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# Aphids in Different Non-crop Areas of Agrarian Landscape in Northern Poland

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## ABSTRACT

The following objectives have been formulated: 1) qualitative and quantitative evaluation of aphid communities (Hemiptera: Aphididae) associated with specific plant communities inside agricultural landscape (so-called within-farm habitats, semi-natural habitats, etc.), such as: field boundaries, bushes and forest islands, typical for the Lower Vistula Valley in northern Poland, and 2) determination of the types of non-crop habitats nutritionally attractive to aphids that affect the diversity of their communities. The study was conducted in the years 1996-2001. Material consisted of aphids from the family Aphididae (Hemiptera: Aphididae). Among ten various types of semi-natural habitats examined within six years of the study, of which six were located in the so-called multicrop agricultural space, and four in the so-called landscape park, more attractive to aphids were the habitats between large crop fields than in the landscape park beside small crop fields. This can indicate that the aphids choose sites with higher availability of suitable food. There were more aphids detected in the bushes with a stable and diverse vegetation structure, predominance of trees, shrubs, and on the forest edges rather than in open areas such as field boundaries. This means that aphids concentrate in the off-field habitats border large crop lands.

*Key words:* Aphididae communities, aphid host plants, non-crop habitats

## INTRODUCTION

Semi-natural habitats in the diverse landscape have greater potential in the preservation of biodiversity and biological plant protection. Mosaic structure of a landscape allows for better use of the natural resistance of the environment in the fight against pests. The formation of a beneficial system: crop-pest-natural enemy, will allow for more effective protection of crops, with simultaneous reduction of the use of chemicals and improvement in the stability of agroecosystems (Bianchi *et al.*, 2006). For instance, field boundaries contribute to the temporal synchronization between agrophages and their natural enemies, and their role as a source of beneficial arthropods should be accounted for (Wratten *et al.*, 2003). At the same time, when there is no food source for aphidophages in the crop fields, i.e., no pests, then their number is increasing in the colonies of aphids of the boundaries (Bianchi and Werf, 2004).

The using of so-called augmentative biological control still poses many problems because integrated crop protection systems are still underdeveloped (Bianchi *et al.*, 2006). A more extensive network of ecotones contributes to increased diversity of flora and fauna associations and expanding the numbers of eurytopic species. In such an environment, processes of exchange of the matter, energy and species occur more intensely and multidirectionally, and consequently, the entire landscape system is more durable and resistant to the unfavorable factors (Dąbrowska-Prot, 1998).

It is therefore reasonable to conduct studies concerning the environmental and farming evaluation of semi-natural habitats in the agricultural landscape such as refuges of aphid fauna. Hence, we have assumed that such habitats beside agricultural landscape can influence agroecosystems or different non-crop areas in an agricultural space as for aphids assemblages. To implement this research task and verify hypotheses, the following specific aims have been formulated: 1) determination of the occurrence and qualitative and quantitative evaluation of aphid communities (Hemiptera: Aphididae) associated with specific plant communities inside agricultural landscape (so-called off-field habitats, non-agricultural habitats or off-field crop habitats), such as: field boundaries, bushes and forest islands, typical for the Lower Vistula Valley in northern Poland, and 2) determination of the types of non-agricultural habitats that affect the diversity of aphid communities and that are nutritionally attractive to aphids.

## MATERIALS AND METHODS

The study was conducted in the years 1996-2001. Material consisted of aphids from the family Aphididae (Hemiptera: Aphididae).

Each year, observations were carried out in study areas, which comprised selected semi-natural habitats, in the period from the appearance of aphids on plants, i.e., from the beginning of May to end of September or beginning of October, when aphids were not recorded on plants anymore. Samples were taken in 10 days intervals, each time 3 samples. One sample composed colonies of the aphids settled on one leaf of a given host plant species. The material was sampled 10 times per season - that means 30 samples, on the average, from a given search area.

The occurrence of aphids in various types of non-crop areas have been documented on the basis of qualitative and quantitative characteristics of their communities associated with particular types of investigated habitats. The investigations were started when the aphids reproduced on the settled plants. The faunistic and ecological characteristics of the material collected were based on the following parameters: species composition and mean number of aphid colonies on marked plants, the dominance structure (D) of the aphid communities, the similarity of the dominance structure between compared communities based on the Renkonen index - Re (similarity for Re is assumed from 50%, e.g., Pawlikowski, 1985), as follow:

$$Re = \sum D_{min.},$$

where $D_{min.}$ is a minimum value of domination for a given species in two compared communities.

The following domination classes were adopted: D4 - a very numerous species - a dominant, constituting more than 20% of material collected in the given habitat; D3 - a numerous species - a subdominant, represented by 10.1 - 20 % of the total number of specimens; D2 - a quite numerous species - a recedent, ranging from 3 to 10% of collected material; D1 - a rare species, subrecedent - represented by less than 3% of total number of specimens. The index of species diversity (H', see below) (Shannon and Weaver, 1963) was applied to assess the qualitative and quantitative differences between the compared communities of aphids and the Euclidean distance measure to compare the similarity of species diversity (unweighted pair-group average - UPGMA).

$$H' = -\sum_{i=1}^{s} p_t \ln p_t$$

where $p_t$ : is the proportion of specimens of the *t*th species (so-called relative abundance), *s* - number of all the species in the compared aphid communities.

Hutcheson's test (Hutcheson, 1970) was used to estimate the significance of differences between the calculated values of H', taking into consideration a Student *t*-test.

Study areas were named as follows.

