

Seasonal Changes in the Antioxidant System in the Leaves of the Ornamental Tree *Paulownia Tomentosa* Introduced for Urban Landscaping in Tashkent

Mukhamedova S. N.

Tashkent State Medical University Assistant, PhD, e-mail: shoxoldarova@gmail.com

Received: 2025, 20, Nov

Accepted: 2025, 21, Dec

Published: 2026, 22, Jan

Copyright © 2026 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).



Open Access

<http://creativecommons.org/licenses/by/4.0/>

Annotation: At present, one of the fundamental problems is the study of cellular and molecular mechanisms of plant adaptation to adverse environmental conditions. The formation of an adaptive response to abiotic stressors in a plant organism occurs as a result of many metabolic changes. It is known that all living organisms have the ability to adapt to biotic and abiotic environmental factors and protect themselves from adverse conditions. The article provides information on the state of the antioxidant system of *Paulownia*, an ornamental plant growing in Tashkent, from June to September. The studies were carried out for 5 years and studied the activity of antioxidant enzymes in paulownia leaves - catalase and SOD, as well as the amount of free proline and malondialdehyde. In addition to the impact of environmental factors, the anthropogenic impact in the form of additional roads was also studied. In July, in the leaves of *Paulownia tomentosa* growing in the Botanical Garden, a sharp decrease in the content of malondialdehyde was observed, at this time catalase activation was observed, and by

August also SOD activation. In connection with the activation of lipid peroxidation in the highway, it can be seen that the amount of proline also has high values during the season, which in turn controls the formation of reactive oxygen species.

Key words: antioxidant system, plant stress resistance, superoxide dismutase, catalase, lipid peroxidation, proline, membrane damage factor.

INTRODUCTION. Studying the mechanisms underlying plant resistance to stress factors allows us to maximize the efficient use of these resources to create favorable living conditions for humans, especially in the context of global urbanization. In large cities, most ornamental trees undergo changes due to additional stress from busy highways and exhaust pollution. One tree frequently used in urban landscaping is *Paulownia tomentosa*, a fast-growing tree up to 25 meters tall with a broad, ovoid crown that can live up to 100 years. This tree is native to South and Southeast Asia. *Paulownia tomentosa* can grow in saline soils and is also drought-resistant and shade-tolerant, making it a preferred choice for landscaping and greening in Uzbekistan.

Urban environmental conditions negatively impact the health, growth, and development of plants, as well as their functional activity [1]. Plant responses to various factors, including anthropogenic impacts, can be monitored by changes in the activity of antioxidant enzymes, SOD and catalase [2].

Due to increasing anthropogenic impact on the environment, studying the impact of environmental factors on living organisms, especially plants, is important. Negative environmental factors have a continuous or intermittent impact on plant life [3].

Due to increasing anthropogenic pressure on the environment, studying the impact of environmental factors on living organisms, particularly plants, is crucial. The degree of resistance is individual and varies depending on the plant species and the influence of other environmental factors. Even different plant cells, tissues, and organs can differ in their tolerance.

Under biotic and abiotic stress, plants produce reactive oxygen species (ROS), causing oxidative stress. ROS also play additional signaling roles in plant adaptation to stress. Understanding the mechanisms of this process allows us to develop new ways to protect organisms, particularly agricultural plants, from negative stress.

Study objective. The aim of our study was to conduct a comparative analysis of the level of oxidative stress in *Paulownia tomentosa* leaves depending on growing conditions—along a busy highway or in the botanical garden of the National University of Uzbekistan—to assess the extent of *Paulownia tomentosa*'s adaptation to the urban conditions of Tashkent. Importantly, oxidative stress is a completely normal physiological process for plants, which also triggers adaptation processes.

MATERIAL AND METHODS. The study was conducted from 2020 to 2025. The leaves of *Paulownia tomentosa* plants growing in the area of the botanical garden and green spaces of the Mirzo Ulugbek National University of Uzbekistan (Botanical Garden group) and the leaves of

plants growing near a busy intersection of the central highway near Amir Timur Square in Tashkent (Highway group) were used. Leaves were collected in the morning (7-9 a.m.). Trees of approximately the same age were used for the study [4]. All measurements were carried out in the summer, over the same time period (June, July, August). The highest air temperatures were observed in July-August (39-42°C).

