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Dominant pests and pathogens of urban plantings in Kyiv: Species composition and prevalence

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Abstract. Impact of pests and pathogens on trees, along with air pollution, are one of the most important factors that determine tree health in parks, squares, boulevards and streets of Kyiv. The purpose of the study was to monitor populations of dominant pests and foci of pathogens of tree ornamental plantings in Kyiv from 2020 to 2022. The objects of the study were horse chestnut leaf miner *Cameraria ohridella* Deschka & Dimic., leaf blotch miner moth *Acrocercops brongniardella* F., Linden gall mite *Eriophyes tiliae* Nal., and powdery mildew of Common Oak *Erysiphe alphitoides* Griffon & Maubl. U. Braun&S. Takam. Using the route method and the E.E. Geschele scale, population indicators were evaluated for *Cameraria ohridella, Acrocercops brongniardella* and *Eriophyes tiliae*. It is found that the number of these species is increasing. It

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is showed that these pests are common on tree species *Aesculus hippocastanum* L., *Quercus robur* L., and *Tilia cordata* Mill., in street and urban plantings under the intense influence of abiotic and anthropogenic factors. In 2021, compared to 2020, the prevalence of *Cameraria ohridella* increased by 7 times, the distribution of *Acrocercops brongniardella* ranged from 76-78%, and powdery mildew damage to Common Oak, on average, is 3.41. According to the results of the study, it is identified that the populations of *Acrocercops brongniardella* and *Eriophyes tiliae* are in a stable condition and do not have substantial deviations by year, while the invasive species *Cameraria ohridella* is characterised by a substantial increase in prevalence and abundance, which means that it causes an intense weakening and decrease in the decorative effect of Chestnut in the city's street plantings. Annual intensive powdery mildew *Erysiphe alphitoides* damage was noted at young ordinary plantings of Common Oak along the main roads of the metropolis. The potential reproduction opportunities of phytophagous insect populations are analysed. In practice, the obtained results can be used for pest management and further monitoring of tree health in street and urban plantings in Kyiv

Keywords: phytophage insects; accounting; *Cameraria ohridella; Acrocercops brongniardella; Eriophyes tiliae; Erysiphe alphitoides*

Introduction

Green spaces of Kyiv perform a variety of functions and are important for the city. They not only provide opportunities for recreation but also act as natural treatment complexes and urban compensation zones. Green areas of Kyiv include various types of green spaces that are characteristic of urbanised ecosystems of megacities. These include parks, including meadow parks, sports parks, and waterfront parks, squares, boulevards, botanical and dendrological gardens, zoos, street and avenue plantings, inner courtyard plantings, plantings near educational, cultural, and healthcare institutions, memorial complexes and cemeteries, as well as urban forests. According to V.V. Rodinkova *et al.* (2020), among the species composition of street plantings, linden (29.7%), maple (26.2%), common and red Horse Chestnut (14.8%), poplar (10.8%), black locust (7.8%), oak and ash (each at 1.1%), hawthorn (0.7%) are most commonly represented. Less frequently found on the city streets are birch, catalpa, elm, cherry, bird cherry, and other species, together accounting for about 8%. The taxonomic composition of Kyiv's dendroflora is quite rich. In the composition of street green spaces of the city, the leading share belongs to representatives of the genus *Tilia* L. which are generally characterised as resistant to urban conditions, but vulnerable to damage by *Eriophyes tiliae* Nal. with the formation of galls (erineums).

According to U. Braun *et al.* (2022), *Microsphaera alphitoides* (*Erysiphe alphitoides*) the most Common Oak leaf disease in Europe, numerous studies confirm the harmful effects of the pathogen on plants due to the absorption of nutrients from leaf tissues and reduced assimilation (Takamatsu *at al.*, 2015). P. Pap *et al.* (2013) note that it is particularly important to identify the influence of environmental factors on the complex relationships that exist between a plant and a pathogen.

L. Guedes *et al*. (2023) note that the bright colours of galls caused by *Eriophyes tiliae* on heart-shaped linden trees, due to the accumulation of pigment in their tissues, these newly

formed organs develop for protection and nutrition. At the structural level, the most common changes caused by halo-forming organisms are homogenisation, hyperplasia, and cell hypertrophy.

