

Aphid migrant activity in refuge habitats of the Wielkopolska agricultural landscape

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Received: September 10, 2014

Accepted: February 11, 2015

Abstract: Refuge habitats have a stabilising effect on the entomofauna in the agricultural landscape. The objective of this research was to follow the migrant activity of aphids in two types of refuge habitats: shrubs and roadsides of rural areas. Moericke traps method were used for testing the seasonal activity of aphids. The dynamics of species numbers were assessed, and the phenology of the dominating taxa was examined. From 2008 to 2010, more than 5,000 winged aphids from 94 species were caught in shrub habitats, and 83 species were caught in rural roadside habitats. The characteristics of aphid groups were defined on the basis of selected indicators. Annually, in both locations, flight activity was shown by a group of several taxa. The rank position of the species was varied in the particular sites and years of the research. Species participation differed when analysing aphid flights, so the seasons were divided into three separate periods: spring, summer, and autumn.

Key words: aphids, biocenotic indices, phenology, roadside, shrubs

Introduction

An increased intensity of agricultural practices in the last decades has caused such environmental problems as contamination, soil degradation, and biodiversity losses (Tilman *et al.* 2002). Former varied and complex landscapes with well-balanced proportions of arable land, grassland, forests, fallows, hedgerows, and other semi-natural habitats have been transformed into homogeneous, simple landscapes with a domination of arable land. These changes are related to the local loss of diversity and ecological functioning (Pickett and Cadenasso 1995; Roland and Taylor 1997; Thies and Tscharnke 1999; Tischendorf and Fahring 2000; Menalled *et al.* 2001; Thies *et al.* 2003).

Agricultural landscape structure, which includes the configuration and the composition of crop and non-crop habitats, affect entomofauna movement, abundance, and diversity. Forests, meadows, hedgerows, and field margins all provide resources and habitat connectivity for different arthropod groups. It is commonly predicted that pest regulation will be greater in landscapes that contain a greater proportion or diversity of these habitats (Bianchi *et al.* 2006; Chaplin-Kramer *et al.* 2011). We lack a detailed understanding of how different components of landscape structure influence insect herbivores, their predators and parasites, the spatial scales at which this occurs, and the effects on crop production (Chaplin-Kramer *et al.* 2011).

Non-crop habitats provide alternative hosts or preys, pollen, nectar, and overwintering sites (Lethmayer 1998; Dennis *et al.* 2000; Martin *et al.* 2013) and favorable environmental conditions for many arthropod species (Bianchi *et al.* 2006).

Landscape structure effects operate at different scales for different arthropod groups depending on the mobility and size of the groups (Tscharnke and Brandl 2004). Many authors argue that to enhance ecosystem services what is needed are pollination or pest biological control by effective habitat management (Tscharnke *et al.* 2007; Martin *et al.* 2013).

Studies about annual crops show that complex landscapes dominated by non-crop habitats can lead to higher predator densities (Gardiner *et al.* 2009) or lower abundance of pests in crop fields (Thies and Tscharnke 1999; Östman *et al.* 2001; Thies *et al.* 2005; Gardiner *et al.* 2009). Several studies, conducted in Poland, have examined the different effects of the elements of landscape on beneficial entomofauna; in particular the parasitoids and predators (Bońkowska 1970; Sawoniewicz 1979; Dąbrowska-Prot 1991; Gałęcka 1991; Twardowski *et al.* 2006; Wojciechowicz-Żytko 2009; Wojciechowicz-Żytko and Wnuk 2009; Piekarska-Boniecka *et al.* 2010) as well as pollinating insects (Banaszak 2000).

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However, studies on the effect of landscape composition and habitat isolation on biological control of pests on tree crops, are scarce. Nevertheless, recent studies found that biological control of pest insects on tree crops is influenced by landscape composition (Brown 2004; Eilers and Klein 2009; Dib *et al.* 2010; Thomson and Hoffmann 2010; Stutz and Entling 2011).

It is very important to know the time periods which insects exploit particular landscape elements. This a crucial aspect of any recommendations for the enhancement of ecosystem services by landscape management.

Aphids are a major pest on a wide range of crops and trees. Adults and larvae of different coccinellid species, larvae of syrphids, chrysopids, and cecidomyiids, and parasitoids, are expected to reduce the population growth of aphids on fruit trees (Brown 2004; Dib *et al.* 2010).

Here we investigated the aphid species composition, abundance, and the phenology of dominating taxa in two non-crop habitats, in the vicinity of apple orchards. In these habitats aphids can be dealt as a potential and alternative food base for all the above-mentioned predators and parasitoids.

The objective of this research was to follow the migrant activity of aphids in two types of refuge habitats in the agricultural landscape of Wielkopolska. The two refuge habitats were: shrubs (S) and roadsides (R). Both habitats were situated near apple orchards. In the studied environments, the species composition and the dynamics of species numbers were assessed, and the phenology of dominating taxa was examined.

Migrant activity of aphids has been widely perceived as a phenomenon of dispersal in search of a host plant. Migration concerns both seasonal flights, undertaken by heteroecious species for the sake of an obligatory change of the host plant (in spring, from the primary host to the secondary host, and in autumn the reverse – from the secondary to the primary host), and flights undertaken in search for other plants belonging to the same host species. This phenomenon is encountered in mono- and heteroecious taxa, and is connected mainly with the nutrient quality and the effect of a large density of specimens in colonies. Aphid seasonal flights can be accurately followed by means of Moericke traps which catch winged morphs of insects. This method was applied to track aphids in the present research.

