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AN ASSESSMENT OF LEAF DAMAGE CAUSED BY MINING FLIES (DIPTERA: AGROMYZIDAE) IN GREEN AREAS

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Urban vegetation perform a lot of functions: they improve the micro-climate, reduce air pollution caused by industry and traffic, absorb carbon dioxide and reduce bacterial and pollen pollution; they also perform aesthetic functions. Thus, trees and shrubs in green areas are often damaged by a wide range of arthropod phytophagous species. This influences aesthetic value of a plant.

The aim of the study was to review the species of Agromyzidae that cause damage to decorative trees and shrubs and to determine the pestfulness for their host plants in green areas of Vitebsk.

Material and methods. *The study was conducted during 2017–2020 in Vitebsk. The samples of damaged leaves were collected, scanned, and data were analyzed using statistical methods.*

Findings and their discussion. *The mines of larvae of 7 species are upper surface, 1 species is lower surface, the mines of 2 species have been registered on both sides. 8 species usually create a single mine per leaf, 2 species often create several mines per leaf; 2 can create communal mines. Aulagromyza cornigera (Griffiths, 1973) belongs to the spring/summer phenological group of phyllobionts. The rest species belong to the summer/autumn group.*

The area of a single Agromyzid mine ranged from 0.005 cm^2 to 5.42 cm^2. In 2017 and 2018 the areas of Populus nigra L. leaf laminae had statistically significant differences ($P<0.05$), but the differences in the areas of individual mines of Aulagromyza populi (Kaltenbach, 1864) were not found to be statistically significant ($P>0.05$).

Conclusion. *The preliminary list of Agromizidae that damage decorative woody plants in the green areas of Vitebsk city includes 10 species.*

On the basis of the analysis of the P. nigra leaf laminae the absence of interannual differences in the areas of individual mines was determined while there were statistically significant differences between the areas of P. nigra leaf laminae.

Key words: *leaf miners, pests, decorative woody plants, area of mines.*

ОЦЕНКА ПОВРЕЖДЕННОСТИ ЛИСТЬЕВ МИНИРУЮЩИМИ МУХАМИ В ЗЕЛЕНЫХ НАСАЖДЕНИЯХ

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Городские зеленые насаждения выполняют множество функций, в том числе улучшают микроклимат, уменьшают загрязнение воздуха, вызванное промышленностью и транспортом, поглощают углекислый газ и уменьшают бактериальное и пыльцевое загрязнение, а также выполняют важные эстетические функции. Поэтому деревья и кустарники в зеленых насаждениях часто повреждаются широким спектром видов членистоногих-фитофагов. Все эти аспекты в той или иной степени влияют на эстетическую ценность растения.

Целью исследования было выяснение круга Agromyzidae, наносящих вред декоративным деревьям и кустарникам, и определение вредоносности их для растений-хозяев в зеленых насаждениях Витебска.

Материал и методы. *Исследование проводилось в 2017–2020 гг. в Витебске. Образцы поврежденных листьев были собраны, отсканированы, данные проанализированы с использованием статистических методов.*

Результаты и их обсуждение. *Мины личинок 7 видов – поверхностные, 1 вида – нижнесторонние, 2 видов – двусторонние. Для 8 видов обычно размещение одной мины на лист, у 2 видов часто регистрируется несколько мин на лист; личинки 2-х видов могут создавать коллективные мины. Aulagromyza cornigera (Griffiths, 1973) принадлежит к весенне-летней фенологической группе филлобионтов; остальные виды относятся к летне-осенней группе.*

Площадь единичной мины агромизид составляла от 0.005 см^2 до 5.42 см^2. В 2017 и 2018 годах площади листовых пластинок Populus nigra L. имели статистически значимые различия (P<0.05), но различия в площадях отдельных мин Aulagromyza populi (Kaltenbach, 1864) не были статистически значимыми (P>0.05).