L. Volter *et al.* (2022) established that an increase in the number of invasive species indicates an aggravation of the problem of degradation of local ecosystems. Therefore, in the studies of A. Cedro & G. Nowak (2022), N. Olenici *et al.* (2022), it is stated that the dynamic propagation *Cameraria ohridella* leads to a substantial weakening of Chestnuts in European countries. A study by A.F. Lihanov *et al.* (2016) of common bitter Chestnut plants indicate that the viability of Chestnut leafminer caterpillars depends on the viscosity of cell sap and has little to do with the content of phenols in the leaves. In late summer, on trees damaged by *Cameraria ohridella,* the development of dormant leaf buds begins, which should normally be in the next spring. Defoliation for a long time can lead to a substantial weakening of the tree, and, as a result, its death.

The purpose of the study is to examine populations of dominant pests (*Cameraria ohridella*, *Acrocercops brongniardella, Eriophyes tiliae, Erysiphe alphitoides*) and foci of pathogens of urban plantings in Kyiv.

Materials and Methods

The object of the study is tree species *Aesculus hippocastanum* L., *Quercus robur* L., *Tilia cordata* Mill. on the territory of the city of Kyiv in the period 2020-2022. The subject of the study is street and urban plantings in the zone of intense influence of abiotic and anthropogenic factors.

Monitoring of populations of dominant pests and foci of pathogens of urban plantings in Kyiv was conducted by the route method, 100 model trees were determined and 100 leaf plates were randomly selected, which were collected and numbered. The score of powdery mildew infestation of Common Oak with *Microsphaera alphitoides* (*Erysiphe alphitoides*) (Braun *et al.*, 2022) was determined by the E.E. Geschele scale visually on each leaf (Fig. 1).

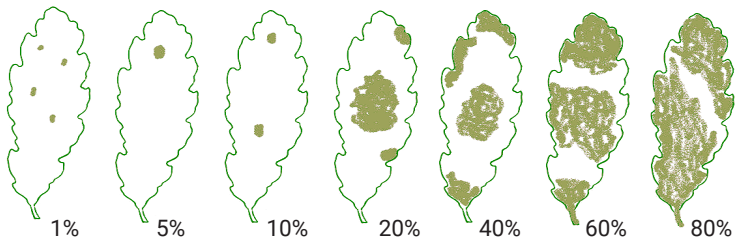

Figure 1. E.E. Geschele scale for investigating the distribution of powdery mildew fungi
Note: 0 points – healthy, 1 point – less than 10% of plants affected (weak degree), 2 points – 11-25% of plants affected (moderate degree), 3 points – up to 50% of plants affected (strong degree), 4 points – more than 50% of plants affected (very strong degree), 5 points – dying or dead plants
Source: A.F. Goychuk *et al.* (2012)

Disease prevalence – the number of affected plants or organs, expressed as a percentage, was determined by the formula (1):

$$P = \frac{n}{N} \cdot 100, \qquad (1)$$

where P – prevalence of the disease, %, N – total number of plants on the test area, pcs., n – number of affected plants on the test area, pcs.

The intensity of disease development is a qualitative indicator of the process of disease

development, calculated by Formula (2) to assess the general condition of woody plants in points:

$$R = \frac{\Sigma(a \cdot b)}{n}, \qquad (2)$$

where R – the intensity of disease development, score, $\Sigma\ (a \cdot b)$ – the sum of products of the number of plants (organs) and the corresponding lesion score, n – total number of plants or organs in accounting (Goychuk *et al.*, 2012; Puzrina *at al.*, 2021).

Inspection of the street and urban plantings for damage by *Cameraria ohridella* and *Acrocercops brongniardella* was conducted in the following periods: during the mass migration of adults and their egg laying, after the birth of the first generation of caterpillars, in the first and second decades of September. During the mass flight of butterflies and egg-laying of *Cameraria ohridella,* the approximate number of butterflies attaching to the bark of Common Horse Chestnut trees was determined (Meshkova, 2020). The counting of mines was conducted in the first and second decades of September using a hand lens. Calculated data regarding the area of the leaf blade and the area of mines for all 100 randomly selected leaf blades were recorded in an inventory sheet (Fig. 2).