To determine the amount of MDA as the end product of lipid peroxidation, a method for determining TBA reaction products was used. The activity of the superoxide dismutase enzyme was determined by inhibition of the superoxide radical in the reaction of adrenaline autooxidation in an alkaline medium in vitro at a wavelength of 347 nm. Catalase activity was studied spectrophotometrically, based on the ability of hydrogen peroxide to form a stable color with molybdenum salts. The ninhydrin reaction was used to determine the amount of free proline [4]. To determine the coefficient of membrane damage, conductometry was determined (Oakton PC2700 conductometer) [5]. Statistical data processing was performed using Excel 2016 (Microsoft, USA). Each of our studies was performed at least 5 times. Statistical data processing was performed using Excel 2016 (Microsoft, USA). The mean deviation was calculated using the Student's t-test.

RESULTS AND DISCUSSION. Quantitative accumulation of MDA in plant leaves can be used as an informational indicator for phytoindication and assessment of their condition under environmental pollution. MDA levels in the leaves of plants at the NUUZ Botanical Garden were nearly 3.5 $\mu\text{m/g}$ wet weight in June, but dropped sharply to near zero in July (Tab. 1).

Table 1 Seasonal dynamics of changes in the amount of MDA in the leaves of *Paulownia tomentosa* ($\mu\text{m/g}$, n=20)

	June	July	August
Botanical Garden	3,5±0,7	0,02±0,01	5,6±0,6
Magistral	2,98±0,2	1,5±0,1	4,8±0,23

At the same time, catalase activation was observed to increase by an average of 2.3 times (Fig. 1). By the end of the summer season, MDA levels increased to 5.6 $\mu\text{g/g}$ wet weight, which is 1.6 times higher than the values obtained in June. The increase in MDA levels is likely due to a 1.2-fold decrease in catalase activity.

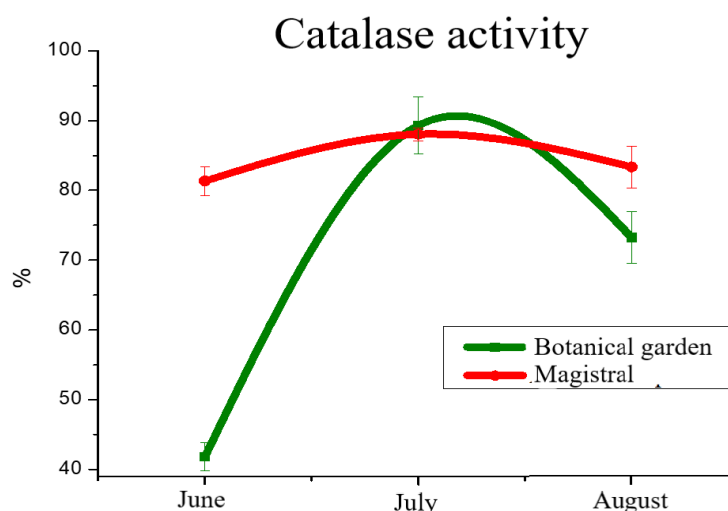


Fig.1. Enzymatic activity of catalase in the leaves of *Paulownia tomentosa* (n=20, p<0.05)

SOD activity increased monotonically and reached maximum values at the end of the observation period (on average, enzyme activity increased 3.6 times compared to values in June) (Fig. 2).

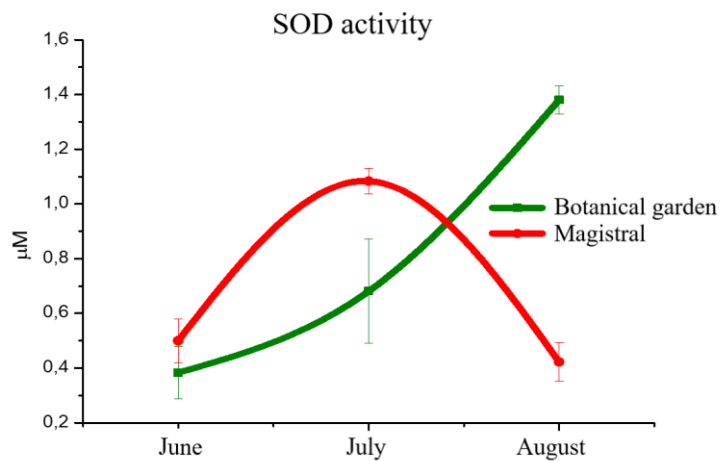


Fig. 2. Enzymatic activity of SOD in the leaves of *Paulownia tomentosa* (n=20, p<0.05)

In the case of *Paulownia tomentosa* trees growing along a highway and a busy intersection, SOD was the main active enzyme in the AOS system. Already at the beginning of summer (June), its activity was 30% higher than that of trees in the NUUz Botanical Garden. This keeps MDA levels relatively low (17% lower than in the NUUz Botanical Garden). In July, due to a 2.2-fold increase in SOD activity, MDA levels decreased by half compared to baseline values. However, in August, a sharp 2.6-fold decrease in SOD activity was observed, accompanied by a 3-fold increase in MDA levels. This can be explained by the cumulative effect of exposure to unfavorable factors and the suppression of AOS activity. However, catalase activity levels in the leaves of these trees did not undergo significant changes.

