. Such unusual development, with a long summer-winter diapause at the egg stage, significantly differs from the development of other local aphid species where sexual forms occur only in late summer and autumn.

CONCLUSIONS

1. The studies of aphid males species in 10- year period in urban greenery detects a trend in decreasing of their number.

2. The results claims to prove a relationship between number of aphid male species and climatic changes in temperature and precipitation.

3. The study shows that there are statistically significant differences in the degree of the differentiation of the number of species in the communities of aphid males occurring

in the urban greenery and the number of days in August with average daily temperature above 20ºC.

4. Present results confirm a clear domination of *R. padi* males in the catches.

REFERENCES

Austin, A.B.M., Tatchell, G.M., Harrington, R., Bale, J.S. (1996). Adaptive significance of changes in morph production during the transition from parthenogenetic to sexual reproduction in the aphid *Rhopalosiphum padi* (Homoptera: Aphididae). Bull. Entomol. Res., 86, 93–99.

Bale, J., Masters, G., Hodkinson, I., Awmack, C., Bezemer, T., Brown, V., Butterfield, J., Buse, A., Coulson, J., Farrar, J. (2002). Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Glob. Change Biol., 8, 1–16.

Blackman, R.L. (1971). Variation in the photoperiodic response within natural populations of *Myzus persicae* Sultz. Bull. Entomol. Res., 60, 533–546.

Blackman, R.L., Eastop, V.F. (1994). Aphids on the World's Trees. An Identification and Information Guide. CAB International, Wallingford, UK.

Brodel, C.F., Schaefers, G.A. (1980). The influence of temperature on the production of sexual by *Aphis rubicola* under short-day conditions. Entomol. Exp. Appl. 27,127–132.

Dixon, A.F.G., Dewar, A.M. (1974). The time of determination of gynoparae and males in the bird cherry-oat aphid, *Rhopalosiphum padi.* Ann. Appl. Biol., 78, 1–6.

Durak, R., Węgrzyn, E., Leniowski, K. (2015). Do all aphids benefit from climate warming? An effect of temperature increase on a native species of temperate climatic zone Cinara juniperi Editorial. Ethol. Ecol. Evol., doi:10.1080/03949370.2015.1034785.

Hales, D.F., Wellings, P.W., Parkes, R.A. (1989). Investment in gynoparae and males by *Myzus persicae* (Sulzer). Funct. Ecol., 3, 727–734.

Halkett, F., Harrington, R., Hullé, M., Kindlmann, P., Menu, F., Rispe, C. (2004). Dynamic of production of sexual forms in aphids: theoretical and experimental evidence for adaptive "coin-flipping" plasticity. Am. Nat., 163, 112–125.

Hardie, J., Lees, A.D. (1985). The induction of normal and teratoid viviparae by a juvenile hormone and kinoprene in two species of aphids. Physiol. Entomol., 10, 65–74.

Hardie, J. (2010). Aphid polyphenism. Photoperiodism: the biological calendare. In: Photoperiodism in insect, Nelson, D.L., Denlinger, R.J, Somers, D.E. (eds). Oxford University Press, UK, 324–363.

Harrington, R., Bale, J.S., Tatchell, G.M. (1995). Aphids in a changing climate. In: Ed. Harrington R., Stork N.E. Insects in a changing environment. London Academic Press, UK, 125–155.

Harrington, R., Fleming, R., Woiwod, I. (2001). Climate change impacts on insect management and conservation in temperate regions: can they be predicted? Agricult. For. Entomol., 3, 233–240.

Hutcheson, K. (1970). A test for comparing diversities based on the Shannon formula. J. Theor. Biol., 29, 151–154.

Lamb, R.J., Pointin, P.J. (1972). Sexual morph determination in the aphid, *Acyrthosiphon pisum*. J. Insect Physiol., 18, 2029–2042.

Lees, A.D. (1966). The control of polymorphism in aphids. Adv. Insect Physiol., 3, 207–277.

Mackoś-Iwaszko, E., Lubiarz, M., Karczmarz, K. (2015). The impact of urban conditions on the occurrence of aphids on *Acer platanoides* L. Acta Sci. Pol. Hortorum Cultus, 14(5), 189–207.

Matsuka, M., Mittler, T.E. (1979). Production of males and gynoparae by apterous viviparae of *Myzus persicae* continuously exposed to different scotoperiods. J. Insect Physiol., 25, 587–593.

Menéndez, R. (2007). How are insects responding to global warming? Tijdschr. Voor Entomol., 150, 355–365.

Pielou, E.C. (1966). Shannon's formula as a measure of specific diversity: its use and misuse. Am. Nat., 100, 463–465.

Ruszkowska, M. (2007). Across the transformation life cycle of *Rhopalosiphum padi* (L.) (Homoptera: Aphidoidea): coevolution with temperature. Rozpr. Nauk. Inst. Ochr. Rośl./Inst. Plant Prot., Poznań, Poland.