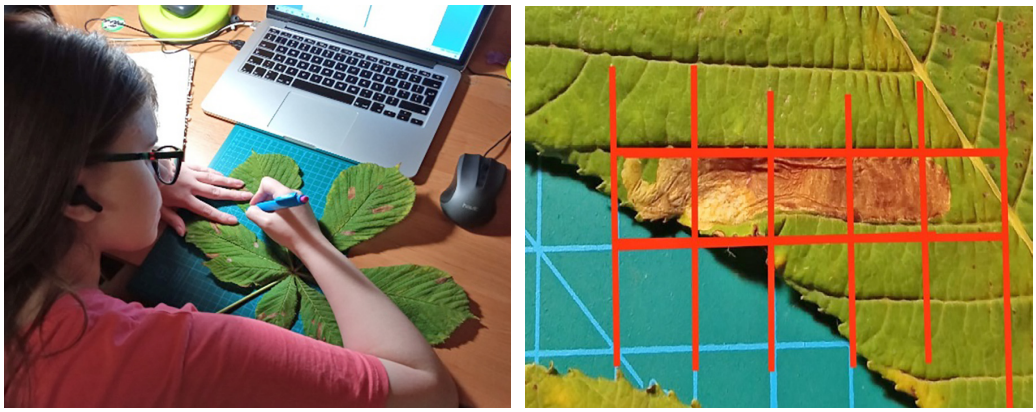

Figure 2. Process for calculating the area of mines on a leaf blade *Aesculus hippocastanum* L
Source: photographed by the authors

Moth generation and age were determined by identifying mines and comparing caterpillars by well-known morphological features (Zavada, 2017; Shvidenko *et al.*, 2020). On one sheet, the number of caterpillars was counted, their age and the number of dead caterpillars were determined.

Monitoring of *Acrocercops brongniardella* F. was conducted in July on damaged leaf plates, on which the area of mines and the number of caterpillars were determined. Leaf blades of Common Oak were selected randomly, the area of damage was determined using a palette in the field, then the average value of the lesion of leaf blades was calculated. Monitoring the spread of Linden gall mite *Eriophyes tiliae* was conducted by the route method, where the leaves of the lower tiers of *Tilia cordata* Mill. were randomly selected, on which the area of the leaf blade and the number of gall were calculated (Fig. 3).

Figure 3. The process of calculating the number of gall and leaf blade area, 2020
Source: photographed by the authors

In the laboratory, work was reduced to processing the collected materials and analysing the results obtained. The study met all the requirements of the Convention on Biological Diversity (1992).

Results and Discussion

In Ukraine, the rate of spread of invasive species and the scale of damage to green spaces in gardens, parks, and squares of cities are becoming more noticeable (Maksymchuk, 2009; Pihalo, 2010). Colonisation by atypical species for the region leads to a decrease in the energy of plant growth and their longevity, loss of decorative properties and yield, and ultimately leads to the gradual death of the plant. According to monitoring and accounting data for *Cameraria ohridella*, information was obtained on the number of species generations in Kyiv (Table 1).

Table 1. Generation of horse chestnut leaf miner in the conditions of Kyiv

Year	Month	Average monthly temperature, °C	Generation
2020	April	9.9	I
	May	12.4	I
	June	21.7	I, 2 dec.* II
	July	21.9	II
	August	21.4	II, 1 dec. III
	September	18.4	III, 1 dec. VI
	October	12.5	VI-fr.**
2021	April	8.0	I
	May	14.4	I
	June	21.3	I, 2 dec. II
	July	24.6	II
	August	21.1	II, 1 dec. III
	September	13.5	III, 1 dec. VI
	October	8.4	fr.

Table 1, Continued

Year	Month	Average monthly temperature, °C	Generation
2022	April	8.1	I
	May	14.6	I
	June	21.7	I, 2 dec. II
	July	20.8	II
	August	22.3	II, 1 dec. III
	September	12.7	III, 1 dec. VI
	October	10.6	VI – fr.