Заключение. *Предварительный список Agromizidae, повреждающих декоративные древесные растения в зеленых насаждениях г. Витебска, включает 10 видов.*

На основе анализа изображений коллектированных листовых пластинок P. nigra установлено отсутствие межгодовых различий в площадях отдельных мин, тогда как между площадью листовых пластинок P. nigra выявлены статистически значимые различия.

Ключевые слова: *минеры, вредители, декоративные древесные растения, листовые минеры.*

Urban green spaces carrying out multiple functions, including improving microclimate (reducing wind and noise, optimizing temperature conditions), lessening air pollution caused by industry and transport, absorbing carbon dioxide and decreasing bacterial and pollen pollution, as well as performing important aesthetic functions. The diverse pressures of anthropogenic factors on plants lead to reducing their resistance towards pests and pathogens. Therefore, trees and shrubs in green spaces often are damaged by wide range of phytophagous arthropod species. All these aspects affect plant's aesthetic value in varying degrees. Accordingly, monitoring of herbivorous insect pests in urban conditions is an important aspect in pest management strategies, allowing to predict future pest population levels and harm that could potentially be caused.

Mining flies (Diptera: Agromyzidae) are a diverse family of at least 2900 recent species in the world fauna [1]. The majority of species in larval state develop inside leaf tissues (some species damage other parts of plants like stems, flower buds, fruits, etc.), producing so called mines. Damage caused by leaf miners leads to a reduction in the assimilation surface area, deformation and necrosis of leaves, also can cause premature defoliation, decreasing decorative plant's aesthetic value and declining productivity of agricultural crops. Adult Agromyzidae may serve as vectors of viral, bacterial and other diseases of cultivated plants (infection occurs when females pierce leaf tissues with the ovipositor) [2]. Many agromyzids are considered as important economic pests [3].

The larvae of most Agromyzid species are host-specific, usually creating serpentine or blotch-like mines, which are characterized by double lines of frass (unlike Lepidopterous and Hymenopterous leaf miners). The specific characteristics of mine (size, color, location on the leaf blade and other features) are widely used for species identification [3].

Material and methods. Studies were conducted during vegetation periods of 2017–2020 in various parts of the city of Vitebsk. Leaves from decorative woody plants (deciduous trees and shrubs) with mining injuries were randomly collected from different green spaces within the city. After processing the specimens using common methods of herbarization [4], species identification was performed based on the identification keys and tables [5–7].

Digital images of leaf laminae (leaf blades) with mines were obtained by scanning herbarium specimens using flatbed scanner Epson Perfection 4180 Photo, resolution – 300 dpi. Image processing was carried out using ImageJ image editing software [8], the subsequent analysis of quantitative data – using freely accessible statistical analysis software PAST 4.05 [9]. The standard error (SE) was taken as a confidence interval for the arithmetic mean ($\bar{X}$). To determine the statistical significance of the observed differences, the non-parametric Mann–Whitney U-test and Kolmogorov–Smirnov tests were used [9].

Findings and their discussion. In green areas of Vitebsk 10 species of Agromyzidae that cause damage to decorative trees and shrubs from 8 genera were recorded. Information on species composition and character of leaf damage is contained in annotated list.

***Betula* L.**

Agromyza alnibetulae Hendel, 1931 damages silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* (Ehrh.)), two native birch species in Belarus.

The species is considered a forest pest [10]. Larvae develop in mines on the upper side of leaves. The mines are light green, sometimes significantly widening at the end, serpentine, extending over the

entire upper surface up to 12 cm long [6]; contain a double row of black frass. The leaf blades, especially in young leaves, is often become deformed (swollen). Pupation takes place on the ground. The species occurs widely in Europe: from Norway to Italy, and from Ireland to Romania [5].

In the sample of damaged leaves collected in 2017, the cumulative area of mines on leaf laminae varied in the range from 0.27 cm^2 to 3.16 cm^2, ($\overline{X}$ = 1.75 ± 0.24 cm^2), while the relative area of the damaged leaf surface varied in the range from 1.86% to 32.34%, ($\overline{X}$ = 14.31 ± 2.88%).