Study area "No.1" (so-called multicrop agricultural space) covered a typical agricultural large area with fields of several dozen hectares, among which the following sites (non-crop habitats) were selected:

1. K1 - bushes - *Pruno-Crataegetum* in the Leszcz village. Typical bushes with a dominant *Prunus spinosa, Sambucus nigra. Rhamnus cathartica*, *Euonymus europaea*, *Corylus avellana* and *Acer platanoides* constituted an admixture, but completely obscured the surface of the earth, hence the herbaceous species growing under the canopy of these shrubs were sparse.

2. K2 - bushes - *Potentillo albae-Quercetum* in the Leszcz village. The habitat was dominated by the approximately 200-year-old stand of *Quercus robur*. Shrub layer was mainly formed by the following species: *R. cathartica*, *Rosa canina, Rosa tomentosa* and *S. nigra*. *Artemisia vulgaris* and *Chenopodium album* also occurred quite frequently.

3. M1 - boundary - *Lamio-Veronicetum politae* and *Tanaceto-Artemisietum* with a predominance of *Elymus repens* in the Leszcz village. It was an intensely sunlit open field boundary without bushes. The highest abundance was found for *E. repens*. It was dominated by the following species: *Matricaria maritima* ssp. *inodora*, *Ch. album*, *Rumex crispus* and *U. dioica*.

4. L1 - the so-called 'forest islands' - were formed by *Pinus sylvestris* and *Urtica dioica* in the Leszcz village. *P. sylvestris* pine stand was heavily exposed to sun light, which promoted the penetration of herbaceous vegetation and shrubs. Among them

were: *Quercus rober*, *Euonymus europaea* and *Cornus sanguinea*. *Sambucus nigra* and *Sambucus racemosa* were also numerous. *U. dioica* was an ubiquitous species.

5. M2 - boundary with vegetation type *Tanaceto-Artemisietum* with a predominance of *Bromus inermis* in the Świerczynki village. Field boundary was a deep, exposed and sunny drainage ditch. Upper part of the ditch was dominated by *T. vulgare*, *A. vulgaris*, and *C. arvense*. The following species were abundant: *E. repens*, *F. rubra*, *P. pratensis* and *Melandrium album*, *U. dioica* and *Phragmites australis*.

6. L2 - 'forest island', formed by *Ribo nigri Alnetum* in the Świerczynki village. *Alnus glutinosa* was predominant in the forest stand, while *Sambucus nigra* was most common among the bushes. Single plants were present of species *Euonymus europaea* and *Sambucus racemosa*. Herbaceous vegetation of the edge of the forest was dominated by *Urtica dioica* and *Bromus inermis*. *Cirsium arvense* and *Arctium lappa* occurred only on the edge of the island.

Study areas "No.2" (so-called landscape park) were part of the Chełmiński and Nadwiślański Landscape Park Complex (ZPKChN) with small fields of the size of one hectare, and numerous wild growing plants.

7. K3 - bushes - *Euonymo-Cornetum*, *Urtico-Sambucetum* with dominant *Salix alba* in the Grabówko village. Bushes covered by stately *Salix alba* trees. Drying of the habitat resulted in the occurrence of species such as: *P. spinosa, E. europaeus, Crataegus* spp., *Cornus sanguinea*, *R. canina* and *S. nigra*. Lush herbaceous vegetation with dominant *U. dioica* and *E. repens* was present under the canopy of trees and shrubs. Less common were *Phragmites australis* and *Arctium* spp.

8. M3 - boundary, consisted of a moist vegetation of the type *Filipendulo-Petasition* in the Topolinek village. It was a fertile field boundary, water logged. Herbaceous plants were most common at this site. Part of the field boundary was covered by *Rubus caesius, P. spinowa* and *Rosa canina.* The following species were dominant among herbaceous plants: *L. album*, *E. repens*, *U. dioica* and *Poa pratensis*, *Phragmites australis* and *Artemisia vulgaris*.

9. K4 - bushes - *Pruno-Crataegetum* Hueck in the Gruczno village. Thickets on a small, well-lit part of the slope of the Vistula Valley. A dense strip of bushes was present at this site with dominant stately *Crataegus monogyna*, *C. laevigata*, *P. spinowa*, *R. cathartica*, *R. canina* and *Rubus caesius*. Exposed, well-lit gaps between shrubs, were occupied by thermophilous herbal vegetation that included: *Centaurea scabiosa* and *Artemisia vulgaris*, *Ch. album*, *Tanacetum vulgare*, and abundant *E. repens*.

10. M4 - boundary, plant association of the type *Calystegion* with *Solidago serotina* in the Chrystkowo village. Herbaceous vegetation dominated on the fertile field boundary with the individual trees of *Alnus glutinosa*, *Fraxinus excelsior* and *Populus alba* and unnumerous shrubs of *Prunus spinowa* and *Rosa canina* species. The most common species were: *Solidago gigantea*, *E. repens*, *Anthriscus sylvestris*, *Urtica dioica*, *Tanacetum vulgare* and *Artemisia vulgaris*.

Location of study areas is presented in the Table 1.