Note: *dec. – decade, **fr. – frosts
Source: compiled by the authors

During accounting, the number of caterpillars on one leaf, their age, and the number of dead caterpillars were determined, for example, on a leaf with an area of 122.8 mm^2 (model tree No, 2) in 2022, 7 caterpillars were identified at different stages of development: 2 of them were in IV-V age, 2 in the pupal stage, and 3 more died at different stages of development (Fig. 4).

a b

Figure 4. Comparison of the size of a caterpillar of stage IV and the tip of a mechanical pencil that has a size of 0.4 mm (a) and the number of caterpillars on the leaf (b)
Source: photographed by the authors

Invasive species are species that have a high ability to spread and pose a substantial threat to natural ecosystems, including flora and fauna. They can spread naturally or with the help of humans. These species have a high potential for expansion, as they have a wide ecological amplitude, resistance to stress, a high rate of reproduction and the ability to take root in new environments, can use resources inaccessible to native species, and substantially affect the balance of the ecosystem by changing its structure (Meshkova *et al.*, 2014). Monitoring of insect populations is essential to optimise pest control with appropriate protection periods and avoid unnecessary use of insecticides (Florian *et al.*, 2023). Accounting results that demonstrate the dynamics of the distribution of *Cameraria ohridella* on the Horse Chestnut are shown in Figure 5.

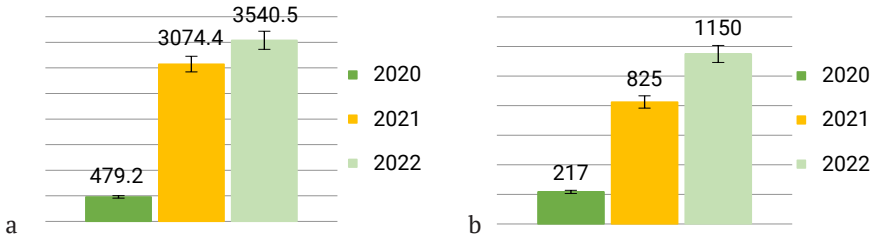

Figure 5. Total area, cm^2 (*a*) and quantity (*b*) of mines on model trees of *Aesculus hippocastanum* L. in the period of 2020-2022

Source: compiled by the authors

Sharp increase in the number of mines and their area in 2021 can be explained by several factors: an increase in the number of caterpillar generations due to rising temperatures and daylight hours. In September 2020, the average monthly temperature was 18.5°C, which led to an extension of the moth's summer period and the formation of the VI generation, therefore, this led to the fact that by the time it left for wintering, the population was dominated by caterpillars, most of which did not have time to pupate and died after frost in the thaw. During the 2021 period, the moth prevalence was much higher than in the 2020 period, due to constant temperatures above 15°C during the summer and favourable conditions for the butterflies to fly and better survival of the first two generations. 2022 was characterised by a very hot August, where the air temperature on some days exceeded 30°C, which led to more favourable conditions for the summer of the third generation of moths, an increase in the number of the fourth generation and the continuation of its activity in October. According to the authors' forecasts for 2023, the prevalence of moths will be 30-50% higher than in previous years under favourable climatic conditions. Early defoliation of Chestnuts (in climatic conditions of Kyiv this usually occurs in August), is a consequence of the colonisation of the leaf plate by moths not even of the third generation, but of the complete settlement by the first and second generations (Fig. 6).

Figure 6. Intensive damage to the leaf blade (a) and V-age larva with a pronounced gnawing oral apparatus (b)

Source: photographed by the authors

Thus, according to the results of monitoring 2020-2022, a substantial spread of *Cameraria ohridella* was identified during this period, the prevalence increased seven-fold, which indicates clear favourable conditions, the absence of natural enemies in the examined conditions, and the rapid reproduction and viability of caterpillars of the first three generations, which, in turn, under favourable temperature conditions in September can produce a fourth generation. This trend towards an increase in the population size under favourable conditions will continue to be relevant in the following years. Accounting results that demonstrate the dynamics of the prevalence of *Acrocercops brongniardella* on Common Oak are shown in Figure 7.