Materials and Methods

The research was carried out on two sites, shrubs (S) (52°10'10"N; 16°81'19"E) and by the roadside (R) (52°10'20"N; 16°81'45"E) in the rural area of Gorzyczki in the Kościan district, 40 km south of Poznań, from 2008 to 2010. Aphids were caught using circular Moericke traps. The traps had a diameter of 18 cm and a height of 11 cm. An aqueous of ethylene glycol and a detergent were used to catch the aphids. The traps were placed at a height of 1.5 m. Ten traps were used at each site and in each growth season, from May until October. Traps were located about 2 m from the edge of each habitat and the distance between the traps was 10 m within the habitat. Every 10 days, the traps were emptied. After the aphids were taken

out of the traps, the aphids were stored in tubes in 75% ethyl alcohol. The material was identified using the keys by Taylor (1984) and by Blackman and Eastop (1994).

Shrub habitat, situated on the edge of a 5 ha apple orchard, constituted a 200 m long and 8 m wide stretch of a plant complex which was spatially diversified and comprised shrub phytocenoses: *Euonymo-Prunetum spinosae* and forest phytocenoses in the form of a fragment of *Quercu-Ulmetum minoris* as well as herbal communities. At this location, trees were comprised of eight different species (*Ulmus laevis*, *Quercus robur*, *Fraxinus excelsior*, *Acer platanoides*, *Acer negundo*, *Malus domestica*, *Salix alba*, *Populus × canadensis*) with maple ash being the most popular. In the dense layer of shrubs, *Crataegus monogyna* dominated, and among the diversified herb plants – the nettle (*Urtica dioica*) and the thistle (*Cirsium arvense*) dominated. The site located by the roadside was situated near a 3-ha-large apple orchard. Tree composition was characterised by a multi-species floral composition where walnut (*Juglans regia*) dominated together with many maple trees, oaks, elms, and ash. Shrubs were more diverse (*Crataegus × media*, *C. monogyna*, *Rosa canina*, *Sambucus nigra*, *Corylus avellana*, *Cornus alba*, *Euonymus europea*, *Symphoricarpos albus*, *Sarothamnus scoparius*, *Ribes niveum*, *Prunus spinosa*) which were characteristic of the *Rhamno-Prunetea* class where *Crataegus × media* dominated as well as herbs, predominantly: *U. dioica*, *Poa pratensis*, *Lolium perenne*, *Equisetum arvense*, and *Galium aparine*.

When analysing the changeability of atmospheric conditions during the course of the research, it was found that all seasons were relatively warm. Over the period of the study, the year 2008 was the warmest, and 2010 the coldest. As far as the total rainfall was concerned, all years were very humid, while 2010 had the most abundant rainfall (Table 1).

On the basis of selected indicators, the following characteristics of aphid groups were defined:

- number of samples (n),
- number of individuals (N),
- dominance index (D) (dominance is the percentage of specimens of particular species in the community), and the following dominance classes were adopted [according to Durak and Wojciechowski (2008)]: eu-dominant – over 20% of the collected material, dominant – 10–20% of the collected material, subdominant – 5–10% of the collected material, recedent – 1–5% of the collected material, subrecedent – less than 1% of collected material;
- index of general species diversity, as defined by Shannon-Weaver (1963) (H'):

$$H' = - \sum_{i=1}^S \frac{n_i}{N} \log_2 \frac{n_i}{N},$$

where: n_i – number of individuals (i) of the species in the grouping of general number of individuals (N), S – number of species in the community;

Table 1. Average monthly air temperatures and monthly rainfalls for the Research Station in Turew from 2008 to 2010

| Months | Temp. [°C] 2008 | Rainfall [mm] 2008 | Temp. [°C] 2009 | Rainfall [mm] 2009 | Temp. [°C] 2010 | Rainfall [mm] 2010 | Long-term average 1971–2000 | |
|----------------|-----------------|--------------------|-----------------|--------------------|-----------------|--------------------|-----------------------------|-----------------------|
| | | | | | | | monthly temp. [°C] | monthly rainfall [mm] |
| I | 2.8 | 59 | -2.5 | 13 | -6.1 | 0 | -0.9 | 37.3 |
| II | 4.6 | 28 | 0.3 | 26 | -0.2 | 13 | 0.1 | 28.2 |
| III | 5.0 | 48 | 4.8 | 51 | 4.5 | 53 | 3.9 | 39.0 |
| IV | 10.0 | 85 | 13.3 | 31 | 10.6 | 27 | 8.6 | 39.7 |
| V | 15.8 | 17 | 14.6 | 93 | 12.7 | 100 | 14.3 | 50.0 |
| VI | 20.2 | 18 | 16.6 | 83 | 18.7 | 47 | 17.3 | 72.1 |
| VII | 19.7 | 77 | 20.1 | 130 | 22.2 | 164 | 19.1 | 88.4 |
| VIII | 19.5 | 184 | 20.0 | 56 | 19.3 | 244 | 18.7 | 68.2 |
| IX | 13.8 | 27 | 16.1 | 103 | 12.9 | 157 | 14.1 | 44.8 |
| X | 10.0 | 66 | 7.9 | 103 | 7.1 | 6 | 9.2 | 38.8 |
| XI | 5.9 | 27 | 7.0 | 49 | 6.3 | 96 | 3.7 | 41.4 |
| XII | 1.8 | 19 | -0.3 | 27 | -6.2 | 36 | 0.2 | 40.0 |
| Annual total | - | 655 | - | 765 | - | 943 | - | 587.9 |
| Annual average | 10.8 | - | 9.8 | - | 8.5 | - | 9 | - |

– indicator of evenness of Pielou’s index of species frequency (1966) (J'):

$$J' = \frac{H'}{H_{\max}} = \frac{H'}{\log_2 N'}$$

– indicator of species richness as defined by Simpson (1949) (d):

$$d = \frac{S-1}{\log N} \times 100\%$$

For comparing the structure of the aphid groups, Marczewski-Steinhouse’s indicator (1959) (MS) was applied in quality categories:

$$MS = \frac{c}{a+b-c} \times 100\%$$

where: a and b – number of species in the first and second community, respectively, c – number of species common to both compared communities.