Table 1. List of the research areas (non-crop habitats)

| Research area | Locality | Types of non-crop habitats |
|---|---|---|
| No.1: so-called multicrop agricultural space | Leszcz | 1. Bushes – K 1 |
| | | 2. Habitats with trees - K2 |
| | | 3. Boundary – M1 |
| | | 4. 'Forest islands' - L1 |
| | Świerczynki | 5. Boundary – M2 |
| | | 6. 'Forest islands' - L2 |
| No.2: so-called landscape park (Chełmiński and Nadwiślański Landscape Park Complex -ZPKChN) | Grabówek | 7. Habitats with trees – K3 |
| | Topolinek | 8. Boundary - M3 |
| | Gruczno | 9. Bushes – K4 |
| | Chrystkowo | 10. Boundary - M4 |

## RESULTS

21 species of aphids have been identified that occurred on 28 plant species in 10 non-crop areas investigated (Table 2). Most species belonged to the subfamily Aphidinae (18), two to Myzocallidinae and one to Pterocommatinae. Within six years of research in the off-field habitats, the largest infestation of plants by aphids was recorder in the year 2000. The greatest number of species of aphids was also reported in this year (Table 2).

Noteworthy is the pest species *Aphis fabae*, which presence was detected in seven plant species. During all the years of the study, the host plants of this species included *Cirsium arvense* and *Matricaria maritima*, and the former species was most frequently infested by this aphid (Table 2). *Aphis sambuci* was comparably frequent on the *Sambucus nigra* bushes, while *Microlophium carnosum* most readily settled on *Urtica dioica*. In 1997-2001, aphid *Hyalopterus pruni* occurred on *Phragmites australis*, while aphids of species *Tuberculoides annulatus* were recorded on *Quercus robur*. For five years (1996 and 1989-2001) aphids of species *Metopeurum fuscoviride* have been observed on *Tanacetum vulgare*. Other aphid species were found on their host plants only in certain years of the study (Table 2).

The richest aphid fauna was found in the shrubs K3 in Chełmiński and Nadwiślański Landscape Park Complex and at the edge of the L2 'forest island' in Świerczynki in the so-called multicrop agricultural space (Table 3). The poorest site in the species of aphids feeding on plants was the field boundary M3 in Topolinek, also located within the discussed landscape park, and the edge of the L1 'forest islands' in Leszcz in the agricultural landscape.

Table 2. Mean number of aphids (Hemiptera: Aphididae) occurring on host plants over 1996-2001

| Aphid species | Plant species | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| *APHIDINAE* | | | | | | | |
| *Aphis fabae* Scop. | *Arctium minus* | | 375 | 171 | 619 | 50 | |
| | *Arctium lappa* | | 8 | | | | |
| | *Cirsum arvense* | 365 | 136 | 1441 | 1334 | 3296 | 1570 |
| | *Euonymus europaeus* | | | | | 47 | 124 |
| | *Matricaria maritima* sp. *inodora* | 826 | 13 | 1089 | 8 | 509 | 246 |
| | *Rumex crispus* | | | 625 | 126 | | |
| | *Rumex obtusifolius* | | | 11 | | 845 | 113 |
| Sum *Aphis fabae* Scop. | | 1191 | 532 | 3337 | 2087 | 4747 | 2053 |
| *Aphis idaei* van der Goot | *Rubus idaeus* | | | | | 69 | |
| *Aphis mammulata* Ghim. & Hill. Ris Lam. | *Rhamnus catharica* | | | | | | 128 |
| *Aphis sambuci* L. | *Sambucus nigra* | 169 | 1283 | 1569 | 303 | 1843 | 1547 |
| *Aphis symphyti* Schr. | *Symphytum officinale* | | | | | 577 | |
| *Aphis urticata* J. F. Gmel. | *Urtica dioica* | 987 | | | 25 | 211 | 7 |
| *Brachycaudus helichrysi* (Kalt.) | *Solidago gigantea* | | 42 | | | | |
| *Brachycaudus lychnidis* (L.) | *Melandrium album* | 137 | 31 | 160 | 18 | | |
| *Brevicorynae brassicae* (L.) | *Sinapis arvensis* | | | 203 | | 829 | |
| *Hyalopterus pruni* (Geoff.) | *Prunus spinosa*<br>*Phragmites australis* | | 39 | 642<br>889 | 202 | 1314<br>2885 | 1128<br>614 |
| Sum *Hyalopterus pruni* (Geoff.) | | | 39 | 1531 | 202 | 4199 | 1742 |
| *Macrosiphum rosae* (L.) | *Rosa canina* | 49 | | | | 50 | 16 |
| *Macrosiphoniella artemisiae* (Boy.de Fons.) | *Artemisia vulgaris* | | | 56 | 26 | | |
| *Macrosiphoniella millefolii* (de Geer.) | *Achillea millefolium* | | | 101 | | | |
| *Metopeurum fuscoviride* Stroy. | *Tanacetum vulgare* | 200 | | 283 | 318 | 499 | 207 |
| *Microlophium carnosum* (Buck.) | *Urtica dioica* | 1177 | 357 | 1014 | 1129 | 58 | 292 |
| *Ovatus crataegarius* (Walk.) | *Crataegus monogyna* Jacq. | | | | | | 15 |
| *Uroleucon cirsii* (L.) | *Cirsium arvense*. | | | 150 | | 61 | |
| *Uroleucon jaceae* (L.) | *Centaurea scabiosa* | | | 284 | 20 | 145 | |

Table 2. Continue

| Aphid species | Plant species | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|
| *MYZOCALLIDINAE* | | | | | | | |
| *Eucallipterus tiliae* (L.) | *Tilia cordata* | | 3 | | | | |
| *Tuberculoides annulatus* (Hart.) | *Quercus robur* | | 197 | 49 | 54 | 129 | 361 |
| *PTEROCOMMATINAE* | | | | | | | |
| *Neopterocomma asiphum* Hille Ris Lam. | *Salix alba* | | | | | 13 | 38 |
| Sum ±SE | | 3910 ±1 73,6 | 2484 ±-128,4 | 8737 ±200,1 | 4183 ±1 82,8 | 13430 ±415,8 | 6406 ±221,9 |

The black bean aphid (*A. fabae*) was found on six plant species in the K1 habitat, on five species of the M1 field boundary and four species on the edge of the L2 'forest island' in the agricultural landscape. In contrast, this aphid species was never recorded in L1, K4 and M3 habitats. The black bean aphid most often settled on *C. arvense* (Table 3).

