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CROWN DEFOLIATION OF *TILIA CORDATA MILL*. AS AN INDICATOR OF AIR POLLUTION LEVELS IN LANDSCAPE GARDEN AREAS WITHIN CITY ENVIRONMENT

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The article highlights aspects of dendroindication for nitrogen dioxide and sulfur pollution of surface air layers in the gardening landscape layout of the M.M. Gryshko National Botanic Garden, NAS Ukraine. There is a number of reasons to involve *Tilia cordata Mill.* as a dendroindicator of air pollution for the research in such conditions. Tree crown defoliation of *Tilia cordata* is an important sign to indicate the presence of atmospheric pollutants (sulfur dioxide and nitrogen) in concentration above 2.5 MPC. The results presented in the article explain the dependence of the pollutants gradation of spreading and the specifics of chosen dendroindicator defoliation within the studied gardening landscape area during 2007–2010. The study used *Tilia cordata* species within Boyarsky forestry as control subjects. The heterogenity of air pollution influence on the gardening landscape is explained. The data on fluctuating levels of dendroindicator defoliation are presented with reference to the levels of technogenic pollution stated during the period of research.

Keywords: *Tilia cordata*, dendroindicator, defoliation, sulfur dioxide, nitrogen dioxide.

INTRODUCTION

Contamination of the surface layers of air affects the formation of gardening landscape complexes and the stability of phytocenosis cultures in urban systems. Interest for phyto-ecological research as a part of comprehensive city monitoring is increasing from year to year. The search for informative dendroindicators of man-made pollution is one of the key tasks of phyto-monitoring. It provides a detailed preliminary analysis of the environmental conditions affected by industrial complexes and other sources of pollution in the area of study. The choice of monitoring methods depends on the particular characteristics of the studied subject.

The choice of methods for assessing the impact of pollutants on vegetation in our study was motivated by the fact that vegetation in landscapes of the M.M. Gryshko National Botanic Garden (NBG) is mainly represented by the species that are virtually ab-

sent from the natural population; changes in these species, caused by anthropogenic impacts, can mask themselves for introduction adaptation.

Tilia cordata is evenly spread throughout the territory of the NBG. The species are typical for these climatic conditions; they have been growing in the area in sufficient quantities for a long period of time. According to the summary indicator of pollution accumulational and morphometric settings changed under influence of pollutants, which caused discoloration, necrosis of leaf plates, crown defoliation, *Tilia cordata* is very sensitive to the effects of sulfur dioxide and nitrogen oxides, formaldehyde and exhaust fumes, and less sensitive to hydrogen sulfide [1, 4, 7, 10].

The purpose of the research was to determine the intensity of the local technology impact on the vegetation of the gardening landscape area featuring *Tilia cordata*. The characteristics of the climat conditions, technological factors affecting the stability of the phytocenosis cultures, distance from urban points of regular city observation as well as the NBG status of the national nature reserve are considered in the research process.

MATERIALS AND METHODS OF THE RESEARCH

Tilia cordata species growing in "relatively clean" zone (Boyarka, Kyiv region) were selected as control testing subjects. The comparison with the control species makes it possible to eliminate the impact of adverse weather and climatic conditions (drought, uneven rainfall, high degree temperature etc.), adverse soil factors that may affect indicator species in a similar way to the effects of pollutants. These dendroindicators show no reaction as well as reaction to the impact of pollutants and other environmental factors, both of anthropogenic and non-anthropogenic origin, but they indicate a clear distress manifestation to the man-made technological pollution by aforementioned substances. Soil conditions in the urban ecosystem and rainfall volume do not have any significant impact on growth and vitality of *Tilia cordata* [1, 10]. Dark gray soils that are the most common on the NBG territory may have nitrogen, phosphorus and potassium deficiency, therefore the differentiation of the leaf plate necrosis caused by shortage of soil nutrition elements was conducted in accordance with the reference book by V. Bergman [2].

The calculation of ground-level concentration of pollutants in the atmosphere caused by industrial objects and motor vehicle traffic was carried out using an automated system for calculating atmospheric pollution "OND-86 Calculator" (version 1.0). Calculation of dispersion of pollutants in the air was conducted considering meteorological characteristics of the area and various factors that determine the conditions for dispersion of pollutants in the atmosphere [5, 6, 8]. Air pollution from mobile sources was determined by counting different types of vehicles. The measurements were taken over 10 days on a quarterly basis, at 8 a.m., 1 p.m. and 6 p.m. The program automatically builds the mapping of fields of contaminant dispersion using the MPC value contours that trace from the source of contamination to the object of investigation and throughout its territory.

To determine the level of contamination of surface layers of air, the secondary standards were used in calculations (for Nature reserve objects the MPC units for vegetation were used) [12].