While in quality-quantity categories, Hutcheson’s test (1970) was applied. The data was statistically analysed using Stat-Soft, Inc. (2010) Statistica, version 9.0.

Results

From 2008 to 2010, there were 5,154 aphid winged individuals from 94 species caught in the shrub habitat located in the rural region of Gorzyczki. Similarly, in the roadside habitat, 3,820 specimens and 83 species were caught (Table 2).

The seasonal dynamics of the activity of winged aphid individuals was consistent for all the seasons studied throughout the research period. This is expressed both in the number of specimens and species caught, and is characterised by two clear peaks in numbers dur-

ing spring and autumn, and a decline in summer, usually lasting from the second decade of July until the second decade of September. The increased intensity of aphid flights in spring and autumn can be easily explained by the phenomenon of mass migration of heteroecious species associated with changing the host plant. The greatest numbers of winged morphs were collected in the shrub habitat during the autumn peaks of 2009 and 2010, with up to 600 individuals/10 traps/decade. Correspondingly, by the roadside, fewer morphs were observed, i.e. up to 300 individuals/10 traps/decade (Fig. 1). During these same periods in the season, i.e. spring and autumn, the maximum diversity of aphid species were recorded. The richest composition of aphid species recorded at both sites was during the spring, when 23 species/10 traps/decade were recorded in the shrub habitat, while in the 2009 season – up to 30 species/10 traps/decade were recorded by the roadside (Fig. 2).

Each year, at both locations, extensive flight activity was shown by a group of approximately thirteen taxa, including the most numerous *Rhopalosiphum padi*. Over the three seasons of the research project, *R. padi* constituted 62.4%, in total, in the shrub habitat. At the roadside location, this taxon comprised 64.7% of all collected winged morphs. The following species occupied the remaining positions in this category: *Phorodon humuli* (5.6%) and *Anoecia corni* (4.3%). The next five consecutive taxa characteristically represented 1–5% of all the collected winged aphids in the season: *Aphis fabae*, *A. sambuci*, *Myzus persicae*, *Sitobion avenae*, and *Acyrtosiphon pisum* (Table 3).

The rank position of taxa continued to vary over the particular sites and years of the research project. In the shrub habitat, *R. padi* was eudominant in 2009 and 2010, amounting to 76.9 and 57.2% of the total aphid catch, respectively. In the first research year, this species was dominant within the group together with *Periphyllus testudinaceus* and *P. humuli*. The class of subdominants for 2008 was comprised of *Drepanosiphum platanoidis* and

Table 2. List of aphid species and their number in shrubs and roadside localities collected using Moericke traps in Gorzyczki from 2008 to 2010