Ruszkowska, M., Strażyński, P. (2011). Elements of changes in the bionomy of aphids on trees in the urbanized environmental. Zesz. Probl. Post. Nauk Roln., 562, 221–227.

Shannon, C.E., Weaver, W. (1964). The mathematical Theory of Communication. The University of Illinois Press, Urbana, Illinois.

Simpson, E.H. (1949). Measurement of diversity. Nature, 163, 688.

Smith, M.A.H., MacKay, P.A. (1990). Latitudinal variation in the photoperiodic responses of populations of pea aphid (Homoptera: Aphididae). Environ. Entomol., 19, 618–624.

Smith, M.A.H., MacKay, P.A., Lamb, R.J. (2011). Temperature modulation of photoperiodism and the timing of late-season changes in life history for an aphid, *Acythosiphon pisum*. Can. Entomol., 143, 56–71.

Smith, M.A.H., MacKay, P.A., Lamb, R.J. (2013). Temperature modulation of photoperiodism: an adaptation for long-distance dispersal in the aphid, *Acyrthosiphon pisum* (Hemiptera: Aphididae). Can. Entomol, 145, 302–313.

Taylor, M.S., Harrington, R., Clark, S.J. (1998). Unseasonal male aphids. In: Aphids in natural and managed ecosystems, Nieto Nafria, J.M., Dixon, A.G. (eds.). Universidad De Leon, Espana, 287–295.

Taylor, L.R., Robert, Y. (1984). A Handbook for aphid identification. Rothamsted Experimental Station, Harpenden, UK.

Ward, S.A., Leather, S.R., Dixon, A.F.G. (1984). Temperature prediction and the timing of sex in aphids. Oecologia, 62, 230–233.

Wilkaniec, B. (2003). Male aphids caught in midfield thickets. Aphids and Other Hemipterous Insects, 9, 181–188.

Wilkaniec, B., 2005. Many years' dynamics of aphid recurrence in urban green spaces of Poznań. Aphids and Other Hemipterous Insects, 11, 203–212.

Wilkaniec, B., Ratajczak, J., Sztukowska, K. (2007). Aphid males in urban green space. Aphids and Other Hemipterous Insects, 13, 83–90.

Wilkaniec, B., Wilkaniec, A. (2013). The biology and ecology of *Brachycaudus divaricatae* Shaposhnikov (Hemiptera, Aphidoidea) on *Prunus cerasifera* in Western Poland. J. Plant Prot. Res., 53, 42–47.

Williams R.S., Lincoln D.E., Norby R.J. (2003). Development of gypsy moth larvae feeding on red maple saplings at elevated CO_2 and temperature. Oceologia, 137, 114–122.

WPŁYW ZMIAN KLIMATYCZNYCH NA SEZONOWĄ AKTYWNOŚĆ LOTÓW SAMCÓW MSZYC

Streszczenie. W strefie klimatu umiarkowanego z przewagą klimatu kontynentalnego pojawianie się samców w populacjach większości gatunków mszyc ma miejsce dopiero jesienią. Gatunki holocykliczne i heteroecyjne charakteryzuje obligatoryjne występowanie uskrzydlonych samców. U gatunków holocyklicznych i monoecyjnych samce nie zawsze są morfami uskrzydlonymi. Podstawowym czynnikiem odpowiedzialnym za zmianę sposobu rozmnażania w ciągu sezonu wegetacyjnego z dzieworodnego na płciowy jest fotoperiod, a czynnikiem modyfikującym temperatura. W pracy przedstawiono wyniki wieloletnich badań dotyczące aktywności lotów samców mszyc w aspekcie ich różnorodności gatunkowej, fenologii pojawu i liczebności w miejskich terenach zieleni prowadzonych metodą pułapek Moerickego. Wyniki badania wskazują na tendencję spadku liczby gatunków samców mszyc w ostatnim dziesięcioleciu, 2005–2014. Wyniki odłowu samców najliczniej reprezentowanego gatunku, *Rhopalosiphum padi*, dowodzą istnienia związku między jego liczebnością jesienią a liczbą dni ze średnią temperaturą dobową przekraczającą 20ºC oraz opadami w sierpniu. Interesującym zjawiskiem było nietypowe dla mszyc bardzo wczesne w sezonie pojawianie się samców *Brachycaudus divaricatae*.

Słowa kluczowe: skład gatunkowy mszyc, aktywność lotów, temperatura, tereny zieleni

Accepted for print: 21.01.2016

For citation: Wilkaniec, B., Borowiak-Sobkowiak, B.,Wilkaniec, A., Trzciński, P., Kozłowska, M. (2016). Effect of climate change on seasonal flight activity of aphid males in urban green area. Acta Sci. Pol. Hortorum Cultus, 15(2), 157–169.