The 74-component monitoring network was set up on the grounds of the NBG. The coordinate steps of the monitoring network were determined by the industrial emissions danger class: 1st and 2nd classes – 250 m, 3rd – 100 m, 4th – 50 m, 5th – 25 m [9].

The research was carried out by visual assessment in early September 2007–2010. The degree of crown defoliation was evaluated as a percentage of the total volume of the tree crown. Localization of focus and specifics of spreading of defoliation in crown as well as quantitative indicators were taken into consideration according to latest European techniques [3].

Correlation and regression analysis was carried out.

RESULTS AND DISCUSSION

Among local sources of air pollution for the NBG area in 2007–2010 significant was emission from industrial area "Budindustriya" (including "Teploelektrotcentral-5" (TEC-5)) and exhaust fumes from the nearby traffic roads. The main industrial enterprises that affect the territory of the Botanical Garden are: TEC-5, woodwork factory "Avers", "Asphalt" factory. They are situated within a distance of 500–1600 meters from the Botanical Garden borders. The territorial proximity to the Dnipro river is of a great importance among the micro-climatic characteristics of the NBG that add to the level of air pollution. It conduces to the increase in humidity and fog volume.

The climatic factors affecting the level of air pollution were analyzed (such as repeatability of surface and upraised inversions, calm, prevailing winds from the sources of pollution). Prevalence of southern and southeastern wind was important in shaping the areas of atmospheric pollution (their frequency ranged from 27–32 % per year). Repeatability of surface inversions in 2007–2008 was 21–28 %, and in 2009–2010 it raised to 48 %. The most fog was observed in 2008.

According to the calculations, the concentration of pollutants that affect the process of defoliation of *Tilia cordata* were: sulfur dioxide – 0.2–4.6 MPC (MPC – maximum permissible concentration), nitrogen dioxide – 0.5–4.5 MPC. Distribution of pollutants over the NBS studied territory depended on the weather conditions of the area, the volume of total emissions of industrial companies, the traffic intensity of surrounding roads. The southern part of the botanical garden and the slope over Naddnipryansky Highway were contaminated the most.

Since nitrogen dioxide and sulfur have the effect of summation and operate one-way, the total performance marks were calculated for them [11].Crown defoliation of the dendroindicator emerged in conditions of pollution substance concentrations in air scoring higher than 2.5 MPC. The impact of lower concentrations of pollutants could be recognized through studying other morphobiometric settings of *Tilia cordata* discoloration, necrosis, fluctuating asymmetry of the leaf plates that changed as a result.

Distance from the source of contamination and relief features determine the localization of crown defoliation .In 2007–2010 the combination of both apical and peripheral types of crown defoliation found on a single individual of *Tilia cordata* prevailed among the studied species of dendroindicators. Exclusively peripheral type of crown defoliation was observed in 2007, 2008 and 2010 at monitoring points in Bastionna Str. Exclusively apical type of defoliation was found in such areas of the NBG as "Altai and Western Siberia", "Tatarian Maple Grove", "Caucasus" (Table 1). This phenomenon is related to the placement of pollution sources and ways of pollutant spread over areas "Altai and Western Siberia", "Tatarian maple grove" and „Caucasus" (altitude difference of about 100 m). Therefore, in these areas the apical crown defoliation type prevailed. The monitoring spot at Bastionna Str. showed the peripheral defoliation prevalence as a result of the air pollution caused by heavy traffic exhaust fumes.

Table 1. **The degree and type of crown defoliation of *Tilia cordata* at monitoring observation points in 2007–2010**

Таблиця 1. **Ступінь і тип дефоліації крони *Tilia cordata* у точках моніторингових спостережень у 2007–2010 рр.**

Point of monitoring observation	Defoliation Type				Damage of crown (mean,% M±m)			
	2007	2008	2009	2010	2007	2008	2009	2010
1 BS–2 BS	P	P	A P	P	27±1.35	23±1.15	50±2.5	30±1.5
1–3 AWS	A	A	A P	A	33±1.65	27±1.35	58±2.9	35±1.75
1–2 SNH	A P	A P	A P	A P	61±3.05	58±2.9	65±3.25	65±3.25
1–3 TMG	A	A	A P	A	19±0.95	25±1.25	52±2.6	20±1.0
1 CA–4 CA	A	A	A P	A	23±1.15	21±1.05	47±2.35	20±1.0
1 CR–6 CR	A P	A P	A P	A P	34±1.7	44±2.2	55±2.75	45±2.25

Comments: Types of defoliation: P – peripheral; A – apical;1 CA–4 CA geo-botanical area “Caucasus”; 1 AWS–3 AWS geo-botanical area “Altai and Western Siberia”; 1 TMG–3 TMG geo-botanical area “Tatarian Maple Grove”; 1 SNH–4 SNH slope to Naddnipryansky Highway; 1 CR–6 CR geo-botanical area “Crimea”; 1 BS–2 BS research area on the Bastionna Street, next to the main entrance to the NBG.