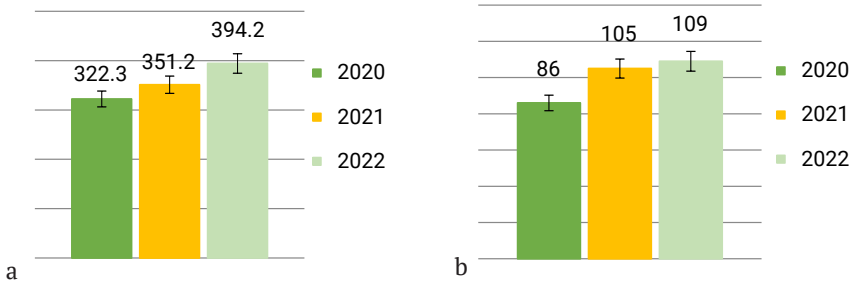

Figure 7. Total area, cm^2 (*a*) and quantity (*b*) of mines on model trees of *Quercus robur*. in the period of 2020-2022

Source: compiled by the authors

It was established that the number and area of mines on the leaf blades of Common Oak in the period from 2020-2022 fluctuated slightly. The Oak broadly leaf-mining moth is an aboriginal species for Ukraine, which means that in the conditions of Kyiv, the moth has natural entomophages among various representatives of the fauna, which regulates the number of species from uncontrolled outbreaks.

According to the phenogram of moth development in the conditions of the forest park zone of Kyiv, it can have two generations within 1 year (Grigoryuk *et al.*, 2014), the first generation of butterflies and the period of mass egg laying begins in April and ends in May. In May 2021 and 2022, the average monthly temperature was 14.4°C and 14.6°C, respectively, which contributed to the stretching of the flight period of *Acrocercops brongniardella* and during the survey period, the development of one generation per year. When examining urban plantings with a predominance of Common Oak for the presence of *Acrocercops brongniardella* it is established that the distribution of the population is 77-79%, and practically does not change over the years.

In addition, during the monitoring period, powdery mildew of Oak developed quite rapidly on the leaves of *Erysiphe alphitoides* (Griffon & Maubl.) U. Braun & S. Takam. According to the E.E. Geshele scale (Fig. 8), powdery mildew damage of Common Oak averages 3.41, that is, the disease has a strong degree of prevalence. Therefore, it can be assumed that young oak plantings are greatly weakened, considering their location opposite the main road where continuous emissions of toxic substances and heavy metals are observed around the clock. The complex of the above factors substantially hndeers the growth and development of young plantings, which can lead to their fall off.

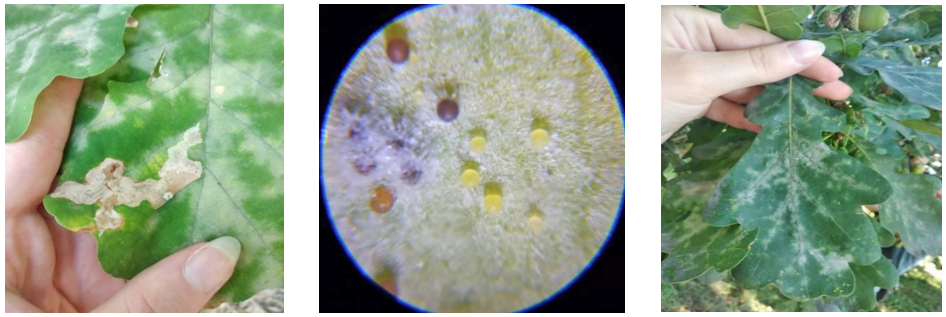

Figure 8. Powdery mildew of Oak *Erysiphe alphitoides*
(in the centre – cleistothecia on the underside of the leaf under the microscope)
Source: photographed by the authors

Based on the results of monitoring the number of galls in outdoor plantings dominated by heart-leaved Linden, the dynamics of distribution of *Eriophyes tiliae* was established (Fig. 9).

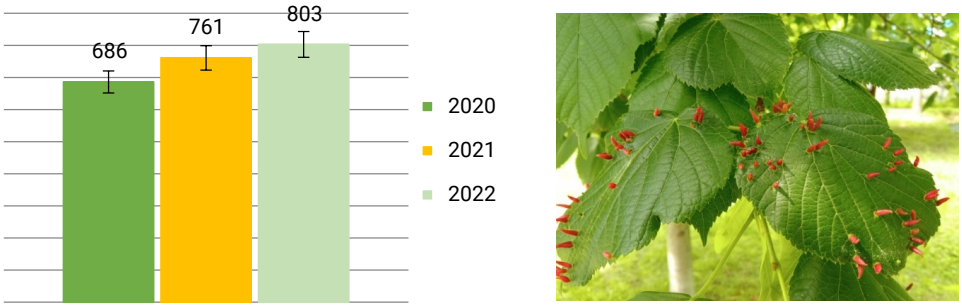

Figure 9. Total number of galls on model trees *Tilia cordata* for the period of 2020-2022
Source: compiled by the authors, photographed by the authors

