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The impact of urban pressure on species composition and number of Arthropoda on trees in a city on the example of Warsaw

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Introduction

This paper reviews the results of research carried out so far on the conditions of growth and development of trees in the urban flora of Warsaw. Trees growing along the streets have the worst conditions, while those in parks and green areas have slightly better conditions. The following factors have a negative influence on trees: trampling by humans and a fully concrete-covered area surrounding the tree, a changing climate (drier, warmer, shaded daylight, lightened up at night), dehydration, air pollution, sodium chloride, and calcium chloride used in winter to eliminate slippery roads. A transformed soil, including the presence of rubble, as well as a neutral or alkaline soil reaction also influence the tree condition. Trees which grow in these conditions have a disturbed duration of particular phenophases and in their leaves, nitrogen and certain amino-acids levels grows leading to a growth in the number of some sucking-piercing Heteroptera species even up to 1000 times. Spider mites, aphids and scale insects are most likely to settle urban trees. Therefore, one can notice necrosis on leaves which fall down a month earlier in comparison with trees in open areas. These trees grow slower, have smaller crowns and trunk diameters.

Conditions in which trees grow in Warsaw

This paper reviews the so far obtained results of our own research and bibliography on the impact of anthropopressure on the condition of trees and arthropods feeding on them. The construction which limits the tree-growing area, climate change and properties of the surface, soil layers, air pollution and dehydration, treading up by pedestrians and vehicles of the urban soil all have a negative influence on plants. Trees of the urban flora take in pollution irrespectively of species and place in which they grow. Trees growing along the streets tend to take in more pollution (Butrynowicz, 1979; Tykarska, 2002; Cichocka & Goszczyński, 2008). In leaves of those trees one can find an increase of sulphur, lead, cadmium, copper, zinc and iron. Other factors also have a negative impact on trees in cities, including the chemicals such as sodium chloride and calcium chloride used for slippery roads, which lead to salinity of the ground and surface waters (Czerwiński *et al,*. 1971; Molski & Sitarski, 1979). Their accumulation in leaves causes necrosis (Strogonow, 1970; Pracz, 1990). Salinity influences also plant metabolism which sometimes leads to protein dissociation (Strogonow, 1973). Kropczyńska-Linkiewicz (1984) observed an increase in the content of general nitrogen, soluble proteins, and a decrease in the content of reducing sugars in leaves of lime-trees which were growing along the streets where swept snow with chlorides was gathered.

The Warsaw soil is also undergoing transformation and it is likely to contain some rubble thus forming soils characteristic for cities which do not fit the categories of types and subtypes which are distinguished in the abiding classification (Czerwiński & Pracz, 1990). This soil has a neutral or alkaline reaction (Dobrzański *et al.*, 1977). The conditions of the mezoclimate and hydrology are changing (dry, warmer and less isolated area, exposed to artificial light at night).

Leaves of urban trees are often strongly covered with dew and dust.

The impact of anthropopressure on trees in a city

The first ever research concerning the fauna of Polish cities and its formation in the urban area was carried out in 1970's (Frankie & Koehler, 1978; Banaszak & Kasprzak, 1978). Most research was carried out in Warsaw but also in Łódź, Poznań, Lublin, Kraków, Toruń and Wrocław.

Trees growing in unfavourable conditions in the city of Warsaw have a disturbed growth pattern, development and health (Suska *et al.*, 1990). In street sites their crowns have smaller diameters, they are lower and have a smaller trunk diameter. Moreover, the urban pressure is reflected unfavourably in tree phenology (Mędrzycki & Figat, 1990). The trees growing by the streets had

a disturbed duration of particular phenophases, growth season, they lost some phases which in some cases returned after a temporal absence. In the street sites, trees had an accelerated onset of spring developmental phases (leaf growth, blossoming, fruit growth). Premature leaf fall was also observed, especially on trees which grew in areas covered in concrete. These differences ranged between 40-80 days in relation to open areas. Sycamore maples and Norway maples reacted most strongly. In Caucasian lime-trees and horse-chestnut (Chmielewski & Gostman, 1979) the drying of flowers was observed at the end of the blossoming phase. In park sites and city suburbs these changes were minor.