In the years 1996-2001, the prevalence of all species of aphids on the plant species studied indicated that most of these phytophages fed in the habitat of M1 boundary (Table 3). More aphids infested also plants on the edge of the L2 'forest islands' and K1 and K4 bushes than in other types of the non-crop habitats (Table 3).

The above data show that in 1996-2001 most of the aphids settled on plants in typically agricultural areas, in the M1 field boundary and K1 bushes in the Leszcz village, and on the edge of the L2 'forest island' in Świerczynki (study area No. 1). In the landscape park, only the K4 bushes in Gruczno (study area "No.2") had comparably high average number of aphids throughout all the years of the study compared to other types of non-field habitats.

The dominant (D) and subdominant (S) aphid species during all the years of the study on agricultural land (study area No. 1), in the off-field habitats L2, K1, K2, M1 and M2, was *A. fabae* and *A. sambuci*, respectively, with the exception of the L1 'forest island' in Leszcz (Table 4). Five species of aphids dominated in the K2 and K1 bushes and these sites had the largest number of dominant species (Table 4). However, in habitats in Chełmiński and Nadwiślański Landscape Park Complex (ZPKChN), the dominant aphid was *H. pruni*, and this species was not recorded only in the M4 boundary in Chrystkowo. Three species of aphids were co-dominant in the K4 bushes in Gruczno, i.e., *A. sambuci*, *H. pruni and M. fuscoviride*.

Aphids *A. fabae*, *A. sambuci* and *H. pruni* were dominant or subdominant species in majority of the habitats investigated, while *M. carnosum* was dominant in five cases only (Table 4).

In general, it can be said that on the edges of 'forest islands' and in the shrub habitats, more species of aphids were co-dominant than in the boundaries. *A. fabae* dominated in the bushes and field boundaries at the study area "No.1". The M2 boundary in Świerczynki was the only one where more species of aphids were dominant than in the remaining boundaries.

Table 3. Aphids occurring on host plant species in non-crop habitats over 1996 - 2001

| | | Research area No.1 | | | | | | Research area No.2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aphid species | Plant species | L1 | L2 | K1 | K2 | M1 | M2 | K3 | K4 | M3 | M4 |
| *Aphis fabae* | *Arctium minus* | | | + | + | + | | | | | + |
| | *Arctium lappa* | | + | | | | | | | | |
| | *Cirsum arvense* | | + | + | | + | + | + | | | + |
| | *Euonymus europaeus* | | + | + | | | | | | | |
| | *Matricaria maritima* | | | + | + | + | + | | | | |
| | *Rumex crispus* | | | + | | + | | | | | |
| | *Rumex obtusifolius* | | + | + | | + | | | | | |
| *Aphis idaei* | *Rubus idaeus* | | + | | | | | | | | |
| *Aphis mammulata* | *Rhamnus catharicus* | | | | | | | | + | | |
| *Aphis sambuci* | *Sambucus nigra* | + | + | + | + | + | + | + | + | | |
| *Aphis symphyti* | *Symphytum officinale* | | | | | | | | | | + |
| *Aphis urticata* | *Urtica dioica* | | + | + | + | + | | | + | | |
| *Brachycaudus helichrysi* | *Solidago serotina* | | | | | | | | | | + |
| *Brachycaudus lychnidis* | *Melandrium album* | | | + | | + | + | + | + | | |
| *Brevicoryne brassicae* | *Sinapis arvensis* | | | | | | + | | + | | |
| *Eucallipterus tiliae* | *Tilia cordata* | | + | | | | | | | | |
| *Hyalopterus pruni* | *Prunus spinosa* | | | + | + | + | | + | + | + | |
| | *Phragmites australis* | | + | | + | | + | + | | + | |
| *Macrosiphum rosae* | *Rosa canina* | | + | | + | | | | | | |
| *Macrosiphoniella artemisiae* | *Artemisia vulgaris* | + | | + | + | + | | + | + | + | + |
| *Macrosiphoniella millefolii* | *Achillea millefolium* | | | | | | | | + | | |
| *Metopeurum fuscoviride* | *Tanacetum vulgare* | | + | | | + | + | | + | | + |
| *Microlophium carnosum* | *Urtica dioica* | + | + | + | | + | + | + | + | + | |
| *Myzus cerasi* | *Galium aparine* | | | | | + | | | | | |
| *Neopterocomma asiphum* | *Salix alba* | | | | | | | + | + | | |
| *Ovatus crataegarius* | *Crataegus monogyna* | | | | | | | | + | | |
| *Tuberculoides annulatus* | *Quercus robur* | + | + | | + | | | | | | |
| *Uroleucon cirsii* | *Cirsum arvense* | | + | + | | | | | | | + |
| *Uroleucon jaceae* | *Centaurea scabiosa* | | | | | | | | + | | |