The number of galls in the period of 2021-2022 on a single leaf blade ranges from 4 to 22, and within the model tree from 50-89 (2021) and 74-103 (2022), respectively. According to the results of observations and accounting, the distribution of the species was established in the range of 76-78%. It was established that the Linden gall mite primarily inhabits the lower part of the crown of the heart-leaved Linden and exhibits a focal pattern of colonisation. Firstly, the harm that *Eriophyes tiliae* Nal. causes consists in deformation of the leaf blade and a decrease in decorative effect, but with mass development, the species causes a disruption of the functions of the assimilation apparatus and the transfer of pathogens.

On trees of the species *Aesculus hippocastanum* the population of *Cameraria ohridella* was identified, the prevalence of which increased 7-times from 2020 to 2022. This clearly indicates favourable conditions, the absence of natural enemies, and rapid reproduction and viability of caterpillars of the first three generations, which under favourable temperature

conditions in September can produce a fourth generation. Under such conditions, the flight of the first generation is predicted to be in mid-April 2023. Although the estimates of the rate of spread of *Cameraria ohridella* have been well investigated over the past few decades, particularly in the conditions of Kyiv (Serova *et al.*, 2007) and are consistent with data obtained by I. Shvidenko *et al.* (2020), K. Holoborodko *et al.* (2022), the data obtained will complement the study of population distribution dynamics and identify factors that affect the spread of the population of invasive species in a megapolises (Tobin & Robinet, 2022; Tokarieva *et al.*, 2022).

Diagnostics of urban plantings with a predominance of Common Oak for damage have showed that most of the plants are damaged by *Acrocercops brongniardella*, the distribution of the species is 77-79%. This is confirmed by the study conducted by I.P. Grigoryuk *et al.* (2014), according to which in urban plantings of Kyiv, the favourable natural and climatic conditions for the development of *Acrocercops brongniardella* are formed, which leads to the rapid spread of the population, but according to the observations of this study, the population had a one-year generation and an extended period of flight and reproduction during the study period. In the examined plantings, a strong lesion of powdery mildew was noted (3.4 points on the scale of E.E. Geschele), so the plants of Common Oak are greatly weakened.

Stable population indicators of the species *Eriophyes tiliae* indicate good adaptability of ticks to environmental conditions, in particular, this is consistent with the study by G. Soika & M. Kozak (2013), who noted that red galls have high levels of anthocyanins and perform various physiological functions, such as antioxidant and UV protection. Distribution of the Linden gall mite *Eriophyes tiliae* population ranges from 76-78%, mainly affecting the foliage from the lower part of the crown.

Notably, the city's garden and park landscapes are located in a dense circle of enterprises and highways, so comprehensive monitoring of the ecological and sanitary condition of the territory is relevant (Ogorodniychuk, 2009; Pihalo, 2010; Polyakov *et al.*, 2012). Monitoring and investigating the dynamics of the number of phytophagous insects and pathogens in urban conditions provides accurate information about their species composition, and harmfulness and allows allows to predict their number and potential reproduction (Grigoryuk *et al.*, 2014; Branco *et al.*, 2019; Holoborodko, 2022). Therefore, monitoring of insect populations is important both in the field of ecology and practical pest control, and is an integral part of integrated control and a primary approach to reducing environmental loads.

Monitoring studies in the period 2020-2022 indicate an increase in damage to urban plantings in Kyiv. This is due to the influence of abiotic (climatic conditions), biotic (growth in the number of phytophagous insects and the spread of pathogens), and anthropogenic (light load, noise, dust, emissions of toxic substances and heavy metals) factors on selected woody plant species.