Species composition and the number of herbivores on trees in Warsaw

Insect fauna on plants in urban green areas is formed by particular conditions of this habitat. Specific terminology of "urban entomology" is used to refer to this phenomenon (Cichocka *et al.,* 1990). Along with this term, "urban pest management" in relation to the population control is treated on a broad basis. All over the world research is carried out on arthropods of the urban green areas, factors controlling their number and methods which control the too numerous species (Helman *et al.*, 1982; Flint & van den Bosh, 1983).

The number of arthropods depends on the type of urban green areas. Trees growing in direct vicinity of streets are most numerously settled whereas those in parks and housing estates are less prone to pest infestation. In leaves of limes growing by the streets (i.e. on salty soil) an increase in amino-acid content was confirmed which attracted a high number of linden spider mite (*Eotetranychus tiliarum* Hermann, 1804) (Kropczyńska-Linkiewicz, 1984). Similar dependencies were recorded for aphids (Cichocka, 1984) and probably for other Hemiptera which appear in a large number in cities (psyllids and scale insects).

Antropogenic pressure which in cities is likely to be extensive has a significant influence on urban zoocenosis (Luniak & Kropczyńska-Linkiewicz, 1990). Data gathered in references points out to deep transformations in the structure of zoocenosis which take place because of urbanisation. The number of species decreases, but the number of those who manage to survive despite urbanisation increases. Among them, there are the phytophags, which mostly have a sucking-piercing mouth apparatus and which form the strongest populations, including spider mites (Kropczyńska-Linkiewicz, 1984), aphids and froghoppers (Aphtophora) (Chudzicka, 1979) and scale insects (Komosińska,1976; 1986a and b; 1987a). In the urban environment aphids develop in an unbelievably dynamic rate (Czechowska *et al.*. 1979). Also Tykarska (2002) states that arthropods coming from the order of the highest number showed little species diversity in urban conditions (Hemiptera and Acarina). On haw-

thorns in Warsaw she pointed out to a numerous presence of two psyllid- and five aphid species. Other sucking-piercing arthropods occurred singly.

It results from the research carried out in Warsaw that arthropods with a sucking-piercing mouth type (spider mites, aphids, froghoppers and psyllids) reach high numbers on maples, limes, oaks and hawthorns (Pisarski, 1979; 1982; Czechowska *et al.*, 1978; Chudzicka, 1979; Cichocka *et al.*, 1990; Kropczyńska *et al.*, 1990; Tykarska, 2002). These arthropods which settle trees growing in the most contaminated areas along the streets are likely to reach the highest number. Their number in these sites was at times much higher than on trees in parks or those outside cities. These arthropods in natural conditions do not usually form such numerous populations. However, sometimes in city parks arthropods can form very large populations which threaten trees. Such a situation was observed in 1986 in the Royal Gardens in Warsaw when copper beech trees growing by a pond were numerously settled by aphids (Cichocka *et al.*, 1990). At that moment chemical intervention was necessary. Perhaps a higher content of N and proteins in leaves of trees growing along streets has a positive influence on the number of sucking-piercing arthropods (Kropczyńska, 1984). These compounds are an important criterion in the selection of the host plant.

According to Komosińska (1987b), the groups of scale insects in Warsaw's parks had a higher number of species and a higher frequency than in the area of housing estates. On trees growing along alleys *Quadraspidiotus ostreaeformis* and *Psuedochermes fraxini* were found to be the most numerous, while in housing estates areas it was *Parthenolecanium corni*, *Lepidosaphes ulmi* and *Sphaerolecanium prunastri*. In parks, the following were found to be the most numerous: *Parthenolecanium corni*, *Chionaspis salicis*, *Lepidosaphes conchiformis* and *Pseudochermes fraxini*. The author proved that scale insects were more numerous in cities than in the natural environment.

The share of phytophags with a biting mouth apparatus amounted only to 0.9% of all the collected herbivores on trees in Warsaw. Beetle, butterfly and hymenopteran larvae were present in small amounts (especially on trees along the streets). Perhaps the dusty leaves, their contamination with heavy metals discouraged biting insects from feeding because eating a leaf they would consume large amounts of damaging substance. However, the sucking-piercing arthropods (aphids, froghoppers, psyllids) when taking in nutrients from phloem or from parenchyma (spider mites) omit the toxic substance on the leaf surface (Cichocka & Goszczyński, 1991). The number of aphids on oak trees (*Quercus robur* L.) in natural conditions was 1000 times lower than in sites by the roads of Warsaw (Rychlik, 1979). In city parks their number was 10 times higher than in natural sites. However, in housing estate green areas the number of aphids was 4-100 times higher than in the control site while in the courtyard green areas it was 500 times higher. The highest percentage of lime