| Aphid species | Number of aphids in locality | | | | | |
|--|------------------------------|------|------|----------|------|------|
| | shrubs | | | roadside | | |
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 |
| <i>Acyrtosiphum pisum</i> (Harris) | 12 | 6 | 2 | 43 | 11 | 1 |
| <i>Adelges</i> sp. | 3 | 3 | 3 | 4 | 1 | – |
| <i>Amphorophora gei</i> (Börn.) | 5 | – | – | 1 | – | – |
| <i>A. rubi</i> (Kalt.) | 5 | – | 2 | 2 | 2 | – |
| <i>Anoecia corni</i> (F.) | 51 | 67 | 18 | 75 | 48 | 41 |
| <i>Aphis fabae</i> Scop. | 58 | 63 | 39 | 27 | 24 | 39 |
| <i>A. pomi</i> De Geer | 3 | 8 | 5 | 1 | 3 | 2 |
| <i>A. sambuci</i> L. | 72 | 45 | 23 | 38 | 10 | 6 |
| <i>Aphis</i> spp. | 32 | 17 | 7 | 36 | 2 | – |
| <i>Atheroides serrulatus</i> Hal. | 1 | – | – | – | – | – |
| <i>Aulacorthum solani</i> (Kalt.) | – | 2 | – | – | 2 | – |
| <i>Betulaphis quadrituberculata</i> (Kalt.) | – | – | 1 | – | – | – |
| <i>Brachycaudus cardui</i> (L.) | – | 9 | 2 | – | 1 | – |
| <i>B. divaricatae</i> Shap. | 14 | 22 | 5 | 11 | 10 | – |
| <i>B. helichrysi</i> (Kalt.) | 3 | – | 1 | 4 | – | 1 |
| <i>B. linariae</i> Stroyan | 1 | – | – | – | – | – |
| <i>Brachycaudus</i> sp. | 25 | – | – | 15 | – | – |
| <i>B. schwartzi</i> (Börn.) | – | – | 1 | – | – | 1 |
| <i>Brevicoryne brassicae</i> (L.) | 4 | 2 | – | 6 | – | – |
| <i>Calaphis betulicola</i> Szeleg. | 1 | – | – | 2 | – | – |
| <i>Callipteriniella tuberculata</i> (Heyd.) | – | – | 1 | – | – | – |
| <i>Capitophorus elaeagni</i> (Del Gu.) | 2 | 3 | 2 | – | – | – |
| <i>C. similis</i> V.D. Goot | – | 1 | – | – | 1 | – |
| <i>Cavariella aegopodii</i> (Scop.) | 48 | – | – | 52 | 1 | – |
| <i>C. konoj</i> Takah. | 1 | – | – | 1 | – | – |
| <i>C. pastinaceae</i> (L.) | 1 | – | – | – | – | – |
| <i>C. theobaldi</i> (Gill. et Bragg) | 31 | – | 1 | 23 | – | – |
| <i>Ceruraphis eriophori</i> (Walk.) | 3 | 1 | – | 2 | – | – |
| <i>Chaitophorus leucomelas</i> Koch | 3 | 1 | 1 | 3 | 7 | – |
| <i>Ch. populeti</i> (Panz.) | – | – | 8 | – | – | 1 |
| <i>Ch. populiabae</i> (B. de F.) | 1 | – | – | 1 | – | – |
| <i>Ch. salicti</i> (Schrk.) | – | 1 | – | – | – | – |
| <i>Cinara</i> sp. | – | 1 | 1 | 5 | – | – |
| <i>Corylobium avellana</i> (Schrk.) | – | – | – | – | 1 | – |
| <i>Cryptomyzus galeopsidis</i> (Kalt.) | 1 | 1 | – | 3 | – | 1 |
| <i>C. korschelti</i> Börn. | – | – | 1 | – | – | – |
| <i>Drepanosiphum platanoidis</i> (Schrk.) | 123 | 1 | 22 | 39 | – | 17 |
| <i>Dysaphis crataegi</i> (Kalt.) | 2 | 4 | 1 | 3 | – | – |
| <i>D. plantaginea</i> (Pass.) | 1 | 3 | 1 | 2 | 1 | 1 |
| <i>Eriosoma ulmi</i> (L.) | 5 | – | 4 | 3 | 1 | – |
| <i>Eucallipterus tiliae</i> (L.) | 5 | – | – | 3 | – | – |
| <i>Euceraphis betulae</i> (Koch) | 7 | – | 20 | 9 | – | 6 |
| <i>Eulachmus agilis</i> (Kalt.) | – | – | 1 | – | – | – |
| <i>Eulachmus</i> sp. | 1 | – | – | – | – | – |
| <i>Forda formicaria</i> Heyd. | 2 | – | 1 | – | 1 | – |
| <i>Holcaphis</i> sp. | 1 | – | – | 2 | – | – |
| <i>Hyadaphis foeniculi</i> (Pass.) | – | – | – | 1 | – | – |
| <i>Hyalopterus pruni</i> (Geoff.) | 1 | 6 | 3 | 18 | 7 | 1 |
| <i>Hypertomyzus lactucae</i> (L.) | – | 17 | 2 | 5 | 7 | 1 |
| <i>H. lamsanae</i> (Börn.) | 1 | – | – | – | – | – |
| <i>H. pallidus</i> H.R.L. | – | 4 | 1 | 1 | – | – |
| <i>Impatietintinum asiaticum</i> Nevsky | 1 | 1 | – | – | – | – |
| <i>Liosomaphis berberidis</i> (Kalt.) | 1 | – | – | – | – | – |
| <i>Lipaphis erysimi</i> (Kalt.) | – | 6 | – | 2 | 4 | – |
| <i>Macrosiphoniella artemisiae</i> (B de F.) | – | – | – | – | 2 | – |
| <i>M. tanacetaria</i> (Kalt.) | – | 3 | – | 2 | 1 | – |
| <i>Macrosiphum euphorbiae</i> (Thom.) | 5 | 1 | – | – | 3 | – |
| <i>M. funestum</i> (Macch.) | – | – | – | – | 1 | – |
| <i>M. gei</i> (Koch) | 1 | – | – | – | – | – |
| <i>M. persequens</i> (Walk.) | – | – | – | 1 | – | – |
| <i>M. rosae</i> (L.) | – | – | 1 | 10 | 2 | 1 |
| <i>Macrosiphum</i> sp. | – | – | – | – | 1 | – |
| <i>Megoura viciae</i> Buckt. | – | 1 | 1 | – | – | – |
| <i>Metopolophium dirhodum</i> (Walk.) | 26 | 6 | 1 | 65 | 5 | – |
| <i>Microlophium carnosum</i> (Buckt.) | 1 | 24 | – | 36 | 18 | 1 |
| <i>Mimeuria ulmiphila</i> (Del Gu.) | – | 2 | – | – | – | – |
| <i>Myzus cerasi</i> (F.) | 5 | 3 | 2 | 12 | 1 | 2 |

Table 2. List of aphid species and their number in shrubs and roadside localities collected using Moericke traps in Gorzyczki from 2008 to 2010 – continuation