Description: K1- bushes at Leszcz, K2- habitats with trees at Leszcz, K3- habitats with trees at Grabówko , K4- bushes at Gruczno; M1- boundary at Leszcz, M2- boundary at Świerczynki, M3- boundary at Topolinek, M4- boundary at Chrystkowo, L1- 'forest island' at Leszcz; L2- 'forest island' at Świerczynki ; No.1- so-called multicrop agricultural space, No.2 - so-called landscape park (Chełmiński and Nadwiślański Landscape Park Complex - ZPKChN)

Table 4. Dominants and subdominants of aphid species occurring on host plants in non-crop areas

| Aphid species | Research area No.1 | | | | | | Research area No.2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Non-crop areas | | | | | | | | | |
| | L1 | L2 | K1 | K2 | M1 | M2 | K3 | K4 | M3 | M4 |
| *Aphis fabae* | | S | D | D | D | D | | | | D |
| *Aphis sambuci* | D | S | D | D | | S | | D | | |
| *Aphis symphyti* | | | | | | | | | | D |
| *Aphis urticata* | | | S | | | | | | | |
| *Brevicoryne brassicae* | | | | | | D | | | | |
| *Hyalopterus pruni* | | D | S | S | | | D | D | D | |
| *Macrosiphum rosae* | | | | S | | | | | | |
| *Metopeurum fuscoviride* | | | | | | S | | S | | |
| *Microlophium carnosum* | D | S | S | | | | D | | D | |
| *Tuberculoides annulatus* | S | | | S | | | | | | |

Description: K1- bushes at Leszcz, K2- habitats with trees at Leszcz, K3- habitats with trees at Grabówko , K4- bushes at Gruczno; M1- boundary at Leszcz, M2- boundary at Świerczynki, M3- boundary at Topolinek, M4- boundary at Chrystkowo, L1- 'forest island' at Leszcz; L2- 'forest island' at Świerczynki ; No.1- so-called multicrop agricultural space, No.2 - so-called landscape park (Chełmiński and Nadwiślański Landscape Park Complex - ZPKChN)

The diversity of aphid species infesting plants in subsequent years, estimated by the Shannon-Weaver index, was in the range from 0,6 to 1,2. Significantly lowest species diversity, compared to other years, was found in 1997, while in 2001, H' index reached significantly higher value than in the years 1996-1999 (Table 5 - 5a).

During the studied years, communities of aphids infesting Gruczno K4 bushes demonstrated the greatest number of feeding aphid species as well as the size of the population compared with other off-field habitats. H' index for this site was 1,8 and was significantly higher compared to majority of the other aphid communities studied (Table 5 - 5b). The lowest statistically significant species diversity showed communities of aphids in the boundaries, particularly in Chrystkowo M4, Topolinek M3 and K3 bushes in Grabówek (study area No.2 - Table 5 - 5b).

In conclusion, community of aphids in K4 bushes in Gruczno had significantly higher species diversity in comparison with communities of aphids of other off-crop habitats with a low degree of anthropogenic transformation in landscape park. However, in the K1 bushes and edges of the L2 'forest island', aphid communities showed a significantly higher species diversity than in other habitats of so-called multicrop agricultural space.

In the analyzed years of research, the communities of aphids with significantly greater diversity in K4 bushes in the landscape park, and K1 bushes and on the edge of L2 'forest island' in the so-called multicrop agricultural space, formed a distinctive group compared to other communities, while exhibiting a similar diversity of species (Fig. 1).

Table 5. Characteristics of aphid communities occurring on host plants over 1996-2001

5a. In different years: index of species diversity (H') and similarity of the dominance structure - the Renkonen index - Re

| Years | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|
| H' | 1,007 | 0,556 | 0,955 | 0,899 | 0,811 | 1,158 |

| Years | 2001-2000 | 2001-1999 | 2001-1998 | 2001-1997 | 2000-1999 | 2000-1998 | 2000-1997 | 2000-1996 | 1999-1998 | 1999-1997 | 1999-1996 | 1998-1997 | 1998-1996 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Re* | 54,3 | 55,2 | 76,8 | 52,0 | 52,3 | 65,4 | 50,0 | 52,5 | 63,8 | 50,0 | 67,0 | 56,1 | 54,2 |

5b. In different non-crop habitats: sum of specimens, index of species diversity (H') and similarity of the dominance structure - the Renkonen index - Re

| Type of non-crop habitats | Research area No. 1 | | | | | | Research area No. 2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L1 | L2 | K1 | K2 | M1 | M2 | K3 | K4 | M3 | M4 |
| Sum of specimens | 518,8 ±55,7 | 6854,3 ±248,2 | 6310,1 ±263,3 | 934,9 ±35,0 | 10174,8 ±891,9 | 3151,3 ±195,3 | 1658,2 ±171,3 | 5456,2 ±153,8 | 1343,7 ±266,6 | 1712,9 ±153,1 |
| H' | 0,734 | 1,363 | 1,345 | 0,900 | 0,958 | 0,503 | 0,469 | 1,809 | 0,328 | 0,408 |
| Re* | K3-M3 = 56,6% | | | | | | | | | |

Description: K1- bushes at Leszcz, K2- habitats with trees at Leszcz, K3- habitats with trees at Grabówko , K4- bushes at Gruczno; M1- boundary at Leszcz, M2- boundary at Świerczynki, M3- boundary at Topolinek, M4- boundary at Chrystkowo, L1- 'forest island' at Leszcz; L2- 'forest island' at Świerczynki ; No.1- so-called multicrop agricultural space, No.2 - so-called landscape park (Chełmiński and Nadwiślański Landscape Park Complex - ZPKChN)