Thus, at least two AOS enzymes are involved in preventing the dramatic development of oxidative stress in plant leaves. However, the choice of the leading enzyme in implementing adaptive processes depends on growing conditions and the complex of external factors (both abiotic and anthropogenic).

In response to unfavorable conditions, the content of carbohydrates and proline (an amino acid) increases in cells. These carbohydrates participate in protective reactions by stabilizing the cytoplasm. Under water deficiency and salinity, the proline concentration in the cytoplasm of some plants increases by 100 times or more. Due to its hydrophilic groups, proline can form aggregates that behave as hydrophilic colloids. This explains the high solubility of proline, as well as its ability to bind to the surface hydrophilic residues of proteins. The unusual nature of the interaction of proline aggregates with proteins increases the solubility of proteins and protects them from denaturation [6]. In particular, proline's role in plant adaptation to drought as an osmoregulator is well known. Its accumulation leads to an increase in cellular osmolarity, which induces water influx into cells or reduces its outflow, thereby providing the water potential necessary to maintain turgor under water-stress conditions [7].

In *Paulownia tomentosa*, proline levels were quite high from the beginning of the season and remained constant throughout the season, regardless of growing location. For example, in the botanical garden, the dynamics were uniform: in June, the amount of free proline was approximately 5.69 μM/g dry matter, in July – 6.08 μM/g dry matter. By August, a slight decrease in proline levels of 1.2% was observed (Fig. 3).

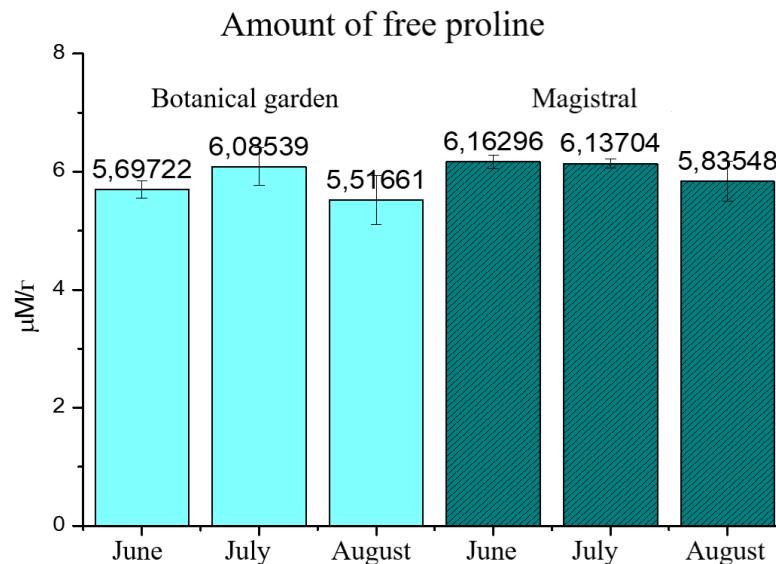


Fig. 3. Dynamics of accumulation of free proline in paulownia leaves ($p < 0.05$, $n = 20$)

Near highways, initial values were already slightly higher than in the botanical garden: $6.16 \mu\text{M/g}$ dry weight in June, changing very little in July ($6.14 \mu\text{M/g}$ dry weight). Here, too, proline levels dropped slightly at the end of the season, to $5.83 \mu\text{M/g}$.

Urbanized conditions negatively impact plant health, growth, and development, as well as their functional activity [1], particularly cell membrane permeability and integrity. The highest temperatures were observed in July and August (average temperatures did not fall below $40\text{--}42^\circ\text{C}$). At the beginning of the season, the membrane damage rate in paulownia leaves growing in the botanical garden was 7.8% . In July, a significant, 130-fold, decrease in the damage rate was observed (the average value did not exceed 0.06%). By the end of the season, the membrane damage rate rises again to almost the initial values and averages 8.04% . These values were adopted as control values (Fig. 4).