| Aphid species | Number of aphids in locality | | | | | |
|--|------------------------------|-------|-------|----------|-------|-------|
| | shrubs | | | roadside | | |
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 |
| <i>M. ligustri</i> Mosl. | 1 | – | 1 | 2 | – | – |
| <i>M. lythri</i> (Schrk.) | 1 | – | – | – | – | – |
| <i>M. persicae</i> (Sulz.) | 10 | 72 | 2 | 30 | 16 | 17 |
| <i>Nasonovia ribisnigri</i> (Mosl.) | – | 1 | – | – | – | – |
| <i>Ovatus crataegarius</i> (Walk.) | 2 | 1 | – | – | 3 | – |
| <i>O. insitus</i> (Walk.) | 1 | 1 | – | – | – | – |
| <i>Panaphis juglandis</i> (Goetze) | – | – | – | 82 | – | – |
| <i>Pemphigus</i> sp. | 4 | – | 1 | 18 | – | – |
| <i>Periphyllus acericola</i> (Walk.) | 1 | 1 | – | 14 | – | – |
| <i>P. aceris</i> (L.) | – | – | 2 | – | – | – |
| <i>P. coracinus</i> (Koch) | 2 | – | – | – | – | – |
| <i>P. hirticornis</i> (Walk.) | 2 | – | – | – | – | – |
| <i>P. lyropictus</i> (Kessl.) | – | – | – | 2 | – | – |
| <i>P. testudinaceus</i> (Fern.) | 290 | 2 | 5 | 44 | 1 | – |
| <i>Phorodon humuli</i> (Schrk.) | 263 | 1 | 23 | 73 | 1 | 28 |
| <i>Phyllaphis fagi</i> (L.) | 1 | 1 | 1 | 3 | 1 | – |
| <i>Phylloxera</i> sp. | – | – | 1 | – | – | – |
| <i>Prociphillus bumeliae</i> (Schrk.) | 1 | – | – | – | – | – |
| <i>Pterocallis alni</i> (De Geer) | 4 | – | 1 | 5 | – | – |
| <i>Pterocomma pilosum</i> Buckt. | 2 | – | – | – | – | – |
| <i>P. populeum</i> (Kalt.) | 5 | – | – | 2 | – | – |
| <i>P. rufipes</i> Börn. | – | – | – | – | 1 | – |
| <i>Rhopalomyzus loniceræ</i> (Sieb.) | – | – | – | 1 | – | – |
| <i>Rhopalosiphoninus latysiphon</i> (David.) | 1 | – | – | – | 1 | – |
| <i>Rhopalosiphum insertum</i> (Walk.) | 2 | 1 | 1 | 4 | – | 1 |
| <i>R. nymphaeae</i> (L.) | – | – | 1 | – | 1 | – |
| <i>R. padi</i> (L.) | 278 | 1,683 | 1,253 | 480 | 662 | 1,329 |
| <i>Sipha maidis</i> Pass. | 1 | – | – | – | – | – |
| <i>Sitobion fragariae</i> (Walk.) | – | 32 | – | – | 1 | – |
| <i>S. avenae</i> (F.) | 11 | 42 | 3 | 43 | 23 | 2 |
| <i>Subsaltusaphis</i> sp. | – | – | – | 1 | – | – |
| <i>Symydobius oblongus</i> (Heyd.) | – | – | 1 | 1 | 1 | – |
| <i>Tetraneura ulmi</i> (L.) | 5 | 14 | 17 | 6 | 10 | 13 |
| <i>Thelaxes dryophila</i> (Schrk.) | 1 | – | – | 3 | – | – |
| <i>Therioaphis luteola</i> (Börn.) | – | – | – | 1 | – | – |
| <i>T. riehmii</i> (Börn.) | – | – | – | 1 | – | – |
| <i>T. trifolii</i> (Mon.) | – | – | – | 4 | 1 | – |
| <i>Tinocallis platani</i> (Kalt.) | 3 | – | – | 6 | – | – |
| <i>Trama rara</i> (Mordv.) | – | – | 2 | – | 1 | – |
| <i>Uroleucon (Uromelan)</i> sp. | – | 2 | 1 | – | 2 | 1 |
| <i>Uromelan</i> sp. | – | – | 2 | 3 | 1 | 1 |
| Number of individuals/year | 1,462 | 2,189 | 1,503 | 1,398 | 907 | 1515 |
| Number of individuals/3 years | – | 5,154 | – | – | 3,820 | – |
| Number of species/year | 67 | 47 | 52 | 63 | 48 | 25 |
| Number of species/3 years | – | 94 | – | – | 83 | – |

A. sambuci. In the 2009 and 2010 seasons, none of these species maintained the same high position within the group structure (Table 4). Groups comprising seven taxa constituted recedents in the three seasons of the research project. Subrecedents in the three research years, consisted of groups of seven taxa each. The group of subrecedents was most numerously represented in the first research season by 55 species, and in the remaining seasons by 39 and 40, respectively.

At the roadside, *R. padi* was eudominant in the aphid groups for all three seasons of the research project. Within the aphid groups, *A. corni*, *Panaphis juglandis*, and *P. humuli* were all subdominant. In 2009, *A. corni* held the same position (Table 4). The group of recedents was also large: in 2008, there were 12 taxa, and in the subsequent years, seven and six, respectively. The subrecedents group was comprised of 48, 39, and 18 species, respectively.

Species participation differed when analysing aphid flights dividing seasons into three separate periods: spring, summer, and autumn. In the spring of all three years, the greatest activity was recorded in the shrubs by: *P. humuli* (19.2%), *P. testudinaceus* (19%), *D. plantanoidis* (9.5%), and *A. sambuci* (8.5%). The most active species at the roadside location were: *P. humuli* (7.9%), *P. juglandis* (7.7%), *S. avenae* (6.3%), *Microlophium carnosum* (5.4%), and *Cavariella aegopodii* (5.2%) (Table 5). Other aphid species dominated in autumnal catches. In both refuge habitats, *R. padi* was certainly the most numerous species, constituting a total of 88.9% of all winged morphs recorded in the shrubs and 85% by the roadside for the three years of the research project. A high rank position was also occupied by *A. corni*, with 4% and 8.3%, respectively. Subsequent positions were taken by *M. persicae* and *A. fabae* (Table 6).