Research area No. 1- so-called multicrop agricultural space, Research area No. 2 - so-called landscape park (Chełmiński and Nadwiślański Landscape Park Complex - ZPKChN)

* / comparison between investigated non-crop habitats (level of similarity ≥ 50%)

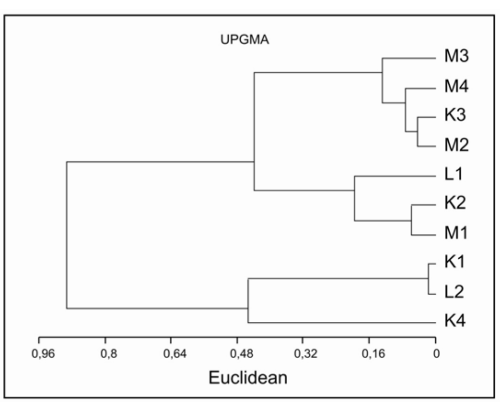


Fig. 1. Similarities of non-crop habitats taking into consideration the diversity (H`) of aphid communities occurring on host plants over 1996 - 2001

Description: K1 - bushes at Leszcz, K2 - thickets with trees at Leszcz, K3- thickets with trees at Grabówko, K4 - bushes at Gruczno; M1 - boundary at Leszcz, M 2- boundary at Świerczynki, M3 - boundary at Topolinek, M 4 - boundary at Chrystkowo, L1 - 'forest island' at Leszcz; L2- 'forest island' at Świerczynki

In years 1996-2001, a similarity of the dominance structure of aphids feeding on plants in the studied habitats occurred only between communities of species in K3 bushes and M3 boundary (Table 5 - 5b). However, the Renkonen's index, during the years of the study, demonstrated a similarity between communities of aphids, with the only exception of the comparison between 1996 and 1997, and 1996 and 2001 (Table 5 - 5a).

## DISCUSSION

This work summarizes six years of research initiated by Barczak *et al.* (2000), attempting to valorization of semi-natural environments, in order to identify ecological sites in the agricultural landscape with a mosaic-like structure in the northern Poland, as reservoirs of aphids and their natural enemies.

The results of the present study as well as of other authors (Robert and Gallic 1991; Fernandez-Quintanilla *et al.*, 2002; Bennewicz, 2012) suggest that the non-agricultural areas comprise habitats, in which aphid species considered as pests either do not occur, or these environments mainly serve as sites for further dispersion of those species. The studies conducted showed that commonly occurring species of *A. fabae*, recorded in the bushes and classified as pest, fed mainly on herbaceous plants, or similarly as *H. pruni* was found primarily on common reed (Barczak *et al.*, 2000; 2013; Bennewicz, 2012). Aphids also play an important role as a link in the food chain. Therefore, the tested fields, bushes and edges of the 'forest islands', adjacent to the fields, only to a limited extent should be treated as reservoirs of aphid species harmful to crops (Bennewicz *et al.*, 2001; Bennewicz, 2012). They also constitute refuges of aphids, which can serve as alternative hosts for beneficial fauna, i.e., natural enemies of pests, like parasitoids and predators.

Various types of bushes are considered very valuable off-crop habitats due to the size of the populations and number of species occurring in them, including aphid parasitoids, less specialized nutritionally predatory aphidophagous Carabidae, and specialized Syrphidae, but also phytophages, forming the food base for those zoophages (Barczak *et al.*, 2000; Landis *et al.*, 2000; Holland and Luff, 2000; Thomas *et al.*, 2001; Bennewicz *et al.*, 2001; Macfadyen *et al.*, 2009; Bennewicz, 2011). Aphids in the biocenoses are an important source of food for many insects. Honeydew secreted by them guarantees food continuity for insect pollinators, and is the source for the development of microflora associated with the fermentation of carbohydrates.

Therefore, non-crop habitats with abundant fauna of aphids are potentially a rich source of food for various aphidophagous insects (Bennewicz, 2011). The prevalence of *M. carnosum* aphid on *U. dioica*, in the bushes in Leszcz, Grabówek and Gruczno, and on the edges of forests, may indicate that this plant species is a reservoir of food primarily for spiders, but also for many insects, including predatory Hemiptera, Coleoptera, Syrphidae and parasitoids (Kean and Müller, 2004; Bennewicz, 2011).

The habitats analyzed are also important sites of refuge from adverse conditions and wintering for many species of other arthropods (Landis *et al.*, 2000; Pfiffner and Luka, 2000).

The Polish agricultural landscape is still dominated by farms with fields crossed by the different types of non-crop areas. These semi-natural refuges - such as the 'forest islands', tree stands, bushes or field boundaries with herbaceous vegetation within crop lands, all cause - potentially - an increase in the richness of insect species. Theoretical studies of Andren *et al.* (cited after Cierzniak, 2003) have shown that the minimum proportion of such areas should be in the range from 1% to 20% of the acreage and with further increasing of the size of these areas, there is a likelihood of a rapid qualitative and quantitative increase in the insect species. Among plants commonly listed in the present study are the following species: *C. arvense* and *Sinapis arvensis*. These plant species have been present in the studied habitats, particularly prevalent was *C. arvense* in the boundaries and on the edges of the 'forest islands'; this plant species has also been readily colonized by aphids. In addition, species that feed on *Cirsium* spp., as discussed above, less frequently colonize crops. For instance, it has been proven that thistles, growing in the fields of barley, caused the decrease in the number of aphid *Rhopalosiphum padi*, settling on this cereal plant. The reason for this phenomenon is sought in the smell of thistle, which acts as a deterrent to the aphid species (Glinwood *et al.*, 2004) or has a dispersive effect on the colonies of harmful *A. fabae* (Barczak, 1992). In areas heavily transformed due to human activity, such as the fresh coniferous forests (e.g., 'forest island' in Leszcz), or large areas of arable land, there is a growing number of single dominant species along with progressive anthropogenic changes. At the same time, the number of co-dominant species is decreasing (Cierzniak, 2003; Bennewicz and Krasicka-Korczyńska, 2004).