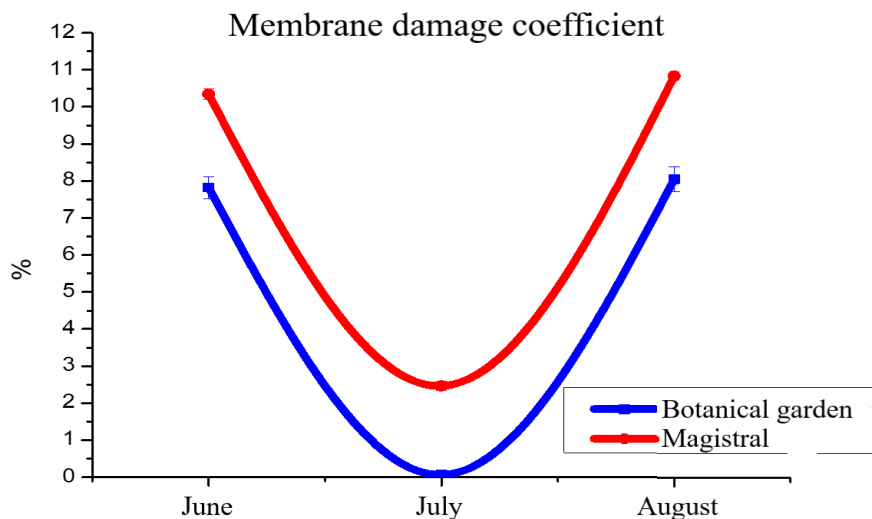


Fig. 4. Membrane damage coefficient in Paulownia tomentosa leaves ($n = 20$, $p < 0.05$)

Anthropogenic stress in the form of a highway proved to be quite critical for plants [4]. The overall picture remained unchanged: a decrease in the damage coefficient was observed in the middle of the hot period and a return to initial values by the end of the season. However, the values were generally higher than those of plants growing in the botanical garden. Thus, in June, the membrane damage coefficient exceeded the control values for this period by an average of 33% and amounted to 10.35% . In July, just as in the botanical garden, a decrease in the damage coefficient to 2.46% was observed, but the decrease was less noticeable and was only 4.2 times

lower than the initial value. By the end of the season, the damage coefficient increased again and amounted to 10.8%, which does not exceed the initial values by more than 5% (Fig. 5).

CONCLUSIONS. Thus, the decrease in MDA levels in paulownia leaves growing in the botanical garden is associated with the activation of antioxidant enzymes—SOD and catalase—during the season. At the same time, activation of all antioxidant enzymes was observed in the leaves of plants growing in highway conditions, and a decrease in SOD activity was observed by August (compared to July values, it was reduced by an average of 2.7 times). Due to the activation of lipid peroxidation in the highway, proline levels also remain high throughout the season, which in turn controls the formation of reactive oxygen species.

Based on our data, we can assume that, under the influence of stress factors, ornamental plants activate their antioxidant defense system, activating one or more antioxidant reactions. Changes in the properties of antioxidant enzymes allow ornamental plants to withstand various growing conditions, as well as adverse environmental conditions.

REFERENCES

1. Симонова З.А., Тихомирова Е.И., Шайденко И.С. Роль железосодержащих оксидаз в адаптации древесных растений к факторам городской среды (на примере городасаратова) // Известия Самарского научного центра РАН. 2016. №2-3. URL: <https://cyberleninka.ru/article/n/rol-zhelezosoderzhaschih-oksidaz-v-adaptatsii-drevesnyh-rasteniy-k-faktoram-gorodskoy-sredy-na-primere-gorodasaratova>.
2. Симонова З.А., Чемаркин Д.А. Активность пероксидазы *Betula pendula* как индикатор качества городской среды (на примере г. Саратова)// Фундаментальные исследования. – 2013. – № 8-5. – С. 1097-1101;
URL: <https://fundamental-research.ru/ru/article/view?id=32091>
3. A. Theocharis, Ch. Clement, E.A. Barka. Physiological and molecular changes in plants grown at low temperature // Planta. – 2012. – Vol. 235. – P. 1091–1105.
4. Мухамедова С.Н. [и др.]. Оценка активности антиоксидантной системы в листьях *Aesculus hippocastanum* в условиях урбанизации на примере города ташкента // Universum: химия и биология : электрон. научн. журн. 2024. 4(118). URL: <https://7universum.com/ru/nature/archive/item/17200>
5. Sairam R.K., Saxena D.C. 2000. Oxidative stress and antioxidants in wheat genotypes: Possible mechanism of water stress tolerance. J. Agron. Crop. Sci. 184, 55–61.
6. Чудинова Л.А., Орлова Н.В. Физиология устойчивости растений: учеб. пособие к спецкурсу/; Перм. ун-т. – Пермь, 2006. – 124с.
7. Joseph, E.A., Radhakrishnan, V.V. & Mohanan, K.V. (2015). A study on the accumulation of proline — an osmoprotectant amino acid under salt stress in some native rice cultivars of North Kerala, India. Univ. J. Agr. Res., 3, pp. 15-22. doi: 10.13189/ujar.2015.030104