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# Ecological and biochemical peculiarities of maple genus in the urban environment (Case study: Norway and Ash-leaved maple)

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## ABSTRACT

The study demonstrates the results of ecological and biochemical studies of Norway maple and ash-leaved maple growing in a large industrial center. High activity of ascorbinate oxidase was recorded in June, and a low one in August. The content of ascorbic acid decreases during the growing season in anthropogenic plantations. Under an increased air content of pollutants, representatives of the maple genus show an increase in the activity of polyphenol oxidase in comparison with the control plantations. It should be said that the content of condensed tannins in the leaves decreases. In the roadside plantations of Norway maple, under the most intense load, in July, the peroxidase activity in the leaves is lower than in the conventional control plantations, and in August it is higher than in control.

**Keywords:** Ash-leaved maple (*Acer negundo* L.), Polyphenol oxidase, Ascorbinate oxidase, Ascorbic acid, Tannins, Urban plantings, Norway maple (*Acer platanoides* L.).

## INTRODUCTION

This survey, as mentioned, mainly focuses on the Ecological and Biochemical Peculiarities of Maple Genus in the Urban Environment and its impact on the environment with an emphasis on the role of antioxidant substances. As a matter of fact, the scientific literature has not fully demonstrated the role of antioxidant substances in plants growing under anthropogenic stress. These are the features of the interaction of enzymes and secondary metabolites involved in the formation of adaptive reactions of the plant organism (Bukharina *et al.* 2014; Kloseiko 2016; Xiaoqian *et al*. 2018; Gowda *et al.* 2018; Ekkal *et al*. 2020). Both domestic and foreign authors draw attention to the joint functioning of the non-enzymatic and enzymatic systems. Their separate elements are substances such as tannins and polyphenol oxidase, ascorbic acid and ascorbinate oxidase. Polyphenol oxidase in joining with phenolic substrates are included in the respiration process at the intermediate stages of hydrogen transfer. The authors provide data indicating an increase in the activity of polyphenol oxidase in damaged tissues. The enzyme ascorbinate oxidase is involved in the neutralization of reactive oxygen species, thereby preserving the plant organism and limiting oxidative stress (Maiti *et al.* 2016; Taïbiacd *et al.* 2016; Afanasyeva 2019; Nunes *et al*. 2019; Rahul *et al.* 2020). It is uncovered that A. rubrum displays the evasion technique as the fundamental component of adapting to soil metal amassing. Nonetheless, a more instructive and top to bottom examination of this system would be exceptionally useful in choosing whether it is carefully physiological or hereditary. The job of epigenetics can be additionally perceived by deciding the conveyance of DNA methylation in both *A. rubrum* and *P. tremuloides* (Kalubi 2018). As naturally dynamic in feedstuffs for mammalian nibblers and programs,

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fragrant plants have the right to be investigated in detail for the appraisal of expected damage (Cappai & Aboling 2020). Primarily assorted biopolymers, including extracellular polysaccharides (EPS), integrated by microscopic organisms can have physicochemical and useful properties that make them significant results of microbial blend with an expansive and adaptable biotechnological potential (Zikmanis *et al.* 2020).

Thus, the study of the antioxidant properties of the deciduous shrub *Cassia alata* L. has identified the features of the enzyme system, the photosynthetic apparatus in various conditions of the abiotic environment. Under abiotic stress, the activity of catalase, ascorbate peroxidase and glutathione reductase increases Jahanifar *et al.* 2018). Other studies have noted the role of antioxidant enzymes, proline, abscisic acid, phenols and ascorbic acid in poplar and green tea plants. A specific reaction of these individuals was revealed under stress conditions, which manifests itself in an increase in the activity of antioxidant enzymes and a decrease in the level of proline and abscisic acid (Chupakhina *et al.* 2012; Garcia *et al*. 2016; Zabihi *et al*. 2018). The objective of the work has been to reveal the ecological and biochemical characteristics of Norway maple, *Acer platanoides* L. and ash-leaved maple, *Acer negundo* L. in urban plantations.