tree leaves infested by aphids was observed in different periods of the growth season in the summer of 1987 (July, August), in the autumn of 1988, and in the spring of 1989. The infestation of over 40% of oak leaves and 100% of maple leaves was registered. Aphids were numerous during rainy and cold years, while spider mites in dry summers with little rainfall. Lime- and oak trees irrespective of the weather were settled more numerously by spider mites or aphids (Cichocka *et al.*, 1990). Maple trees were more likely settled by aphids and hoppers. In each year of the observation, about 80% of the leaves of these trees were infested by sucking-piercing arthropods (Cichocka *et al.*, 1998).

Kowalczyk *et al.* (1990) also noticed also that most insect groups in the city of Łódź have a smaller number of families and species, especially in city centres in comparison with the suburbs. In the city centres there were more polyphags than monophags.

Chudzicka *et al.* (1998) divided the insects into 3 groups depending on the type of reaction on the urban pressure:

1. those in which a small decrease of the number of species is recorded,
2. those in which there is a significant decrease of the number of species,
3. those in which there is an increase in the number of species.

Hoppers, the species composition of which is smaller in cities only by 5% belong to the first group. Sphecidae increase the number of species in cities by over 20% (Skibińska, 1986a) while owlet moths (Noctuidae) develop a fauna which is decreased by 50% (Skibińska, 1986b).

Dependencies between phytophags and zoophags in urban conditions

In urban flora one may encounter not only herbivorous arthropods but also predatory species and parasitoids. In the parks of the town of Sandomierz one may encounter quite numerous mantises (Krawczyńska, 2007). This stenothermal predatory insect does not represent a numerous species in Poland, and the town of Sandomierz is one of its habitats. Moreover, in the Pieprzowe Mountains (which partially lie within the town of Sandomierz), other rare stenothermal and xerophylous insect species are present.

Data collected on the basis of a review of research by other scholars point out to deep transformations in the structure of zoocenosis taking place due to urbanization pressure. The effect of these changes are the phenomena of immense gradation of harmful herbivores (Franke & Koehler, 1978; Pisarski, 1979; 1982; Kropczyńska *et al.*, 1990) however, the number of its natural enemies does not always increase proportionally. The species composition of predatory and parasitic fauna increases sometimes. Kropczyńska-Linkiewicz (1984) referred to high numbers of herbivorous acarins on lime trees in Warsaw, especially in the street sites. On those trees *Eotetranychus tiliarium*

(Hermann, 1804) was especially numerous followed by the species of the Eriophyidae. The cause of the growth in the number of spider mites on street trees was the increase in their fecundity in these sites which was stimulated by high contents of non-protein forms of nitrogen in leaves. Moreover, street sites have a higher temperature and a lower humidity which favours the development tempo of spider mites and lowers their mortality. However, in the predatory group of acarins (Phytoseidae) dominated species with lower reduction ability (in relation to spider mites). TYKARSKA (2002) states that with high numbers of aphids and psyllids the highest number among the zoophags on hawthorns was reached by arachnids, and in particular by spiders and predatory acarins.