***Caragana* L.**

Siberian peashrub (*Caragana arborescens* Lam.) and Russian peashrub (*Caragana frutex* (L.) K. Koch) are widely used in landscaping in Belarus, particularly the first species.

According to our previous data [11], larvae of at least 3 species of Agromizidae can develop on pea shrubs in Belarus: *Aulagromyza caraganae* Rohdendorf-Holmanová (1959), *Amauromyza obscura* (Rohdendorf-Holmanová, 1959), and *Liriomyza congesta* (Becker, 1903). The last species is polyphagous, rather rare on *Caragana* spp., was not recorded for Vitebsk.

In Belarus *A. caraganae* is the most abundant pest of Siberian peashrub. *A. caraganae* is monophagous on plants of the genus *Caragana* L. The mines of the larvae can be located on both sides of a leaf (mainly on the lower side). The mine begins with a short, relatively broad corridor that quickly turns into a blotch. The mines are whitish; frass in dark discrete grains, located randomly. Pupation usually takes place in the mine.

The species is widespread in Europe, including the countries bordering Belarus – Poland and Lithuania [5].

The samples of *C. arborescens* leaves with mines were collected during vegetation period of 2020. There may be one or several mines per compound leaf (up to 6 mines, according to our observations). The percentage of upper-surface mines in the sample was 9.76%. The area of individual mines on a leaf varied in the range from 0.005 cm^2 to 0.633 cm^2. The average area of individual mines was: for upper-surface mines – 0.14 ± 0.05 cm^2, lower surface mines – 0.29 ± 0.03 cm^2. The total area of mines on the compound leaves varied from 0.042 cm^2 to 1.073 cm^2.

The value of the relative area of the damaged leaf surface varied in the range from 0.38% to 8.30%, with an average value of 2.75 ± 0.31%. The data on damage indicate a relatively low level of harmfulness of this invasive phytophagous species.

A. obscura (Rohdendorf-Holmanová, 1959) is a locally abundant pest of Russian peashrub (*C. frutex*). The species is monophagous on *Caragana* spp. In Vitebsk it was recorded only on *C. frutex.* The larvae form blotch-like whitish mines on the upper side of the leaves, frass in black grains. There may be several mines per leaf. Pupation occurs outside the mine.

In the sample of *C. frutex* leaf laminae collected in 2020 the area of individual mines on a leaf varied from 0.01 cm^2 to 0.54 cm^2. The average area of individual mines was 0.21 ± 0.02 cm^2. The total area of mines on a compound leaf blade varied from 0.06 cm^2 to 1.12 cm^2. The values of the relative area of the damaged leaf surface were in the range from 0.41% to 11.00%; according to the data in Table 1, the average value was 3.44 ± 0.39%.

Table 1

The parameters characterizing damage caused to leaf laminae of Siberian peashrub (*Caragana arborescens* Lam., 1785) and Russian peashrub (*Caragana frutex* (L.) K. Koch) by larvae of miner flies *Aulagromyza caraganae* Rohdendorf-Holmanová (1959) and *Amauromyza obscura* (Rohdendorf-Holmanová, 1959) in urban green spaces of the city of Vitebsk

Mines (of)	The area of individual mines, cm^2		The total area of leaf mines, cm^2	The relative area of the damaged leaf surface, %
	upper-surface mines	lower surface mines		
A. caraganae Rohdendorf-Holmanová (1959) on *C. arborescens* Lam., 1785	0.14 ± 0.05	0.29 ± 0.03	0.39 ± 0.23	2.75 ± 0.31
A.obscura (Rohdendorf-Holmanová, 1959) on *C. frutex* (L.) K. Koch.	0.21 ± 0.02	–	0.29 ± 0.03	3.44 ± 0.39

***Cornus* L.**

Siberian dogwood (*Cornus alba* L.) and bloodtwig dogwood (*Cornus sanguinea* (L.) Opiz) are widely represented in urban green spaces. *C. sanguinea* is a single native species of the genus *Cornus* L. in the flora of Belarus, and is planted in green areas less frequently than the other one.

