Hungarian University of Agriculture and Life Sciences

Festetics Doctoral School

Changes in arthropod communities of maple trees (*Acer* spp.) along stress gradients in urban environment

THESIS

By:

Dávid Korányi

Supervisors:

PROF. DR. VIKTOR MARKÓ

PROF. DR. ELŐD KONDOROSY

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1. Background and objectives

1.1. Background

Urbanization changes the landscape considerably by covering natural areas with artificial structures (e.g., buildings and roads) and results in reduction and degradation of original habitats. In addition to all these features, alterations that occur with increasing urbanization, involve fragmented vegetation, increased temperature, microclimatic shifts, and altered soil and atmospheric chemistry. As an additional consequence, disturbance created by cities has a great local effect on animal communities contributing to biodiversity loss and biotic homogenization.

Arthropods are regarded as suitable indicators of human-induced environmental changes and one of the most important components of urban ecosystems. They are a megadiverse group, relatively easy to sample, show quick responses to altering environmental conditions, and represent a wide spectrum of trophic levels. Among others, arthropod community dynamics in urban environment might be driven by bottom-up factors, such as host plant availability and quality, and top-town factors, such as the abundance and community composition of natural enemies.

Generally, plants in urban areas are exposed to greater environmental stress compared to natural habitats, at the same time, urbanization results in reduced availability of host plants for phytophagous species. Therefore, plant stress and host plant specialization might be important factors in shaping herbivore communities in cities. City centers often provides unfavorable conditions for natural enemies due to decreased number of refuges and alternative food resources. Furthermore, impervious surfaces and artificial structures in cities may act as dispersal barrier for many species at higher trophic levels. All these factors can modify prey-natural enemy interactions, thus providing opportunity for herbivores to reach high densities in highly urbanized areas.

Urban trees provide a range of ecosystem services. Among them, maples (*Acer* spp.) appear to predominate the urban green areas worldwide. Maple species support numerous specialist and generalist phytophagous species and tolerate urban stress in different degrees, thus they are ideal choice for studying the direct and indirect effects of urbanization on arthropods.

1.2. Objectives

This thesis comprises three studies conducted in and around the city of Budapest, Hungary with the following aims:

1. To explore the canopy dwelling arthropod fauna of maple trees.
2. To assess the abundance pattern and composition of phytophagous insect communities of three commonly planted maple species (*Acer pseudoplatanus*, *A. platanoides* and *A. campestre*) in urban environment considering their stress level and condition.
3. To examine the effect of urbanization on aphids, predatory arthropods, and ants as well as their predator-prey-mutualist interactions on field maple (*A. campestre*).

2. Materials and methods

2.1. New records for the Hungarian spider and insect fauna

Arthropods were collected from the canopy of maple trees by beating method from 25 different locations in and around Budapest from 2014 to 2017. Individuals were examined in the laboratory of the Department of Entomology of Hungarian University of Agriculture and Life Sciences and Department of Zoology of Hungarian Natural History Museum. Identification was done with stereomicroscope using characters of exoskeleton and genitalia.

2.2. Abundance pattern and composition of phytophagous insects on urban maple trees (*Acer* spp.)

We selected four study sites in Budapest that are situated close to each other and have sufficient numbers of field (*A. campestre*), Norway (*A. platanoides*), and Sycamore maples (*A. pseudoplatanus*). We selected 12 individuals per tree species (three at each site) in 2014 and 20 individuals per tree species (five at each site) in 2015 for arthropod collection, all of which had similar ages and undamaged trunks.

Arthropods were collected from the canopy of the trees by beating method on 14 dates in 2014 and on seven dates in 2015. We identified the phytophagous insects i.e. aphids (Aphididae), psyllids (Psylloidea), plant- and leafhoppers (Auchenorrhyncha), heteropterans (Heteroptera), and curculionids (Curculionidae) to species.