Примітки: Тип дефоліації: Р – периферійний; А – верхівковий; 1 СА–4 СА ботаніко-географічна ділянка “Кавказ”; 1 AWS–3 AWS ботаніко-географічна ділянка “Алтай та Західний Сибір”; 1 TMG–3 TMG ботаніко-географічна ділянка “Пакленова діброва”; 1 SNH–4 SNH схил до Наддніпрянського шосе; 1 CR–6 CR ботаніко-географічна ділянка “Крим”; 1 BS–2 BS дослідна ділянка на вул. Бастіонна, біля центрального входу в ботанічний сад.

According to the assessment scale of the International Union of Forest Research Organizations when defoliation in a population reaches above 60 %, the type is considered severely damaged. Nearly 60 % of defoliation in *Tilia cordata* at the NBG is caused by the total pollution of the surface layers of air with the nitrogen dioxide and sulfur scores of 5 MPC and above.

A wide range of pollution levels at the Botanical Garden is present due to the fact that formation of the dispersion fields was happening over an uneven terrain and under different weather conditions.

The Botanical Garden is located over the low-rise Pechersk slopes of the Kiev plateau in the Zvirynets tract. The NBG territory is cut up by steep banks, gorges and valleys, giving the area a significant branching. Highest altitude points within the NBG are at 190–198 m above sea level, the lowest ones are at 89–92 m. The relative excess in altitude is 101–106 m above sea level. The process of linear erosion development is contributed by a significant surface dissection and an almost 100-meter layer of rock formation that is easily eroded. The calculations use daily average MPC for nitrogen dioxide and sulfur which are 0.02 mg/m^3. During the period of study pollution levels in the research areas varied within the following limits: BS - from 1.4 to 4.1 MPC; AWS 1.3 – 5; SNH 5 – 8.3; TMG 1.3 – 5; CA 1.4 – 5; CR 1.6 – 5,3 (Table 2).

In 2009, the level of defoliation of the dendroindicator was caused by increased levels of aero-technogenic air pollution by sulfur dioxide and nitrogen (because of replacement of natural gas using fuel oil as an alternative fuel), which covered larger areas of the NBG. This condition affected the level and type of defoliation of *Tilia cordata* in

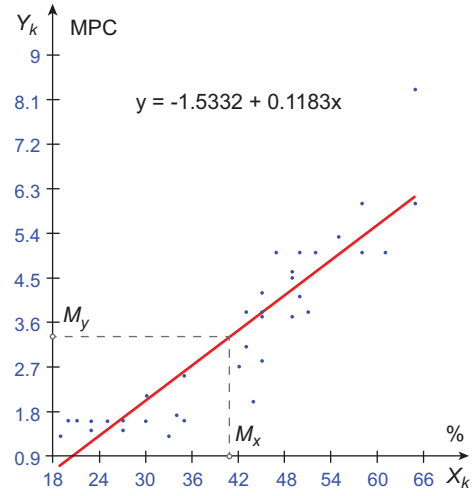
other sections of the NBG, such as Beech and Linden Alleys, Forest plains of Ukraine, Ukrainian Carpathians, Caucasus.

Table 2. **Levels of atmospheric pollution at monitoring observation points in 2007–2010**

Таблиця 2. **Рівні атмосферного забруднення у точках моніторингових спостережень у 2007–2010 рр.**

Point of monitoring observation	Level of atmospheric pollution (MPC)			
	2007	2008	2009	2010
1 BS–2 BS	1.4	1.6	3.7–4.1	1.6
1–3 AWS	1.3	1.6	5.0	1.6
1–2 SNH	5.0	6.0	8.3	6.0
1–3 TMG	1.3	1.6	4.2–5.0	1.6
1 CA–4 CA	1.4	1.6	4.2–5.0	1.6
1 CR–6 CR	1.6–1.7	1.8–2.1	4.4–5.3	2.1–2.9

In 2007–2010, the average percentage of defoliation of *Tilia cordata* depended on the level of contamination of surface layers of air by sulfur dioxide and nitrogen. Calculated pollution scores were: 1.3–1.7 MPC, causing 26 % defoliation crowns respectively 1.8–2.1 MPC – 37 %; 2.2–3.2 MPC – 43 %; 3.3–4.2 MPC – 47 %; 4.3–5.0 MPC – 52 %; 5.1–6.0 MPC – 59 %; 8.3 MPC – 65 % (see Figure).