Phytomyza agromyzina Meigen, 1830 is a widely distributed in Belarus species of mining flies. The species known as narrow oligophagous, larvae damage dogwoods.

The larvae feed in long, unbranched, serpentine galleries on the upper side of dogwood leaves. The mines containe a broad row of brown frass. Pupation occurs usually externally. On a leaf blade (especially small-sized) several *Ph. agromyzina* mines often merge and create a communal (joint) mine with indistinguishable boundaries.

The obtained data (Table 2) show that the total area of *Ph. agromyzina* leaf mines on the leaf laminae of *C. alba* and *C. sanguinea* varied in the range from 0.23 см^2 to 3.67 cm^2.

Table 2

The area of leaf laminae and the parameters characterizing damage caused to leaf laminae of Siberian dogwood (*Cornus alba* L.) and bloodtwig dogwood (*Cornus sanguinea* (L.) Opiz) by larvae of miner fly *Phytomyza agromyzina* Meigen, 1830 in urban green spaces of the city of Vitebsk

Plant	Year	The area of leaf laminae, cm^2	The area of individual mines, cm^2	The total area of leaf mines, cm^2	The relative area of the damaged leaf surface, %
Cornus alba L.	2017	16.99 ± 1.99	1.80 ± 0.09	1.87 ± 0.11	16.98 ± 2.04
	2018	17.41 ± 2.54	1.73 ± 0.13	2.02 ± 0.18	18.12 ± 4.82
	2020	20.38 ± 2.78	1.68 ± 0.12	1.68 ± 0.12	10.07 ± 1.54
Cornus sanguinea L.	2017	24.12 ± 3.31	1.41 ± 0.13	1.41 ± 0.13	7.39 ± 2.03

The differences in the area of individual mines and the total area of *Ph. agromyzina* mines on leaf laminae of *C. alba* and *C. sanguinea* was not statistically significant (P>0.05, Mann–Whitney U-test and Kolmogorov–Smirnov test). But due to the significant differences in the values of the area of *C. alba* and *C. sanguinea* leaf laminae (P=0.037, Mann–Whitney U-test; P=0.021, Kolmogorov–Smirnov test), the differences in the relative area of their damaged leaf surface were also statistically significant (P=0.021, Mann–Whitney U-test; P=0.015, Kolmogorov–Smirnov test).

***Lonicera* L. and *Symphoricarpos* Duhamel**

In Belarus, 2 species of plants from the family Caprifoliaceae Juss. are widely used in green areas: Tatarian honeysuckle (*Lonicera tatarica* L.) and common snowberry (*Symphoricarpos albus* (L.) S.F. Blake). The third species, fly honeysuckle (*Lonicera xylosteum* L.), is common in parks which are former forests, and also in recreational forests.

Two species of mining flies were recorded in Vitebsk during growing seasons of 2017 and 2018: *Aulagromyza cornigera* (Griffiths, 1973) and *Aulagromyza luteoscutellata* (de Meijere, 1924).

A. cornigera larvae occur in spring (April – May) with one generation annually. The larvae form upper-surface, gradually widening gallery that runs along the leaf margin. Pupation takes place externally. There may be several mines per leaf (in the processed samples – 1–4, but most often only a single mine).

In the sample of *L. tatarica* leaf blades collected in 2017 the area of individual mines of *A. cornigera* on a leaf varied from 0.21 cm^2 to 1.18 cm^2. The average area of individual mines was 0.54 ± 0.03 cm^2. The total area of mines on the leaf blades varied from 0.21 cm^2 to 1.40 cm^2. The values of the relative area of the

damaged leaf surface were in the range from 0.68% to 17.17%; according to the data in Table 3, the average value was 4.5 ± 0.01%.