We determined the stress level of the trees by measuring peroxidase (POD) enzyme activity of the leaves in July, 2015 during the activity peak of phytophagous insects. Leaves were homogenized in sodium acetate buffer and centrifuged and the extracted supernatant was used for further analyses. Peroxidase (POD) activity was determined by spectrophotometry in a H_2O_2 substrate with ortho-dianizidine used as chromogenic indicator at 460 nm. POD activity was expressed in units of peroxidase per ml. To assess the condition of trees, we evaluated visually the degree of leaf necrosis and leaf fall of trees as indicators of environmental stress in October, 2015 when these symptoms became apparent. The evaluations were done in five-point scales along ordinal conditional gradients.

We used R version 3.4.4 statistical environment for all analyses. To determine the effect of maple species on phytophagous insects, we ran general linear mixed models (GLMMs) and

ANOVA. For post-hoc analysis, least square (LS) means were calculated. We performed non-metric multidimensional scaling (NMDS) to examine the effect of tree species on the community composition of abundant phytophagous insect species and ran indicator species analysis to identify potential phytophagous character species for each maple species.

To determine the differences between stress levels and conditions of maple species, we ran GLMMs, cumulative link mixed models (CLMMs), and ANOVA tests with LS means calculations. To examine the effect of phytophagous insects on POD activity and to assess whether the condition of trees would influence the abundance of phytophagous insects we ran GLMMs. We ran CLMMs to test the effect of phytophagous insects on the condition of trees.

2.3. Effect of urban landscape on aphids and their predator assemblages on urban trees

We selected 22 sites for this study in or near the city of Budapest, Hungary representing a range of seminatural rural, suburban, and urban areas. We chose three field maple (*A. campestre*) trees at each site for arthropod collection by having similar trunk and canopy diameters and the shortest distance between them.

Arthropods were collected from the canopy of the trees by the beating method on seven dates in 2016 and on three additional dates in 2017. We identified and counted all collected aphids to species. Predatory arthropods and ants were identified to species or, if not possible, to genus or family, using characters of the exoskeleton or genitalia.

Aphidophagous predator species were classified into five dispersal groups. We considered wing morphology for true bugs, ladybirds, and lacewings and ballooning ability for spiders. The collected dermapteran species were considered as species with the lowest dispersal category.

We calculated landscape composition around each sampling site within a 500 m radius buffer using Quantum GIS 2.16 software and used the percentage of impervious surfaces (pooled proportion of buildings and roads) as an index of the degree of urbanization (2–95%).

We used quasi-Poisson-distributed generalized linear models (quasi-GLMs) to test the effect of urbanization on the abundance of aphids, predators, and ants and to test how aphid abundance depended on the abundance of predators and ants. We tested how abundance of predators and ants was influenced by the abundance of aphids (tracking) using GLMMs with penalized quasi-likelihood (GLMMPQL). We performed NMDS with Bray-Curtis distance measure to examine the differences in composition for the predator assemblages and generated smooth surfaces along impervious surface gradient with generalized additive models (GAMs). We calculated community weighted means (CWM) for dispersal trait of predators and used GLMs to test whether percentage of impervious surfaces had a significant effect on CWM of dispersal trait in 2016 and 2017 separately. Quasi-GLMs were used to assess whether predators with lower dispersal ability would have a more important role in aphid suppression than those with higher dispersal ability. Finally, Predators were classified into eleven groups based on their taxonomic status and abundance and NMDS with Euclidean distance measure was used to analyze how these species and groups were associated to aphid abundance. Smooth surfaces along aphid infestation were generated with GAMs.