In the present study, an attempt has been made to evaluate semi-natural refuges in the so-called multicrop agricultural space and in landscape park, in terms of the occurrence of aphid communities. Six years of research has shown that the diversity of aphid species was highest in the bushes of the landscape park and in the bushes and edges of the 'forest islands' in the so-called multicrop agricultural space.

Off-field habitats are a specific type of refuges, elements of ecological corridors and environmental islands, and play an important role in preserving the biodiversity of habitats, and thus consitute a part of integrated pest management programme (IPM) (Barczak *et al.*, 2000; Holland and Luff, 2000; Landis *et al.*, 2000; Thomas *et al.*, 2001; Waldhardt, 2003; Vickery *et al.*, 2009). It is important to maintain or to create new edge plant communities on the border of these habitats and cultivated fields to preserve and enrich the fauna of insects in trees, shrubs and 'forest islands'. Conditions in agroecosystems are unfavorable for natural enemies, and the sole creation of ecological structure, i.e., various types of habitats, bordering the fields in the agrarian landscape, will provide food for natural predators and shelter from adverse conditions (Landis *et al.*, 2000). The study of Frank (1999) proved the effectiveness of biological control of aphids through retaining the strips of wild vegetation among cultivated fields, because they were a very attractive place providing both shelter and food for Syrphidae.

European countries, which for many years have carried out cultivation on multi-hectare crop fields, start to realize that these small natural islands of vegetation

remaining among the fields such as semi-natural habitats, planted hedges, or even set-aside fields, are rich source of the diversity of fauna and flora in the entire environment (Duelli, 1997; Moonen and Marshall, 2001; Marshall and Moonen, 2002).

The greatest species richness is found in tree stands, bushes, midfield forests, roadsides and boundaries, which constitute ecological corridors, forming bridges between the crop fields inside agrarian landscape (Salveter, 1998; Barczak *et al.*, 2000; Bennewicz *et al.*, 2001; Ciezniak, 2003; Waldtardt, 2003; Bennewicz and Krasicka-Korczyńska, 2004; Bennewicz, 2012).

Among ten various types of non-crop areas examined within six years of the study, of which six were located in the so-called multicrop agricultural space (study area "No.1"), and four in the Chełmiński and Nadwiślański Landscape Park Complex (ZPKChN) (study areas "No.2"), more attractive to aphids were semi-natural habitats in the multi-hectare crop fields than in margins of small fields in the landscape park. This indicates that the aphids choose sites with higher availability and quantity of food. There were more aphids detected in the bushes with a stable and diverse vegetation structure, predominance of trees, shrubs, and on the forest edges rather than open areas such as field boundaries. This means that aphids concentrate in the areas where off-field habitats border large crop lands. The bushes in Gruczno was the richest habitat of aphid fauna in the landscape park (ZPKChN), which probably was associated with a large variety of vegetation, forming a convenient food base for the various species of these Hemiptera - Aphididae.

In addition, studies Weibull *et al.* (2003) showed that the diversity of insect species is primarily influenced by the size, reach and richness of habitats bordering farmland, than a cultivation method (ecological or conventional farming system).

## REFERENCES

Barczak, T., 1992, Functional response of the tritrophic system: *Aphis fabae* Scop. - primary parasitoids - hyperparasitoids to different types of habitat. Preliminary results. *Polish Journal of Entomology*, 61:119-124.

Barczak, T., Kaczorowski, G., Bennewicz, J., Krasicka-Korczyńska, E., 2000, *Znaczenie zarośli* śródpolnych *jako rezerwuarów naturalnych wrogów mszyc (Role of midfield thickets as reservoirs of aphid natural enemies*). Bydgoszcz, Wydawnictwo Uczelniane ATR, 147 pp. (in Polish, English summary).

Barczak, T., Bennewicz, J., Kaminski, P., 2013, Parasitoids (Hymenoptera: Braconidae, Aphidiinae) of the mealy plum aphid *Hyalopterus pruni* (Geoffr.) on common reed (*Phragmites australis*) in different types of habitat in Poland. *Archives of Biological Sciences,* 65: 71-79.

Bennewicz, J., 2011, Aphidivorous hoverflies (Diptera: Syrphidae) at field boundaries and woodland edges in an agricultural landscape. *Polish Journal of Entomology,* 80:129-150

Bennewicz, J., 2012, Aphids (Hemiptera: Aphididae) of midfield thickets in an agricultural landscape. *Polish Journal of Entomology*, 81: 11-33.

Bennewicz, J., Krasicka-Korczyńska, E., 2004, Importance of midfield thickets in aphid distribution. *Journal of Plant Protection Research*, 44: 21-34.

Bennewicz, J., Kaczorowski, G., Barczak, T., 2001, Aphids in midfield thickets in Lower Vistula Landscape Park. *Journal of Plant Protection Research*, 41: 348-362.