Dependence of crown defoliation of *Tilia cordata* on total content of nitrogen and sulfur dioxide in the surface layers of air at the NBG

Залежність дефоліації крони *Tilia cordata* від сумарного вмісту діоксидів азоту і сірки у приземних шарах атмосферного повітря НБС

We set the correlation coefficient between these factors (r = 0.9121) which confirms the close relationship between these parameters. This dependence is linear and is approximated by the equation **y = -1.5332 + 0.1183x** (Fig.), where "x" is the degree of defoliation (as a percentage) and "y" is the total concentration of pollutants (in the MPC). During the period of observation defoliation most clearly manifested itself in places of monitoring observations in such areas of the NBG as "Crimea", "Caucasus", "Tatarian

Maple Grove", "Altai and Western Siberia", the slopes to Naddnipryansky Highway and Bastionna Street. This indicative feature was not fixed in individual plants – this fact can be explained by diminished levels of pollution in some points of observation and certain individual resistance to these pollutants.

CONCLUSIONS

Among the studied gardening landscape areas of the NBG the southern part and the slopes to Naddnipryansky Highway appeared to be the most polluted.

The level of crown defoliation of *Tilia cordata* is a highly informative symptom for detecting high levels of air pollution by nitrogen dioxide and sulfur.

The levels of crown defoliation in dendroindicators within gardening landscape areas of the NBG ranged from 25 to 65 % depending on the pollution of surface layers of air by sulfur dioxide and nitrogen at 1–8 MPC. The linear relationship between the percentage of crown defoliation of *Tilia cordata* and the level of air pollution by sulfur dioxide and nitrogen was established.

During the research period, apical and peripheral types of crown defoliation of *Tilia cordata* on a single individual prevailed. Localization of crown defoliation on a dendroindicator is related to the allocation of pollution sources and transport pathways of pollutants. Combined types of crown defoliation of both apical and peripheral localization on one individual observed with the raise of the air pollution level.

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ДЕФОЛІАЦІЯ КРОНИ *TILIA CORDATA* MILL. ЯК ПОКАЗНИК РІВНЯ АТМОСФЕРНИХ ЗАБРУДНЕНЬ САДОВО-ПАРКОВИХ ЛАНДШАФТІВ В УМОВАХ МЕГАПОЛІСУ

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У статті висвітлено аспекти дендроіндикації забруднення приземних шарів атмосферного повітря садово-паркових ландшафтів Національного ботанічного саду ім. М.М. Гришка НАН України діоксидами азоту і сірки. Обґрунтовано мотивацію вибору *Tilia cordata* Mill. для індикації атмосферного забруднення за таких умов дослідження. Дефоліація крони *Tilia cordata* є вагомою ознакою для індикації атмосферних забруднень діоксидами сірки й азоту в концентраціях вище 2,5 ГДК. З'ясовано залежність градацій поширення полютантів і особливостей дефоліації обраного дендроіндикатора в межах досліджуваних садово-паркових ландшафтів упродовж 2007–2010 рр. Як контроль у дослідженні використані особини *Tilia cordata* Боярського лісництва. Описана неоднорідність впливу атмосферного забруднення на садово-паркові ландшафти. Наведено дані щодо коливань рівнів дефоліації дендроіндикатора залежно від рівня техногенного забруднення протягом періоду досліджень.

Ключові слова: *Tilia cordata,* дендроіндикація, дефоліація, діоксид сірки, діоксид азоту.

ДЕФОЛИАЦИЯ КРОНЫ *TILIA CORDATA* MILL. КАК ПОКАЗАТЕЛЬ УРОВНЯ АТМОСФЕРНЫХ ЗАГРЯЗНЕНИЙ САДОВО-ПАРКОВЫХ ЛАНДШАФТОВ В УСЛОВИЯХ МЕГАПОЛИСА

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В статье освещены особенности дендроиндикации загрязнения нижних слоев атмосферного воздуха садово-парковых ландшафтов Национального ботанического сада им. Н.Н. Гришко НАН Украины двуокисями азота и серы. Обоснована мотивация выбора *Tilia cordata* Mill. для индикации атмосферного загрязнения для данных условий исследования. Дефолиация кроны *Tilia cordata* является важным признаком для индикации атмосферных загрязнений двуокисей серы и азота в концентрациях выше 2,5 ПДК. Показана зависимость градаций распространения загрязнителей и особенностей дефолиации избранного дендроиндикатора в пре-

делах исследуемых садово-парковых ландшафтов на протяжении 2007–2010 гг. В качестве контроля в исследовании использованы особи *Tilia cordata* Боярского лесничества. Описана неоднородность влияния атмосферного загрязнения на садово-парковые ландшафты. Приведены данные по колебаниям уровней дефолиации дендроиндикатора в зависимости от уровня техногенного загрязнения в течение периода исследований.

Ключевые слова: *Tilia cordata*, дендроиндикация, дефолиация, двуокись серы, двуокись азота.

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