3. Results

3.1. New records for the Hungarian spider and insect fauna

Icius subinermis Simon, 1937 (Araneae, Salticidae), *Latilica maculipes* (Melichar, 1906) (Hemiptera: Issidae), *Synophropsis lauri* (Horváth, 1897) (Hemiptera: Cicadellidae), *Psallus assimilis* Stichel, 1956 (Hemiptera: Miridae), and *Cybocephalus nipponicus* Endrödy-Younga, 1971 (Coleoptera: Cybocephalidae) proved to be new arthropod species for the fauna of Hungary. Most of these species might have been introduced to Hungary unintentionally by human mediation, but the possibility of a natural expansion of their distribution area due to the warming climate could not be excluded. *Psallus assimilis* was one of the most abundant true bug species in the canopy of maple trees. This species is zoophytophagous feeding on pollen of field maple trees and also reported as a predator of various insects including psyllids. *Cybocephalus nipponicus* is feeding on species of Diaspididae Asterolecaniidae, Coccidae and Pseudococcidae and eggs of mites. Therefore, *P. assimilis* and *C. nipponicus* might have a role in control of some pests.

3.2. Abundance pattern and composition of phytophagous insects on urban maple trees (*Acer* spp.)

Taxa recorded

In total, we identified 33072 phytophagous insects, 12302, 7835 and 12935 individuals from the canopy of sycamore, Norway, and field maple, respectively. *Metcalfa pruionosa* (Say) (*n* = 21852) was by far the most abundant species, representing 66.1% of all individuals examined, followed by *Periphyllus testudinaceus* (Fernie) (*n* = 2791, 8.4%), *Drepanosiphum platanoidis* (Schrank) (*n* = 2502, 7.6%), *Halyomorpha halys* (Stål) (*n* = 1182, 3.6%), *Phyllobius oblongus* (Linnaeus) (*n* = 571, 1.7%), *Nezara viridula* (Linnaeus) (*n* = 566, 1.7%), and *Acericerus ribauti* Nickel & Remane (*n* = 549, 1.7%).

Effect of tree species on the abundance and composition of phytophagous insects

The total number of aphids was the highest on sycamore and the lowest on Norway maple trees in both years. The abundance of the planthopper *M. pruinosa* was the highest on field maple and the lowest on Norway maple. For other planthoppers and leafhoppers, the overall abundance was significantly higher on field maple compared to sycamore maple. This pattern was also observed for the total abundance of heteropterans in 2014, but not in 2015 (LS means, ANOVA, GLMM). Altogether we analyzed the association of 19 phytophagous insect species with the studies maple species.

NMDS analysis clearly separated the phytophagous insect communities of sycamore and field maple, and also showed that Norway maple had the least specific phytophagous insect community, with a high overlap especially with that of field maple. Indicator species analysis identified two species, *D. platanoidis* and *Periphyllus acericola* (Walker), as character species of sycamore maple and other two species, *Zyginella pulchra* Low and *Bradybatus kellneri* Bach, as character species of Norway maple. Seven further indicator species, *Drepanosiphum aceris* Koch, *Periphyllus obscurus* Mamontova, *Rhinocola aceris* (Linnaeus), *A. ribauti*, *Japananus hyalinus* (Osborn), *Gonocerus acuteangulatus* (Goeze), and *N. viridula* showed a preference for field maple.

Stress level and condition of maple tree species

Although on average Norway maple individuals had the highest POD activity values, we did not find significant differences between maple species for this variable (LS means, ANOVA, GLMM). In contrast, we found significant differences in the leaf necrosis levels between the maple species, which were the highest on Norway maple and were lowest on field maple. We found no statistically significant differences in leaf fall between maple species (LS means, ANOVA, CLMM).

Effect of phytophagous insects on stress level of trees

Overall, we observed a significant increase in POD activity in maple trees with increasing numbers of *M. pruinosa* individuals, while the abundant phytophagous groups (other plant- and leafhoppers, aphids, and heteropterans) had no effect on this variable. We found a significant positive relationship between *M. pruinosa* abundance and POD activity of sycamore and field maple trees, but no such relationship was found for Norway maple (GLMM).

Relationships between phytophagous insects and tree condition

Analyzing the relationship between the abundance of phytophagous insects and tree condition we found that the abundance of phytophagous insect groups had no significant effect on the degree of leaf fall or necrosis of maple trees (CLMM). Conversely, advancing degree of leaf fall and leaf necrosis negatively affected the abundance of the super-abundant species *M. pruinosa*. The abundance of other insect groups showed no response to the changing conditions of the trees (GLMM).