Table 3. Aphid species caught in large numbers and annually using Moericke traps in refuge habitats in Gorzyczki during the 2008–2010 time period

| Species | Shrubs | | Roadside | |
|---------------------------|--------|------|----------|------|
| | number | % | number | % |
| <i>Rhopalosiphum padi</i> | 3,214 | 62.4 | 2,471 | 64.7 |
| <i>Phorodon humuli</i> | 287 | 5.6 | 102 | 2.7 |
| <i>Aphis fabae</i> | 160 | 3.1 | 90 | 2.4 |
| <i>A. sambuci</i> | 140 | 2.7 | 54 | 1.4 |
| <i>Anoecia corni</i> | 136 | 2.6 | 164 | 4.3 |
| <i>Myzus persicae</i> | 84 | 1.6 | 63 | 1.6 |
| <i>Sitobion avenae</i> | 56 | 1.1 | 68 | 1.8 |
| <i>Acyrtosiphum pisum</i> | 20 | 0.4 | 55 | 1.4 |

Table 4. Abundance of aphid species in refuge habitats in Gorzyczki in the 2008–2010 time period

| Species | Shrubs | | | Roadside | | |
|----------------------------------|---------------------|------|------|---------------------|------|------|
| | dominance index [%] | | | dominance index [%] | | |
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 |
| <i>Rhopalosiphum padi</i> | 19.0 | 76.8 | 57.2 | 34.3 | 72.9 | 87.7 |
| <i>Anoecia corni</i> | 3.5 | 3.1 | – | 5.4 | 5.3 | 2.7 |
| <i>Aphis fabae</i> | 4.0 | 2.9 | 1.8 | 1.9 | 2.6 | 2.6 |
| <i>A. sambuci</i> | 4.9 | 2.1 | 1.1 | 2.7 | 1.1 | – |
| <i>Phorodon humuli</i> | 18.0 | – | 1.1 | 5.2 | – | 1.8 |
| <i>Microlophium carnosum</i> | – | – | – | 2.6 | 1.9 | – |
| <i>Cavariella aegopodii</i> | 3.3 | – | – | 3.7 | – | – |
| <i>Drepanosiphum platanoidis</i> | 8.4 | – | 1.0 | 2.8 | – | – |
| <i>Metopolophium dirhodum</i> | – | – | – | 4.6 | – | – |
| <i>Periphyllus testudinaceus</i> | 19.8 | – | – | 3.1 | – | – |
| <i>Sitobion avenae</i> | – | – | – | 3.0 | 2.5 | – |
| <i>Panaphis juglandis</i> | – | – | – | 5.9 | – | – |
| <i>Acyrtosiphum pisum</i> | – | – | – | 31.0 | – | – |
| <i>Myzus persicae</i> | 0.7 | 3.3 | – | 2.1 | 1.8 | – |

Table 5. Aphid species caught in large numbers in spring in refuge habitats in Gorzyczki during the 2008–2010 time period

| Species | Shrubs | | Roadside | |
|----------------------------------|--------|------|----------|-----|
| | number | % | number | % |
| <i>Phorodon humuli</i> | 287 | 19.2 | 81 | 7.9 |
| <i>Periphyllus testudinaceus</i> | 285 | 19.0 | 43 | 4.2 |
| <i>Drepanosiphum platanoidis</i> | 142 | 9.5 | 48 | 4.7 |
| <i>Aphis sambuci</i> | 128 | 8.5 | 48 | 4.7 |
| <i>Rhopalosiphum padi</i> | 70 | 4.7 | 42 | 4.1 |
| <i>A. fabae</i> | 66 | 4.4 | 47 | 4.6 |
| <i>Cavariella aegopodii</i> | 45 | 3.0 | 53 | 5.2 |
| <i>Brachycaudus divaricatae</i> | 41 | 2.7 | 21 | 2.0 |
| <i>Sitobion avenae</i> | 32 | 2.1 | 65 | 6.3 |
| <i>C. theobaldi</i> | 31 | 2.1 | 23 | 2.2 |
| <i>Metopolophium dirhodum</i> | 28 | 1.9 | 44 | 4.3 |
| <i>Euceraphis betulae</i> | 27 | 1.8 | 15 | 1.5 |
| <i>Microlophium carnosum</i> | 23 | 1.5 | 55 | 5.4 |
| <i>Panaphis juglandis</i> | 0 | 0 | 79 | 7.7 |

Table 6. Aphid species caught in large numbers in autumn in refuge habitats in Gorzyczki during the 2008–2010 time period

| Species | Shrubs | | Roadside | |
|---------------------------|--------|------|----------|------|
| | number | % | number | % |
| <i>Rhopalosiphum padi</i> | 3,119 | 88.9 | 2,314 | 85.0 |
| <i>Anoecia corni</i> | 137 | 4.0 | 225 | 8.3 |
| <i>Myzus persicae</i> | 62 | 1.8 | 49 | 1.8 |
| <i>Aphis fabae</i> | 56 | 1.6 | 23 | 0.8 |
| <i>Acyrtosiphon pisum</i> | 11 | 0.3 | 37 | 1.6 |