Aphids as no other phytophagous group have an extensively structured group of predators and parasitoids (CZECHOWSKA *et al.*, 1979). In large parks and suburbs there occur numerous parasitoids and predators that feed on aphids thus limiting their number. However, worsening biotic conditions limit the number of zoophags which leads to an increased number of aphids (RYCHLIK, 1979) or psyllids (TYKARSKA, 2002). Along with a decreasing park area and an increase in pollution, the number of predators decreases, whereas the overall number of species remains unchanged and the number of herbivores increases (DRABER-MOŃKO *et al.*, 1979). The number of predators in the Saski Garden (a small polluted park in Warsaw city centre) was twice as low as in the palace park in the neighbourhood of Ursynów (Warsaw outskirts), whereas the number of phytophags was five times as high (DRABER-MOŃKO *et al.*, 1979). A tree growing by the road in comparison with a tree growing in the Royal Park, had a twice lower number of predators and 2.5 times increased lowering of the value of the relation predator-herbivore as well as a decrease in the number of predator species. Moreover, a part of predatory species which were recorded in the road site was not registered to occur inside the park. Therefore, one can observe here a phenomenon of species replacement favourable to biocenosis balance (DRABER-MAŃKO *et al.*, 1979). When studying the presence of the Aphididiae and Jassidae on maple, lime trees and oaks, KROPCZYŃSKA *et al.* (1990) did not record such a sharp difference in the pradator-victim ratio. Together with the increase of urban pressure the ratio of the number of aphids (e.g. *Eucallipterus tiliae* Linnaeus, 1758) on linden tree (*Tilia euchlora*) to the number of aphidofagi (CZECHOWSKA *et al.,* 1979) also changed. A decrease in the green area and an increasing antropopressure led to an increase in the number of aphids and a decrease in the number of predators such as Coccinellidae, Neuroptera, Syrphidae and Sphaecidae. The number of aphids on lime trees was the highest in the park outskirts. Fifty percent of the whole aphid population of the park was recorded there along with 45% of predators (larvae of Neuroptera and imagines of Coccinellidae). The deeper inside the park, the lower these values (CZECHOWSKA *et al.*, 1979).

According to Czechowska *et al.* (1979) the Coccinellidae have the lowest level of sensibility to pollution. The number of their larvae and adults increased proportionally to the number of victims. The Neuroptera on the other hand seem to depend on humidity and temperature. In the road sites they occurred in a small number while their greatest number was recorded deep inside the park. Cold and rainy growth seasons may seem to be the exception when in the road sites one could observe numerous Neuroptera and Syrphidae which was adequate to the number of victims.

Damage caused by numerous sucking-piercing arthropods

Trees situated by the roads were found to be the most strongly infested by the herbivore arthropods. The farther from the road they were (deeper into the park) the smaller the number of herbivores and the less visible the damage.

Tuberculoides annulatus (Hartig, 1841), which was present in large numbers on oak trees in Warsaw excreted large amounts of honeydew, which along with the dust and dusty powder forms a layer of pollution on the leaf surface which makes assimilation difficult (Rychlik, 1979). Many aphids of this species contributed to an earlier leaf fall. However, many aphids of the Phylloxera genus when taking in nutrients from the parenchyma, a true assimilation tissue, damage them, thus as soon as in July some leaf blades do not take part in the assimilation which does not favour oak metabolism (Rychlik, 1979). *Eucalipterus tiliae* (Linnaeus, 1758), which was present in some growth seasons on lime trees, excreted such large amounts of honeydew that pavements below the trees became sticky, while leaves were heavily covered in it. Dusting powder and dust stuck to the honeydew on leaves which certainly influenced the lowering of assimilation and breathing as well as it lowered the decorative value of these trees (Cichocka & Goszczyński, 1991). Also numerous populations of spider mites on lime trees caused discolouring of leaf blades and an earlier leaf fall, especially on trees in sites situated by the roads (Kropczyńska-Linkiewicz, 1984).

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Wpływ presji urbanizacyjnej na skład gatunkowy i liczebność stawonogów na drzewach w mieście na przykładzie Warszawy

Streszczenie

Praca jest przeglądem dotychczasowych badań nad wpływem urbanizacji na liczebność stawonogów na drzewa miejskie na przykładzie Warszawy. Drzewa rosnące w mieście narażone są na wiele niekorzystnych dla wzrostu i rozwoju czynników: nasady ich pni są często opłytowane, zmienione są właściwości powierzchniowych warstw gleby, zanieczyszczone powietrze i gleba, odwodnione i ubite podłoże, doświetlanie nocą. Najbardziej narażone na presję urbanizacyjną są drzewa rosnące wzdłuż ulic a mniej w osiedlach mieszkaniowych i w parkach. Zmiany zachodzące w roślinach powodują zmianę składu gatunkowego roślinożerców. Zmniejsza się liczba gatunków a rośnie liczebność tych, które oparły się presji urbanizacyjnej. Przędziorki, mszyce, koliszki i czerwce osiągają w Warszawie ogromne liczebności na klonach, lipach, dębach i głogach. Gatunki o narządach gębowych gryzących (chrząszcze, larwy motyli i błonkówek) są mniej liczne niż na terenach poza miastem. Gatunki ograniczające liczebność roślinożerców (parazytoidy i drapieżce) najczęściej nie dają rady w obniżaniu ich liczebności.