3.3. Effect of urban landscape on aphids and their predator communities on urban trees

Taxa recorded

In total, we collected 10197 individual aphids, 8955 predators, and 3555 ants from the canopy of *A. campestre* trees. The collected aphids belonged to four genera and nine species. Among these, two ant-tended species, *P. testudinaceus* and *P. obscurus*, were collected in the largest numbers (59.5% and 30.9% of total aphid abundance, respectively) followed by two non-ant-tended species, *D. aceris* and *D. platanoidis*, which occurred only in small numbers (2.1% and 1.8% of the total aphid abundance, respectively). The most abundant ant species were *Prenolepis nitens* (Mayr), *Lasius niger* (Linnaeus), and *Lasius emarginatus* (Olivier) (32.7%, 21.6%, and 10.4% of the ants collected, respectively). The predators we collected comprised 24 families, 103 genera, and 145 species. The most abundant predator species were *Deraeocoris lutescens* (Schilling) (Miridae, *n* = 1450), *Harmonia axyridis* Pallas (Coccinellidae, *n* = 1439), *Forficula auricularia* Linnaeus (Forficulidae, *n* = 675), and two species groups of spiders – *Philodromus aureolus* group (*n* = 752) and *Ph. rufus* group (*n* = 692) (Philodromidae).

Effects of urbanization on the abundance of aphids, predators and ants

Aphids were abundant in spring and autumn, while in summer they were almost absent. Predator abundance was lowest in spring and increased throughout the growing season. Ants were abundant in April and June in 2016 and in May and September in 2017.

The annual abundance of aphids increased significantly with increase in the percentage of impervious surfaces in both years. In contrast, the abundance of predators and ants was negatively affected by the percentage of impervious surfaces, and these relationships were also significant for both groups in 2016 and nearly significant for ants in 2017. Surprisingly, predators and ants did not follow the spatial abundance pattern of aphids in spring and even less in autumn (quasi-GLM).

Aphid-predator-ant interactions

The presence of predators negatively affected the total abundance of aphids in 2016 and we found significant negative relationship between monthly predator and total aphid abundance in September and October in this year. However, there was no association between the yearly or monthly abundances of ants and the total aphid density, either in 2016 or in 2017. We found no association between yearly abundances of predators and ants in either year (quasi-GLM). During the months of peak aphid abundance, number of aphids had no significant effect on the abundance of predators or ants, i.e. predators and ants did not track aphid abundance (GLMMPQL).

Species of aphids and predators and taxonomic composition of predator community

The main aphid species showed a positive response to percentage of impervious surfaces. This relationship was significant in the cases of *P. testudinaceus* in 2016 and *P. obscurus* in 2017.

Considering the 25 studied predator taxa and groups, one earwig species (*Apterygida media* [Hagenbach]) and most of the spider taxa and groups were negatively affected by urbanization. In contrast, most true bugs and coccinellids showed no response or responded positively to increasing levels of urbanization (quasi-GLM).

NMDS ordination revealed that the community composition of predators changed along the urbanization gradient in both 2016 and 2017. In accordance with species-specific responses, this pattern was most typical for the spider assemblage and to a lesser extent for true bugs and coccinellids.

Effect of dispersal ability of predators on aphids

We found a significant shift in the CWM trait values for predator dispersal ability along the urbanization gradient in both years, where the proportion of predatory species with higher dispersal ability increased with the increasing level of impervious surfaces (GLM) and the annual abundance of aphids decreased significantly when the predator community contained more low-dispersing predators (quasi-GLM).