## MATERIALS AND METHODS

The object of the study was analyzing and testing the peculiarities in Norway maple, *Acer platanoides* L. and ash-leaved maple, *Acer negundo* L., which grows in plantations of sanitary protection zones of factories (foundry and blacksmith) of the auto giant Kamaz PJSC, main plantations (Prospekt Mira, Kazansky prospect). The plantations of the Chelninsky forestry and the park zone of the city of Naberezhnye Chelny were chosen as the zone of conventional control. To that end, we laid three test plots in the study areas. Test plots were laid in a regular way, with different configurations based on the terrain. The size of the trial plot is minimum 0.25 ha. Further, the selection and numbering of the accounting plants was carried out (10 plants each, of which plants of a good average regenerative ontogenetic state were selected for biochemical studies). We assessed the degree of air pollution in places where woody plants grow. The assessment was carried out on the basis of the materials of the "Report on the Ecological State of the Republic of Tatarstan". Comprehensive Air Pollution Index 2013-2018 (API = 12.6) characterizes the state of air pollution in the city as very high (Natural Resources and Environmental Protection Organization, 2019). Within the trial plots for the study of biochemical indicators, at least 10 individuals were selected and numbered. In the summer months, samples of the median leaves on the annual vegetative shoot (from the lower third of the crown section of the southern exposure) were taken from the studied individuals. In the main plantings, a part of the crown of the southern exposure was directed directly to the roadway of the avenue. Leaves were taken on the same day in all types of plantations. Under laboratory conditions, the content of condensed tannins in the leaves of woody plants was determined by permanganatometry (Leventhal's method, modified by Kirsanov). The quantitative content of ascorbic acid was determined in accordance with GOST 24556-89. The activity of ascorbinate oxidase was determined based on the property of ascorbic acid to absorb light with a maximum at 265 nm. The activity of the enzyme was judged by the decrease in the optical density, given that the oxidation state of ascorbic acid is proportional to the amount of the enzyme. The activity of polyphenol oxidase was determined by a spectrophotometric method based on measuring the optical density of the reaction products that are formed during the oxidation of pyrocatechol over a certain period of time (Ermakov *et al.* 1987). Each studied plant was analyzed in triplicate. The content of ascorbic acid and tannins in the leaves was determined for 2015–2018, the activity of polyphenol oxidase and ascorbate oxidase during 2014 and 2015. The materials were processed using Statistica 10.0. Methods of descriptive statistics were used to analyze the data obtained.

## RESULTS AND DISCUSSION

Within the studied anthropogenic plantations, excess of the highest permissible concentration for nitrogen, benzo(a)pyrene, carbon oxides, formaldehyde, and phenols was found. In the plantings of the sanitary protection zone of industrial enterprises, the average annual excess of MPC was noted for the following substances: nitrogen oxides, formaldehyde, sulphur dioxide, phenol, carbon monoxide, as well as benzo(a)pyrene. In the zone of main plantations, the average annual excess of MPC was noted for the following substances: carbon monoxide; formaldehyde; phenol; benzo(a)pyrene.

We assessed the ecological and biochemical state of Norway maple and ash-leaved maple and its response to technogenic stress by the content of low-molecular and high-molecular substances in the leaves (Table 1). Both in the Norway maple and ash-leaved maple of various functional zones, the differences in the activity of ascorbinate

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oxidase in the leaves are insignificant during the entire growing season. Notable disagreements were noted in the increasing dynamics of ascorbinate oxidase activity from June to July in various types of plantations. The content of ascorbic acid in the leaves of the Norway maple and ash-leaved maple under the conditions of main plantings (160.1 and 60.5) and plantings of sanitary protection zones (115.8 and 30.8) in June was significantly higher than in the zone of conventional control. In July, Norway maple retained the same trend, while ash maple showed a lower content of ascorbic acid in its leaves. A remarkable rise in the ascorbic acid content in plant leaves has been observed in all the plantations under investigation.

**Table 1.** The content of ascorbic acid and the activity of ascorbinate oxidase in the leaves of ash-leaved maple and Norway maple in various types of plantations.

| Plantations types | Ascorbic acid oxidase activity, act.un. | | | Ascorbic acid, mg/% | | |
|---|---|---|---|---|---|---|
| | June | July | August | June | July | August |
| ***Acer platanoides* L.** | | | | | | |
| Conventional control zone | 2.44 ± 0.27 | 4.15 ± 0.06 | 3.82 ± 0.34 | 195.3 ± 8.7 | 164.1 ± 5.8 | 146.4 ± 2.1 |
| | 1.83-3.04 | 4.01-4.29 | 3.09-4.56 | 157.7-232.5 | 139.2-189.1 | 137.4-155.5 |
| Buffer zone | 2.58 ± 0.31 | 4.13 ± 0.20 | 3.90 ± 0.27 | 311.1 ± 16.4 | 207.4 ± 19.5 | 184. 9 ± 5.7 |
| | 1.90-3.28 | 3.68-4.58 | 3.31-4.49 | 240.4-381.9 | 123.3-291.4 | 160.4-209.5 |
| Roadside plantations | 3.18 ± 0.26 | 4.55 ± 0.24 | 3.96 ± 0.24 | 357.2 ± 19.1 | 186.1 ± 9.7 | 146.8 ±13.2 |
| | 2.61-3.76 | 4.01-5.09 | 3.43-4.50 | 275.2-439.1 | 144.4-227.7 | 90.1-203.5 |
| ***Acer negundo* L.** | | | | | | |
| Conventional control zone | 2.73 ± 0.36 | 4.28 ± 0.06 | 3.69 ± 0.30 | 318.4 ± 9.0 | 257.2 ± 6.1 | 177.1 ± 7.1 |
| | 1.93-3.52 | 4.15-4.41 | 3.04-4.34 | 305.3-331.4 | 241.5-272.9 | 158.9-195.3 |
| Buffer zone | 2.76 ± 0.36 | 4.47 ± 0.11 | 4.60 ± 0.08 | 349.2 ± 8.9 | 252.9 ± 9.3 | 185.4 ± 13.8 |
| | 1.96-3.56 | 4.23-4.71 | 4.42-4.77 | 336.3-372.2 | 229.0-276.8 | 149.9-220.9 |
| Roadside plantations | 3.25 ± 0.28 | 4.73 ± 0.20 | 4.62 ± 0.06 | 378.9 ± 10.9 | 203.7 ± 6.2 | 164.9 ± 6.3 |
| | 2.64-3.87 | 4.30-5.16 | 4.48-4.76 | 351.7-407.2 | 187.8-219.6 | 148.7-181.1 |