In the sample of *L. tatarica* leaf laminae collected in 2018 the area of individual mines (in the present case, coinciding with the total area of mines on the leaf) of *A. cornigera* on a leaf varied from 0.34 cm^2 to 0.90 cm^2. The average area of individual mines (and their total area) was 0.54 ± 0.05 cm^2. The values of the relative area of the damaged leaf surface were in the range from 1.30% to 11.22%; according to the data in Table 3, the average value was 3.36 ± 0.81%.

Mann–Whitney U-test showed no statistically significant differences (P>0.05) in *L. tatarica* leaf laminae area, in the area of *A. cornigera* individual mines, in the total area of leaf mines and in the relative area of the damaged leaf surface between the samples collected in 2017 and 2018.

In the sample of fly honeysuckle (*L. xylosteum*) leaf blades collected in 2017 the area of individual mines (in the present case, coinciding with the total area of mines on the leaf) of *A. cornigera* on a leaf varied from 0.24 cm^2 to 0.84 cm^2. The average area of individual mines (and their total area) was 0.69 ± 0.11 cm^2. The values of the relative area of the damaged leaf surface were in the range from 1.64% to 27.90%; according to the data in the table 3, the average value was 11.70 ± 4.56%.

In the sample of fly honeysuckle (*L. xylosteum*) leaf blades collected in 2018 the area of individual mines of *A. cornigera* on a leaf varied from 0.02 cm^2 to 1.83 cm^2. The average area of individual mines was 0.60 ± 0.11 cm^2. The total area of mines on a leaf blade varied from 0.11 cm^2 to 3.63 cm^2. The values of the relative area of the damaged leaf surface were in the range from 1.29% to 24.99%; according to the data in Table 3, the average value was 7.33 ± 1.87%.

In the sample of common snowberry (*S. albus*) leaf blades collected in 2017–2018 the area of individual mines (in the present case, coinciding with the total area of mines on the leaf) of *A. cornigera* on a leaf varied from 0.19 cm^2 to 0.63 cm^2. The average area of individual mines (and their total area) was 0.42 ± 0.06 cm^2. The values of the index of the relative area of the damaged leaf surface were in the range from 2.49% to 15.96%; according to the data in Table 3, the average value was 9.03 ± 2.06%.

Table 3

The parameters characterizing damage caused to leaf laminae of *Lonicera tatarica* L., *Lonicera xylosteum* L. and *Symphoricarpos albus* (L.) S.F. Blake by larvae of miner fly *Aulagromyza cornigera* (Griffiths, 1973) in urban green spaces of the city of Vitebsk

Plant	Year	The area of leaf laminae, cm^2	The area of individual mines, cm^2	The total area of leaf mines, cm^2	The relative area of the damaged leaf surface, %
Lonicera tatarica L.	2017	19.49 ± 1.91	0.54 ± 0.03	0.59 ± 0.04	4.5 ± 0.01
	2018	21.02 ± 2.45	0.54 ± 0.05	0.54 ± 0.05	3.36 ± 0.81
Lonicera xylosteum L.	2017	9.25 ± 2.32	0.69 ± 0.11	0.69 ± 0.11	11.70 ± 4.56
	2018	12.39 ± 1.00	0.60 ± 0.11	0.95 ± 0.27	7.33 ± 1.87
Symphoricarpos albus (L.) S.F. Blake	2017–2018	5.75 ± 0.98	0.42 ± 0.06	0.42 ± 0.06	9.03 ± 2.06

A. luteoscutellata (de Meijere, 1924) mines are formed on the upper surface of leaves, not associated with the leaf margin. Frass in a broad green central line with black grains. Pupation occurs outside the larval mine.

In the sample of Tatarian honeysuckle (*L. tatarica*) leaf blades collected in 2017 the area of individual mines on a leaf varied from 0.09 cm^2 to 1.33 cm^2. The average area of individual mines was 0.45 ± 0.03 cm^2. The total area of mines on a leaf blade varied from 0.10 cm^2 to 1.33 cm^2. The values of the relative area of the damaged leaf surface were in the range from 0.67% to 5.39%; according to the data in Table 4, the average value was 2.410 ± 0.002%.