According to the NMDS ordination based on the association between the abundance of aphids and predatory groups, earwigs (mean dispersal value of the group: 0.0, n = 831) and web building spiders (0.61, 649) were associated with the sites with the lowest, while *H. axyridis* larvae (1.0, 255) and other coccinellids (1.0, 1082) were associated with the sites with the highest aphid abundances. This suggest, that generalist predators with low dispersal ability such as earwigs and some spiders may play a major role in the biological control of aphids.

4. New scientific results

Based on the results of my dissertation, I conclude the following theses:

1) I reported one spider (*I. subinermus*) and four insect species (*L. maculipes*, *S. lauri*, *P. assimilis*, and *C. nipponicus*) for the first time from Hungary.

2) I characterized the phytophagous insect communities in the canopy of three maple species (*A. pseudoplatanus, A. platanoides*, and *A. campestre*) in urban environment. I showed that most herbivorous species were associated with field maple, sycamore had the highest aphid densities, and Norway maple had the least abundant and least characteristic phytophagous insect community.

3) I assessed the physiological condition of maple trees and showed that field maple has the highest and Norway maple has the lowest stress tolerance, with sycamore being intermediate, in urban conditions in the city of Budapest, Hungary.

4) I reported *Metcalfa pruinosa* to be by far the most abundant phytophagous species on urban maples. I also showed that its abundance was primarily driven by tree condition, i.e. this species reached higher abundances on healthier trees.

5) I found increasing aphid and decreasing ant abundances with increasing level of urbanization. I also found that abundance of predatory arthropods and occurrence of poorly dispersing species within the predator community are negatively related to urbanization and identified these two independent factors as significant predictors of aphid abundances.

6) Altogether, I showed that urbanization, by altering the abundance and composition of predator communities, can disrupt biological control of aphid populations, and thus may contribute to the aphid outbreaks on urban trees.

5. Publications

5.1. Publications related to the topic of the thesis

Publications in scientific journals

Korányi, D., Szigeti, V., Mezőfi, L., Kondorosy, E., & Markó, V. (2020). Urbanization alters the abundance and composition of predator communities and leads to aphid outbreaks on urban trees. *Urban Ecosystems,* in press. DOI: 10.1007/s11252-020-01061-8

Korányi, D., Markó, V., Haltrich, A., & Orosz, A. (2018). First records of *Latilica maculipes* (Hemiptera: Issidae) and *Synophropsis lauri* (Hemiptera: Cicadellidae) in Hungary. *Opuscula Zoologica* 49: 71–75. DOI: 10.18348/opzool.2018.1.71

Korányi, D., Markó, V., & Kondorosy, E. (2018). First record of *Psallus assimilis* in Hungary (Hemiptera: Heteroptera: Miridae). *Opuscula Zoologica* 49: 17–22.
DOI: 10.18348/opzool.2018.1.17

Korányi, D., Mezőfi, L., & Markó, V. (2017). First record of the jumping spider *Icius subinermis* (Araneae, Salticidae) in Hungary. *Arachnologische Mitteilungen* 54: 38–40.
DOI: 10.5431/aramit5408

Merkl, O., Károlyi, B., & **Korányi, D.** (2017). First record of *Cybocephalus nipponicus* in Hungary (Coleoptera: Cybocephalidae). *Folia Entomologica Hungarica* 78: 71–76.
DOI: 10.17112/FoliaEntHung.2017.78.71

Conference abstracts

Korányi, D., Szigeti, V., Mezőfi, L., Kondorosy, E., & Markó, V. (2019). A város biztonságában – urbanizáció hatása juharfák levéltetű és ragadozó ízeltlábú-együtteseire. *7. Szünzoológiai Szimpózium*, Budapest.

Korányi, D., Szigeti, V., Mezőfi, L., Kondorosy, E., & Markó, V. (2019). Juharfák levéltetű és predátor együtteseinek szerveződése urbanizációs gradiens mentén. *65. Növényvédelmi Tudományos Napok*, Budapest.

Korányi, D., Szigeti. V., Mezőfi, L., Kondorosy, E., & Markó, V. (2018). Városi táj hatása juharfák levéltetű és afidofág predátor együtteseire. *I. Urbanizációs Ökológia Konferencia*, Veszprém.