Note: Conventional control zone; Buffer zone plantations; Roadside plantations; mg% milligram percentage is a non-systemic unit of concentration measurement, i.e. the number of milligrams of ascorbic acid contained in 100 g of leaves.

Thus, we can conclude that for Norway maple and ash-leaved maple, an increase in ascorbinate oxidase activity in July and a decrease in August in all types of plantations are characteristic. Individuals growing in buffer zone plantations of industrial enterprises and in roadside plantations are characterized by a decrease in ascorbic acid throughout the entire period of active vegetation. In addition, we studied the features of the content of condensed tannins and the activity of polyphenol oxidase in the leaves of Norway maple in connection with the conditions of the place of growth. In roadside plantations of Norway maple plants during the entire growing season we noted a significantly lower content of condensed tannins in the leaves than in individuals in the control: in June - by 0.28; in July - by 1.24; in August - by 0.78 mg $g^{-1}$ dry matter (Table 2).

**Table 2.** The content of condensed tannins and the activity of polyphenol oxidase in the leaves of Norway maple in different types of plantations.

| Plantations types | Polyphenol oxidase activity, act.un. | | | Condensed tannins, mg/g DW | | |
|---|---|---|---|---|---|---|
| | June | July | August | June | July | August |
| ***Acer platanoides* L.** | | | | | | |
| Conventional control zone | 1.41 ± 0.06 | 3.59 ± 0.20 | 2.48 ± 0.08 | 4.46 ± 0.04 | 6.59 ± 0.11 | 8.10 ± 0.09 |
| | 1.28-1.53 | 3.15-4.03 | 2.30-2.66 | 4.30-4.62 | 6.11-7.07 | 7.70-8.50 |
| Buffer zone | 1.50 ± 0.05 | 3.96 ± 0.26 | 4.24 ± 0.16 | 4.86 ± 0.04 | 5.84 ± 0.08 | 7.16 ± 0.09 |
| | 1.39-1.61 | 3.39-4.53 | 3.88-4.61 | 4.66-5.06 | 5.51-6.17 | 6.79-7.53 |
| Roadside plantations | 1.85 ± 0.16 | 4.49 ± 0.27 | 4.84 ± 0.27 | 4.18 ± 0.01 | 5.35±0.03 | 7.34 ± 0.08 |
| | 1.50-2.20 | 3.89-5.09 | 4.69-4.99 | 4.12-4.24 | 5.20-5.50 | 6.98-7.69 |
| ***Acer negundo* L.** | | | | | | |
| Conventional control zone | 1.22 ± 0.09 | 3.86 ± 0.12 | 3.41 ± 0.19 | 3.95 ± 0.07 | 5.24 ± 0.06 | 7.19 ± 0.03 |
| | 0.97-1.42 | 3.57-4.12 | 2.92-3.88 | 3.78-4.13 | 5.27-5.40 | 7.11-7.27 |
| Buffer zone | 1.23 ± 0.08 | 4.27 ± 0.14 | 5.09 ± 0.12 | 3.84 ± 0.04 | 4.55±0.07 | 6.82 ± 0.06 |
| | 0.96-1.44 | 3.91-4.61 | 4.77-5.37 | 3.72-3.96 | 4.37-4.73 | 6.66-6.97 |
| Roadside plantations | 1.65 ± 0.19 | 4.71 ± 0.17 | 5.28 ± 0.15 | 3.68 ± 0.08 | 5.02 ± 0.08 | 6.58 ± 0.07 |
| | 1.18-2.11 | 4.27-5.14 | 4.91-5.63 | 3.48-3.87 | 4.82-5.22 | 6.39-6.76 |