Conclusions

Based on the results of an examination of model trees, the settlement of Horse Chestnut leaves with *Cameraria ohridella* and the area of mines increased from 217 mines (2020) to 1,150 mines (2022) and from 479.2 cm^2 up to 3540.5 cm^2 accordingly. Such an intensive increase in these indicators is indicative of favourable conditions for the reproduction and viability of *Cameraria ohridella* due to the formation of the fourth generation of insects.

In urban plantings with a predominance of Common Oak, the distribution of *Acrocercops brongniardella* was observed in the range of 77-79% and almost did not change from year

to year. The total area of mines ranged from 322.3 cm^2 (2020) up to 394.2 cm^2 (2022), the number of mines was from 86 to 109, respectively. In addition, the rapid development of powdery mildew of Oak *Erysiphe alphitoides* was recorded annually, which is characterised by a high degree of damage (3,41).

Heart-leaved Linden trees have been established to have a focal nature of Linden gall mite *Eriophyes tiliae* colonisation, which caused deformation of the leaf blade and a decrease in decorative effect. Studies have shown that the number of galls on a single leaf blade varies from 4 to 22 during the period of 2021-2022. Within the model tree, the number of galls ranged from 50 to 89 in 2021 and from 74 to 103 in 2022.

Thus, the populations of *Cameraria ohridella, Acrocercops brongniardella, Eriophyes tiliae* and the pathogen *Erysiphe alphitoides* are the most common in street and urban plantings of the metropolis. Further investigation into the biology of the mentioned phytophagous insect species and associated disease pathogens will allow for the identification of patterns in their interactions within complex habitats and ecosystems and the level of threat to the green spaces of Kyiv.

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None.

Conflict of Interest

The authors declare no conflict of interest.

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Домінантні шкідники і збудники хвороб міських насаджень м. Київ: видовий склад та розповсюдженість

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Анотація. Однією з важливих проблем, які стосуються мережі парків, скверів, бульварів, озеленених вулиць та площ м. Києва залишається поширення шкідників та збудників хвороб

деревних насаджень. Мета дослідження полягала у моніторингу популяцій домінуючих шкідників та осередків збудників хвороб деревних декоративних насаджень м. Київа з 2020 по 2022 роки. Об'єктами дослідження були каштанова мінуюча міль *Cameraria ohridella* Deschka & Dimic., дубова широкомінуюча міль *Acrocercops brongniardella* F., липовий галовий кліщ *Eriophyes tiliae* Nal. та борошниста роса дуба звичайного *Erysiphe alphitoides* Griffon & Maubl. U. Braun & S. Takam. За допомогою маршрутного методу та шкали Е. Е. Гешеле проведено оцінку показників популяції *Cameraria ohridella, Acrocercops brongniardella* та *Eriophyes tiliae*. Встановлено, що чисельність зазначених видів зростає. Констатовано, що зазначені шкідники поширені на деревних видах *Aesculus hippocastanum* L., *Quercus robur* L. та *Tilia cordata* Mill., у вуличних та міських насадженнях за інтенсивного впливу абіотичних та антропогенних чинників. У 2021 році порівняно з показниками 2020 року, розповсюдженість *Cameraria ohridella* збільшилася у 7 разів, поширення *Acrocercops brongniardella* коливалося в межах 76-78 %, а ураження борошнистою росою дуба звичайного, в середньому, становить 3,41. За результатами досліджень виявлено, що популяції *Acrocercops brongniardella* та *Eriophyes tiliae* перебувають в стабільному стані і не мають суттєвих відхилень по рокам, тоді як інвазивний вид *Cameraria ohridella* відрізняється значним збільшенням розповсюдженості та чисельності, а відтак, спричиняє інтенсивне ослаблення та зниження декоративності гіркокаштана у вуличних насадженнях міста. Відмічено щорічне інтенсивне ураження борошнистою росою *Erysiphe alphitoides* молодих рядових посадок дуба звичайного вздовж магістральних шляхів мегаполісу. Проаналізовано потенційні можливості розмноження популяцій комах-фітофагів. На практиці отримані облікові дані, можна використовувати для подальших моніторингових спостережень у вуличних та міських насадженнях м. Києва

Ключові слова: комахи-фітофаги; облік; *Cameraria ohridella*; *Acrocercops brongniardella*; *Eriophyes tiliae*; *Erysiphe alphitoides*