Table 4

The parameters characterizing damage caused to leaf laminae of *Lonicera tatarica* L. and *Lonicera xylosteum* L. by larvae of miner fly *Aulagromyza luteoscutellata* (de Meijere, 1924) in urban green spaces of the city of Vitebsk

Plant	Year	The area of leaf laminae, cm^2	The area of individual mines, cm^2	The total area of leaf mines, cm^2	The relative area of the damaged leaf surface, %
Lonicera tatarica L.	2017	23.73 ± 1.75	0.45 ± 0.03	0.52 ± 0.04	2.41 ± 0.002
	2018	23.65 ± 2.87	0.54 ± 0.03	0.61 ± 0.06	4.13 ± 1.46
Lonicera xylosteum L.	2017	11.28 ± 2.54	0.60 ± 0.18	0.60 ± 0.18	7.43 ± 3.17
	2018	14.08 ± 2.10	0.93 ± 0.15	1.61 ± 0.29	14.24 ± 2.38

In the sample of Tatarian honeysuckle (*L. tatarica*) leaf blades collected in 2018 the area of individual mines of *A. luteoscutellata* on a leaf varied from 0.33 cm^2 to 0.76 cm^2. The average area of individual mines was 0.54 ± 0.03 cm^2. The total area of mines on a leaf blade varied from 0.33 cm^2 to 1.20 cm^2. The values of the relative area of the damaged leaf surface were in the range from 1.18% to 24.01%; according to the data in Table 4, the average value was 4.13 ± 1.46%.

The area of *A. luteoscutellata* individual mines on *L. tatarica* leaf laminae in 2017 and 2018 showed statistically significant difference (P=0.028, Mann–Whitney U-test; P=0.023, Kolmogorov–Smirnov test. But the differences between 2017 and 2018 for other considered parameters were not statistically significant (P>0.05).

In the sample of fly honeysuckle (*L. xylosteum*) leaf blades collected in 2017 the area of individual mines (in the present case, coinciding with the total area of mines on the leaf) of *A. cornigera* on a leaf varied from 0.15 cm^2 to 0.89 cm^2. The average area of individual mines (and their total area) was 0.60 ± 0.18 cm^2. The values of the relative area of the damaged leaf surface were in the range from 0.94% to 13.10%; according to the data in Table 4, the average value was 7.43 ± 3.17%.

In the sample of fly honeysuckle (*L. xylosteum*) leaf blades collected in 2018 the area of individual mines varied from 0.04 cm^2 to 3.25 cm^2. The average area of individual mines was 0.93 ± 0.15 cm^2. The total area of mines on a leaf blade varied from 0.58 cm^2 to 4.01 cm^2. The values of the relative area of the damaged leaf surface were in the range from 4.10% to 37.48 %; according to the data in Table 4, the average value was 14.24 ± 2.38%.

Despite the fact that in 2017 the difference in area of individual leaf laminae of *L. tatarica* and *L. xylosteum* were statistically significant (P=0.022, Mann–Whitney U-test; P=0.036, Kolmogorov–Smirnov test), the differences in relative areas of the damaged leaf surface, as well as the values of other considered parameters were not statistically significant (P>0.05).

***Populus* L.**

Common aspen (*Populus tremula* L.) and black poplar (*Populus nigra* L.) are among the most common deciduous tree species in Belarus. Two species of Agromyzidae, *Aulagromyza populi* (Kaltenbach, 1864) and *Aulagromyza tremulae* (Hering, 1955), were recorded for Vitebsk during our investigation.

The larvae of *A. tremulae* form yellowish irregular gallery always on the lower side of the leaves. Fully grown larvae pupate externally on the ground. Mines with dark discrete patches of frass. The larva leaving behind a characteristic unusual semi-circular exit hole in lower epidermis. The species is narrow oligophagous, larvae feed on *Populus* spp.