The plants of ash-leaved maple had the same tendency in July and August in buffer zones and roadside plantations; the decrease in the content of this metabolite in leaves was in July - by 0.69 and 0.22; in August - by 0.37 and 0.61

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$g^{-1}$ dry matter, respectively. The plants of Norway maple from buffer zones of industrial enterprises had the higher content of the test substance by 0.40 mg $g^{-1}$ dry matter (June), and then lower by 0.75 and 0.94 mg $g^{-1}$ dry matter (respectively, in July and August). The resulting picture indicates the active use of condensed tannins and its involvement in the processes of plant adaptation to the conditions of anthropogenic pollution. By August, we noted a significant increase in the content of tannins in the leaves of Norway maple and ash-leaved maple in all areas of the study. As a result, the quantitative content of condensed tannins in the leaves of representatives of the genus maple increased over the entire observation period in all regions of the study.

Polyphenol oxidase is an enzyme involved in the synthesis of tannins.

We compared the index of polyphenol oxidase activity in leaves in plants growing in different types of plantations (Table 2). In the Norway maple in August, the ash-leaved maple in July and August in the buffer zone plantations of industrial enterprises and roadside plantations, the activity of this enzyme was significantly higher than in the control. The substantial variations were near the August under the conditions of the most intense technogenic load of main plantings. They reached 2.99 for Norway maple and 1.87 units of activity in ash-leaved maple. We also analyzed the dynamics of polyphenol oxidase activity in the leaves of Norway maple and ash-leaved maple in each type of plantation. In parks, we observed a significant increase in the enzyme activity in July, and then a significant decrease in August, and the enzyme activity indices, despite a significant decrease compared to July, were significantly higher than in June. The enzyme activity in the plants of industrial zones and in main plantations increased in July and further increased in August. Thus, the study of the activity of polyphenol oxidase in the leaves of Norway maple showed that in August the highest values of this indicator are observed both in plantations of buffer zones and in roadside plantings in comparison with parks.

## SUMMARY

1. The investigated low- and high-molecular substances are actively involved in adaptive reactions to the conditions of the technogenic environment in representatives of the *Acer* genus.
2. A species-specific feature was revealed in the activity of enzymes in individuals under conditions of technogenic stress. A decrease in the activity of ascorbinate oxidase and an increase in the activity of polyphenol oxidase are noted, while the content of ascorbic acid decreases by August, and the content of tannins increases.
3. The plants of Norway maple and ash-leaved maple experience a significant anthropogenic impact in the urban environment. But at the same time, compensatory mechanisms of adaptation are triggered at the biochemical level.

## CONCLUSION

Over the entire course of active vegetation, the representatives of the genus maple were characterized by a rise in the ascorbinate oxidase activity in leaves in plantations of various ecological categories. The minimum values of ascorbic acid were noted in August in the plants from plantations with intense technogenic load. Thus, an increase in the degree of technogenic load leads to an increase in the content of ascorbic acid in the leaves of Norway maple and ash-leaved maple at the beginning steps of the growing season (June) and its subsequent decrease at the end of the growing season (August).

As for the activity of polyphenol oxidase and the content of tannins in the leaves, in the plantations of buffer zones of industrial enterprises and roadside plantations, Norway maple and ash-leaved maple were distinguished by an increase in the activity of polyphenol oxidase, compared with control plantations. A decrease follows an increase in the activity of polyphenol oxidase in the content of tannins, which undoubtedly indicates the active participation of tannins in the adaptive reactions of plants associated with the mechanisms of neutralizing the action of pollutants.

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# ویژگی‌های بوم شناختی و بیوشیمیایی جنس افرا در محیط شهری (مطالعه‌ی موردی: افرای نروژی و مانیتوبایی)

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**چکیده**

این مطالعه، نتایج مطالعات بوم شناختی و بیوشیمیایی افرای نروژی و مانیتوبایی که در مرکز صنعتی بزرگ رشد می‌کند، را نشان می‌دهد. فعالیت بالای آسکوربینات اکسیداز در ماه ژوئن و فعالیت پایین آن در ماه آگوست ثبت شد. مقدار اسید اسکوربیک در طی فصل رشد در نهالستان‌های مصنوعی (کشت‌شده توسط انسان) کاهش می‌یابد. تحت افزایش مقدار آلاینده‌های هوا، جنس‌های افرا، افزایش فعالیت پلی فنول در مقایسه با آلاینده‌های شاهد را نشان می‌دهند. لازم به ذکر است که محتوای تانن در برگ‌ها کاهش می‌یابد. در درختان افرای نروژی کشت‌شده در کنار جاده، تحت بار آلودگی شدید در ماه ژولای، فعالیت پروکسیداز در برگ‌ها کم‌تر از نهالستان‌های شاهد و در آگوست، بالاتر از آنهاست.

*مولف مسئول

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