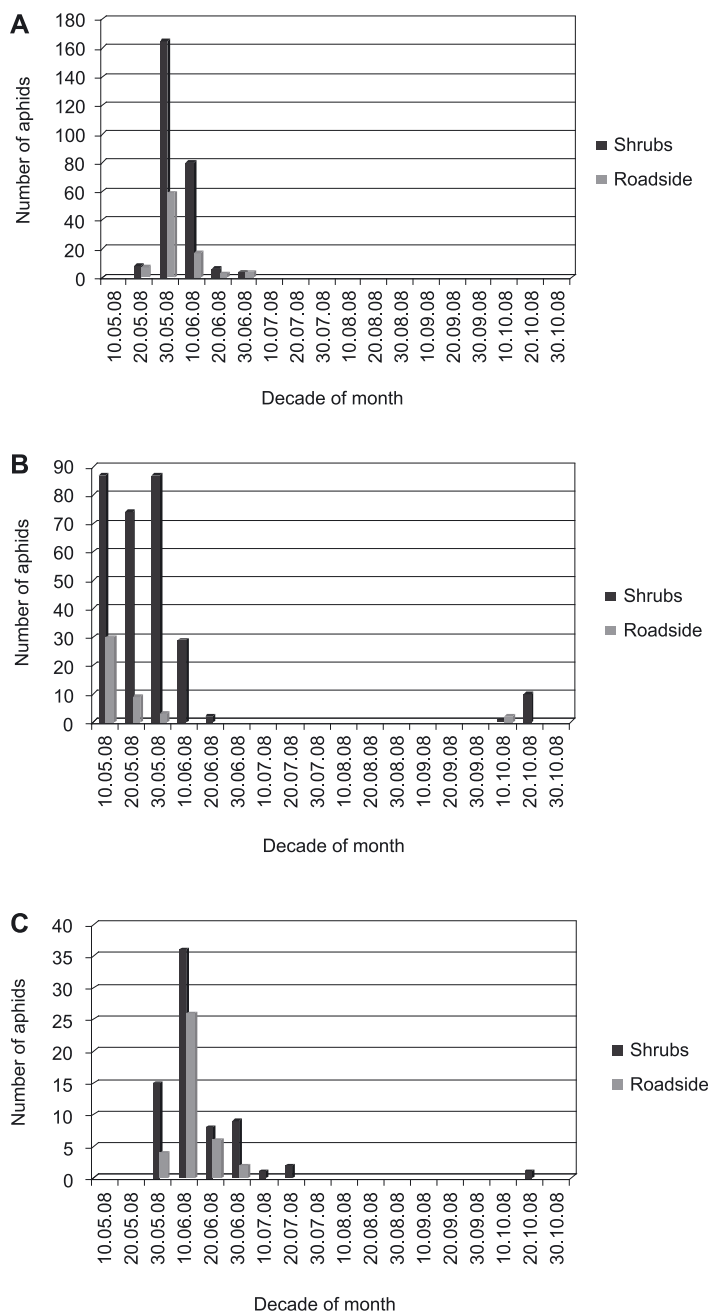


Fig. 3. Phenology of *Phorodon humuli* (A), *Periphyllus testudinaceus* (B), and *Aphis sambuci* (C) in shrubs and roadside habitats in Gorzyczki in 2008

Particular taxa differed when it came to the phenology of the appearance of the winged individuals in a season. The flights of *P. humuli*, *P. testudinaceus*, and *A. sambuci* were particularly active in spring (Fig. 3). Yet in autumn, the most active were *R. padi* and *A. corni* (Fig. 4). The flights of *A. fabae* were highly active throughout the entire season (Fig. 4).

The comparison of the refuge habitats of the different aphid groups during particular research years, showed that habitats differed significantly. The habitats differed in terms of general species diversity, as expressed by the H' coefficient but these did not differ between the years of the study (Table 7). In 2008, the highest species diversity expressed by the Shannon-Weaver index was recorded at the roadside and the shrub locations as 4.12

and 3.74, respectively. The lowest was recorded in both locations in 2010 as 1.40 and 0.95, respectively. The same relations were recorded between groups compared on the basis of two subsequently calculated indices: Pielou's uniformity of species frequency (J') and Simpson's species diversity (d) (Table 7).

Hutcheson's test was applied both quantitatively and qualitatively to compare the aphid communities in refuge habitats, shrubs, and roadside. The differences between them were proven statistically on the basis of the Shannon-Weaver formula (Table 7).

A comparison of the groups in terms of quality using the Marczewski-Steinhaus index, showed that the shrub habitat groups had between 30 to 33 common species. The similarity of species ranged from 38.37 to 43.48%. The