In the sample of *P. tremula* leaf laminae collected in 2018, we observed only a single mine of *A. tremulae* per leaf. The area of individual mines (in the present case, coinciding with the total area of mines) on a leaf varied from 0.23 cm^2 to 2.20 cm^2. The average area of individual mines (and their total

area) was 1.26 ± 0.14 cm^2. The values of the relative area of the damaged leaf surface were in the range from 0.76% to 25.66%, the average value was 10.94 ± 2.02%.

In the collected samples of *P. tremula* (2018), only a few specimens of *A. populi* were found, the sample size was insufficient for analysis.

A. populi is a narrow oligophagous species, larvae feed on *Populus* spp. The mines are yellowish-white, irregular, linear with frass scattered on both sides of the corridor; usually (but not always) begin on the upper surface of leaves. Pupation takes place in the mine, that allows to distinguish this species from *A. tremulae*. There were a single mine per leaf blade in the processed samples.

In the processed sample of *P. nigra* leaves, collected in 2017, only *A. populi* was found. There were 1–2 mines on leaf blades (usually one per leaf). The area of upper-surface individual mines varied in the range of 0.07 cm^2 to 1.42 cm^2; and for lower surface mines – varied in the range of 0.18 cm^2 до 2.81 cm^2. The total area of upper-surface individual leaf mines was 0.51 ± 0.07 cm^2; the total area of lower surface individual leaf mines was 0.60 ± 0.09 cm^2. The total area of leaf mines was between 0.18 cm^2 and 2.81 cm^2. The values of the relative area of the damaged leaf surface were in the range from 0.74 % to 25.30%, according to the data in Table 5, the average value was 4.12 ± 0.69%.

Table 5

The parameters characterizing damage caused to leaf laminae of black poplar (*Populus nigra* L.) by larvae of miner fly *Aulagromyza populi* (Kaltenbach, 1864) in urban green spaces of the city of Vitebsk

Year	The area of leaf laminae, cm^2	The area of individual mines, cm^2		The total area of leaf mines, cm^2	The relative area of the damaged leaf surface, %
		upper-surface mines	lower surface mines		
2017	27.80 ± 1.90	0.51 ± 0.07	0.60 ± 0.09	0.95 ± 0.1	4.12 ± 0.69
2018	18.49 ± 1.76	1.03 ± 0.28	0.74 ± 0.09	1.35 ± 0.23	11.20 ± 2.58

In the processed sample of *P. nigra* leaves, collected in 2018, only *A. populi* was found. There were 1–2 mines on leaf blades (usually a single per leaf). The area of upper-surface individual mines varied in the range of 0.29 cm^2 to 5.42 cm^2; and for lower surface mines – varied in the range of 0.09 cm^2 to 2.16 cm^2. The total area of upper-surface individual leaf mines was 1.03 ± 0.28 cm^2; the total area of lower surface individual leaf mines was 0.74 ± 0.09 cm^2. The total area of leaf mines was between 0.35 cm^2 and 7.09 cm^2. The values of the index of the relative area of the damaged leaf surface were in the range from 1.17% to 59. 85%, according to the data in Table 5, the average value was 11.20 ± 2.58%.

The differences in area between upper- and lower-surface mines was not found to be statistically significant (P>0.05) in 2017 and 2018, and in general during this period. Meanwhile, in 2017 and 2018 the difference in area of individual upper-surface mines was statistically significant (P=0.006, Mann–Whitney U-test; P=0.045, Kolmogorov–Smirnov test).

The statistically significant differences in area of individual leaf laminae in 2017 and 2018 were also found (P=0.002, Mann–Whitney U-test; P=0.018, Kolmogorov–Smirnov test), that determined meaningful differences in relative area of the damaged leaf surface.