Korányi, D., Merkl, O., Károlyi, B., & Markó, V. (2018). *Cybocephalus nipponicus* (Coleoptera, Cybocephalidae): a hazai kagylós pajzstetvek (Hemiptera, Diaspididae) új természetes ellensége. *64. Növényvédelmi Tudományos Napok,* Budapest.

Korányi, D., Palla, B., Stefanovits-Bányai, É., & Markó, V. (2017). Kártevő egyedsűrűség és a növényi stresszállapot összefüggéseinek vizsgálata városi juharfákon. *XXIII. Ifjúsági Tudományos Fórum*, Keszthely.

Korányi, D., Palla, B., Stefanovits-Bányai, É., & Markó, V. (2016). A preliminary study on the possibilities to indicate the effects of urban stress on maple trees. *Proceedings of the 22nd International Symposium on Analytical and Environmental Problems,* Szeged.

5.2. Other publications

Publications in scientific journals

Kuli-Révész, K., **Korányi, D.**, Lakatos, T., Szabó, Á. R., Batáry, P., & Gallé, R. (2021). Smaller and isolated grassland fragments are exposed to stronger seed and insect predation in habitat edges. *Forests* 12: 103670. DOI: 10.3390/f12010054

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Vétek, G., **Korányi, D.**, Mezőfi, L., Bodor, J., Pénzes, B., & Olmi, M. (2019). *Neodryinus typhlocybae* (Hymenoptera: Dryinidae), a biological control agent of *Metcalfa pruinosa* (Hemiptera: Flatidae), spreading in Hungary and reaching Slovakia. *Bulletin of Insectology* 72: 1–11.

Vétek, G., Károlyi, B., Mészáros, Á., Horváth, D., & **Korányi, D.** (2018). The invasive brown marmorated stink bug (*Halyomorpha halys*) is now widespread in Hungary. *Entomologia Generalis* 38: 3–14. DOI: 10.1127/entomologia/2018/0631

Vétek, G., & **Korányi, D.** (2017). Severe damage to vegetables by the invasive brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), in Hungary. *Periodicum Biologorum* 119: 131–135. DOI: 10.18054/pb.v119i2.4935

Szöllősi-Tóth, P., **Korányi, D.**, & Vétek, G. (2017). First record of *Neodryinus typhlocybae* in Hungary (Hymenoptera: Dryinidae). *Folia Entomologica Hungarica* 78: 97–100. DOI: 10.17112/FoliaEntHung.2017.78.97

Mezőfi, L., & **Korányi, D.** (2017). A harlekinkatica (*Harmonia axyridis* Pallas 1773) színváltozatai Magyarországon és polimorfizmusának ökológiai vonatkozásai. *Növényvédelem* 53: 193–205.

Conference abstracts

Korányi, D., Lakatos, T., & Batáry, P. (2020). Effect of urbanization on biological control of herbivorous insects. *Student Conference on Conservation Science*, Tihany.

Korányi, D., Gallé, R., Donkó, B., Chamberlain, D. E., & Batáry, P. (2019). Different type of green infrastructures supports different species and functional groups of bird communities in urban environment. *Annual Meeting of the British Ecological Society*, Belfast.

Korányi, D., Gallé, R., & Batáry, P. (2019). Effects of urbanization on bird communities in different types of green spaces. *Student Conference on Conservation Science*, Tihany.

Korányi, D., Gallé, R., & Batáry, P. (2019). A városi táj hatása parkok és közösségi kertek madárközösségeire. *20. Kolozsvári Biológus Napok*, Kolozsvár.

Korányi, D., Gallé, R., & Batáry, P. (2019). A zöld infrastruktúra szerepe az urbanizáció madárközösségekre gyakorolt negatív hatásainak enyhítésében. *7. Szünzoológiai Szimpózium*, Budapest.

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