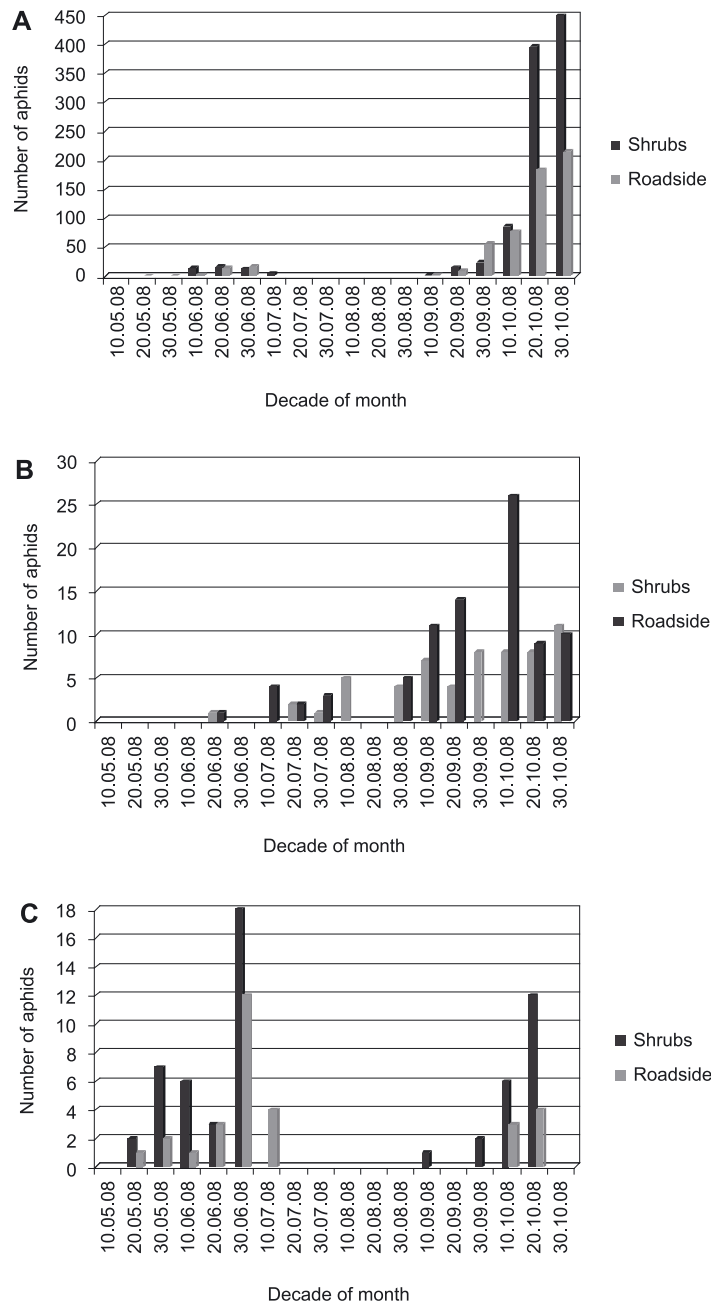


Fig. 4. Phenology of *Rhopalosiphum padi* (A), *Anoecia corni* (B), and *Aphis fabae* (C) in shrubs and roadside habitats in Gorzyczki in 2008

Table 7. Biocenotic indices from 2008–2010, characterising aphid communities at particular refuge habitats in Gorzyczki

| Refuge habitat | Year | Number of species | Number of individuals | H' | J' | d |
|----------------|------|-------------------|-----------------------|-------|------|-------|
| Shrubs | 2008 | 67 | 1,462 | 3.74* | 0.62 | 20.85 |
| | 2009 | 47 | 2,189 | 1.75* | 0.32 | 13.77 |
| | 2010 | 52 | 1,503 | 1.40* | 0.25 | 16.05 |
| Roadside | 2008 | 64 | 1,398 | 4.12* | 0.69 | 20.03 |
| | 2009 | 48 | 907 | 2.03* | 0.36 | 15.89 |
| | 2010 | 25 | 1,515 | 0.95* | 0.20 | 7.55 |

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

number of common species by the roadside was more diverse and the degree of similarity during the years of the study was smaller, ranging between 32.73 and 38.27%. In the 2008 season, a comparison of the two groups settled in the shrubs and by the road, indicated that their similarity was high; reaching 55.97% and 47 common species.

Discussion

The large-scale activity of winged aphids in the researched refuge habitats in the agricultural landscape of Wielkopolska points to a wealth of aphid fauna. The presence of 94 and 83 aphid species or groups of aphid species, respectively, was recorded within the winged aphid groups, in shrubs, and by the roadside. The method applied, allows for the gathering of an abundant amount of material but does involve certain difficulties when interpreting the research results. This stems from the fact, that winged aphid specimens from neighbouring habitats could also be found in the yellow dishes. Taking the above information into consideration, those species which were captured in large quantities during the period following spring, whilst their host plants dominated in phytocoenosis, were considered to be characteristic of the studied sites. On this basis, thirteen aphid species were included within the group of taxa characteristic for both research sites: *P. humuli*, *P. testudinaceus*, *D. platanoidis*, *A. sambuci*, *R. padi*, *A. fabae*, *C. aegopodii*, *B. divaricatae*, *S. avenae*, *C. theobaldii*, *M. dirhodum*, *E. betulae*, *M. carnosum*, and additionally *P. juglandis* for the roadside. As stated in previous research articles, many of these species were observed as being characteristic of various non-agricultural sites regarded as typical across the agricultural landscape of the Wielkopolska and Kujawy regions, such as mid-field thickets, roadsides, forest edges or boundaries (Wilkaniec 2000, 2001; Bennewicz *et al.* 2001; Wilkaniec *et al.* 2000, 2008; Bennewicz 2010). Their significance stems primarily from the common occurrence of these host plant habitats in phytocoenosis including: *P. humuli* – blackthorn and cherry plum, *P. testudinaceus* and *D. platanoidis* – maple trees, and *A. fabae* – euonymus, *C. aegopodii* and *C. theobaldi* – willow, *E. betulae* – birch, *B. divaricatae* – cherry plum, *R. padi* – black cherry and grass, *S. avenae* – grasses, and *M. carnosum* – nettle. Only *P. juglandis*, a taxon growing on walnut, was unusual for roadside sites in Wielkopolska as this tree rarely grows by the side of a road.

The unique position of *R. padi* in the caught material should be commented on. A large quantity of this specimen is captured in traps, mainly in autumn; from mid-September until the end of the growth season. The same phenomenon can be observed not only in the agricultural landscape but also in e.g. urban green spaces (Wilkaniec 2000, 2001; Wilkaniec *et al.* 2000, 2008, 2012). In terms of numbers in catches, two species also found growing in grasses and cereals, i.e. *A. corni* and *S. avenae*, can never be on par with *R. padi*, hence, it is difficult to explain this phenomenon purely in terms of the extensive availability of host plants in phytocoenosis.

The obtained results point to significant differences in the number of groups within the research years, which impacts a whole array of factors, both abiotic and biotic.

The best conditions for aphid development were during the first season of the research. This was primarily associated with favourable weather conditions, i.e. a warm and moderately humid season.

Our understanding of the impact of landscape composition on the biological fight with pests in horticultural crops is relatively small (Brown 2004; Eilers and Klein 2009; Dib *et al.* 2010; Thomson and Hoffmann 2010; Stutz and Entling 2011). The results of the presented research point to the fact that uncultivated habitats surrounding apple orchards provide a good location for a wealth of aphid fauna to develop. The issue of to what extent this potential nutrient base may be used by different groups of predatory and parasitic insects, which could regulate the number of orchard pests, requires further research.

The results of our studies can be used in assessing the biodiversity of this group of insects in refuge habitats. Aphids are important as pests of plants, and vectors of virus diseases.

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