Bianchi, F. J. J. A., van der Werf, W., 2004, Model evaluation of the function of prey in non-crop habitats for biological control by ladybeetles in agricultural landscapes. *Ecological Modelling*, 171: 177-193.

Bianchi, F. J. J. A., Booij, C. J. H., Tscharntke, T., 2006, Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proceedings of the Royal Society B (Biological Sciences)*, 273: 1715-1727.

Cierzniak, T., 2003, Ekologia pszczół w dynamicznym kręgu zbiorowisk grądowych (Ecology of bees in a dynamic range of dry-ground communities). Bydgoszcz, Wydawnictwo Akademii Bydgoskiej im. K. Wielkiego 158 pp. (in Polish).

Dąbrowska-Prot, E., 1998, *Ekologiczne problemy wysp środowiskowych w krajobrazie ze szczególnym uwzględnieniem wysp leśnych (Eco-environmental problems of environmental islands in the landscape with particular emphasis on forest islands). In*: Banaszak, J. (Ed.). Ekologia wysp leśnych (Ecology of forest islands). Wyd. Uczelniane WSP, Bydgoszcz, 177-192 (in Polish).

Duelli, P., 1997, Biodiversity evaluation in agricultural landscapes: An approach at two different scales. *Agriculture, Ecosystems and Environment*, 62: 81-91.

Fernandez-Quintanilla, C., Fereres, A., Godfrey, L., Norris, R. F., 2002, Development and reproduction of *Myzus persicae* and *Aphis fabae* (Hom., Aphididae) on selected weed species surrounding sugar beet fields. *Journal of Applied Entomology*, 126: 98-202.

Frank, T., 1999, Density of adult hoverflies (Dipt., Syrphidae) in sown weed strips and adjacent fields. *Journal of Applied Entomology*, 123: 351-355.

Glinwood, R., Ninkovic, V., Pettersson, J., Elham, A., 2004, Barley exposed to aerial allelopathy from thistles (*Cirsium spp*.) becomes less acceptable to aphids. *Ecological Entomology*, 29: 188-195.

Holland, J. M., Luff, M. L., 2000, The effects of agricultural practices on Carabidae in temperate agroecosystems. *Integrated Pest Management Reviews*, 5: 109-129.

Hutcheson, K., 1970, A test for comparing diversities based on the Shannon formula. *Journal of Theoretical Biology*, 20: 151-154.

Kean, J. M., Müller, C. B., 2004, Can competition explain local rarity of a nettle aphid? *Ecological Entomology*, 29: 706-710.

Landis, D. A., Wratten, S. D., Gurr, G. M., 2000, Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology*, 45: 175-201.

Macfadyen, S., Gibson, R., Raso, L., Sint, D., Traugott, M., Memmott, J., 2009, Parasitoid control of aphids in organic and conventional farming systems. *Agriculture, Ecosystems and Environment*, 133: 14-18.

Marshall, E. J. P., Moonen, A. C., 2002, Field margins in northern Europe: their functions and interactions with agriculture. *Agriculture, Ecosystems and Environment*, 89: 5-21.

Moonen, A. C., Marshall, E. J. P., 2001, The influence of sown margin strips, management and boundary structure on herbaceous field margin vegetation in two neighbouring farms in southern England. *Agriculture, Ecosystems and Environment*, 86: 187-202.

Pawlikowski, T., 1985, Zgrupowania dzikich pszczołowatych (Hymenoptera Apoidea) na kserotermicznych siedliskach wydmowych Kotliny Toruńskiej (Wild bees communities from xerothermic-dune habitats of Toruń Basin). *Studia Societatis Scientiarum Torunensis Sectio E,*10: 1-4 (in Polish, English summary).

Pfiffner, L., Luka, H., 2000, Overwintering of arthropods in soils of arable fields and adjacent semi-natural habitats. *Agriculture, Ecosystems and Environment*, 78: 215-222.

Robert, Y., Le Gallic, J. F., 1991, Two important Host-plants for Black Aphids of the "*Aphis fabae* complex" in the west of France (Homoptera: Aphididae). *Entomologia Generalis*, 16: 285-293.

Salveter, R., 1998, Habitatnutzung adulter Schwebfliegen (Diptera: Syrphidae) in einer stark gegliederten Agrarlandschaft. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 71: 49-71.

Shannon, C. E., Weaver W., 1963, *The Mathematical Theory of Communication*. Urban. University of Illinois Press Champaign, IL, USA, 125.

Thomas, C. F. G., Parkinson, L., Griffiths, G. J. K., Fernandez Garcia, A., Marshall, E. J. P., 2001, Aggregation and temporal stability of carabid beetle distributions in field and hedgerow habitats. *Journal of Applied Ecology*, 38: 100-116.

Vickery, J. A., Feber, R. E., Fuller, R. J., 2009, Arable field margins managed for biodiversity conservation: A review of food resource provision for farmland birds. *Agriculture, Ecosystems and Environment*, 133: 1-13

Waldhardt, R., 2003, Biodiversity and landscape - summary, conclusions and perspectives. *Agriculture, Ecosystems and Environment*, 98: 305-309.

Weibull, A. C., Östman, Ö., Granqvist, Å., 2003, Species richness in agroecosystems: the effect of landscape, habitat and farm management. *Biodiversity and Conservation*, 12: 1335-1355.

Wratten, S. D., Bowie, M. H., Hickman, J. M., Evans, A. M., Sedcole, J. R., Tylianakis, J. M., 2003, Field boundaries as barriers to movement of hover flies (Diptera: Syrphidae) in cultivated land. *Oecologia*, 134: 605-611.

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