***Spiraea* L.**

Most of *Spiraea* species in urban plantings are cultivars of Japanese spirea (*Spiraea japonica* L.f.). This species distinguished by the greatest variety of forms and high esthetic value [12].

Agromyza spiraeoidearum Hering, 1954 is the oligophagous species, larvae feed on *Aruncus* L. and *Spiraea* L. [5]. The mines occur on the upper side of the leaves, they relatively broad, gradually widening

into expansive blotch. Frass in granules, progressively increasing in size. Pupation occurs externally. Individuals of *A. spiraeoidearum* overwinter as pupae within puparia. After fusion of several mines, the final mine is often communal (joint mine).

In the sample of *S. japonica* leaf blades collected in 2017–2018 the area of individual mines (coinciding with the total area of mines) of *A*. *spiraeoidearum* on a leaf varied from 0.08 cm^2 to 2.15 cm^2. The average area of individual mines (and the total area) was 1.32 ± 0.15 cm^2. The values of the index of the relative area of the damaged leaf surface were in the range from 0.63% to 77.08%; the average value was 23.70 ± 4.47%.

***Sambucus* L.**

Larvae of *Liriomyza amoena* (Meigen, 1830) damage elders (*Sambucus* L.)*,* but the size of the sample was insufficient for further quantitative analysis. The mine starts as a narrow gallery, then widens into a substantial blotch, usually with conspicuous feeding lines. Pupation takes place externally. The species is monophagous on *Sambucus* [5].

Conclusion. In 2017–2020 10 species of mining flies (Insecta: Diptera: Agromyzidae) have been registered in green areas of Vitebsk (Belarus) as pests of decorative trees and shrubs. Among them *Agromyza alnibetulae* Hendel, 1931 on *Betula pendula* Roth and *Betula pubescens* (Ehrh.); *Aulagromyza caraganae* Rohdendorf-Holmanová (1959) and *Amauromyza obscura* (Rohdendorf-Holmanová, 1959) on *Caragana* spp.; *Phytomyza agromyzina* Meigen, 1830 on *Cornus alba* L. and *Cornus sanguinea* (L.); *Aulagromyza cornigera* (Griffiths, 1973) and *Aulagromyza luteoscutellata* (de Meijere, 1924) on *Lonicera tatarica* L., *Symphoricarpos albus* (L.) S.F. Blake and *Lonicera xylosteum* L.; *Aulagromyza populi* (Kaltenbach, 1864) and *Aulagromyza tremulae* on *Populus tremula* L. and *Populus nigra* L.; *Agromyza spiraeoidearum* Hering, 1954 on *Spiraea japonica* L.f. and *Liriomyza amoena* (Meigen, 1830) on *Sambucus* L.

Mines of larvae of *A. alnibetulae*, *A. obscura, Ph. agromyzina A. cornigera*, *A. luteoscutellata, A*. *spiraeoidearum,* and *L. amoena* are upper-surface, larvae of *A. tremulae* are lower surface, mines of larvae of *A. caraganae* and *A. populi* have been registered on both sides of leaf blades. For the majority of mining fly species a single mine per leaf is a characteristic feature, but larvae of *Ph. agromyzina* and *A*. *spiraeoidearum* can create communal mines, two species, *A. obscura* and *A. caraganae*, often create several mines on a leaf.

A. cornigera belongs to the spring/summer phenological group of phyllobionts. The larvae of the rest Agromyzidae damage woody plants mainly in summer/autumn period.

Estimated square of a single Agromyzid mine ranged from 0.005 cm^2 to 5.42 cm^2. In 2017 and 2018 the squares of *P. nigra* leaf blades had statistically significant differences (P=0.002, Mann–Whitney U-test; P=0.018; Kolmogorov–Smirnov test), but the differences in the areas of individual mines of *A. populi* were not found to be statistically significant (P>0.05).

On the basis of the analysis of the *P. nigra* leaf laminae the absence of interannual differences in the areas of individual mines was determined while there were statistically significant differences between the squares of *P. nigra* leaf laminae.

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