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A ANALYSES OF ABIOTIC FACTORS AFFECTING THE TREE PLANT *PAULOWNIA SIEBOLD & ZUCC*

The article analyses the environmental factors i.e. abiotic conditions of adaptation and introduction of the woody plant *Paulownia Siebold & Zucc* growing in the local conditions of Kazakhstan. The *Paulownia* tree naturally grows in China and is now cultivated in various other countries. There are approximately 9 natural species known, as well as many hybrid species. The spectrum of uses for the *Paulownia* tree is broad: agroforestry and land reclamation, pulp industry, biofuel and biomass production, timber harvesting, phytoremediation, and reclamation, among others, making it of significant practical value. The *Paulownia* plant has been cultivated in Kazakhstan for the past 5-6 years and is growing and developing in the southern and southeastern regions of the country. In Kazakhstan, the *Paulownia* plant has been recently introduced and transplanted, so biological and ecological studies of the *Paulownia* in local environmental conditions have not yet been conducted. Our research is being carried out in the villages of Uzynagash and Beriktas in the Zhambyl District of Almaty City and the Almaty Region.

For the purpose of the study, climatic and edaphic factors of the examined area were considered and analyzed to assess the impact of local abiotic factors on the growth of hybrid species of the *Paulownia* family. Thus, the agroclimatic conditions and agrochemical properties of the soil in Almaty City and the Almaty Region are suitable for planting Paulownia trees.

Key words: *Paulownia Siebold & Zucc*, abiotic factors, tolerance, adaptation**.**

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Paulownia Siebold & Zucc ағаш өсімдігіне әсер ететін абиотикалық факторларды талдау

Мақалада Қазақстандық жергілікті жағдайда өсіп жатқан *Paulownia Siebold & Zucc* өсімдігінің бейімделу және жерсіну, яғни орта факторларына талдау жасалады. *Paulownia* (Павловния) ағаш өсімдігі Қытайда табиғи жағдайда өседі. Қазіргі уақытта әлемнің басқа елдерінде де өсіріледі. Табиғи 9 жуық түрі белгілі және көптеген гибрид түрлері де бар. *Paulownia* ағашын қолданудың ауқымы кең: агроорман-мелиорациялық, целлюлоза өнеркәсібі, биоотын және биомасса алу, ағаш-сүрек алу, фиторемедиациялық, рекультивациялық т.б. практикалық маңыздылығы көп. Қазақстанда *Paulownia* өсімдігі соңғы 5-6 жылда қолға алынып, Қазақстанның оңтүстік, оңтүстік-шығыс аймақтарында өсіріліп дамып келеді. Қазақстан жағдайында жаңадан өсіріліп, жерсінуде, сол себептен жергілікті экологиялық жағдайда *Paulownia* өсімдігіне биологиялық-экологиялық зерттеулер жүргізілмеген. Біздің жұмысымыздағы зерттеулер Алматы қаласы мен Алматы облысы Жамбыл ауданының Ұзынағаш ауылы мен Беріктас ауылдық округінде жүргізілуде.

Зерттеудің мақсатына орай *Paulownia* туысының гибрид түрлерінің өсуіне жергілікті жердің абиотикалық факторларының әсерін бағалау барысында зерттелінетін аймақтың климаттық және эдафикалық факторлары қарастырылып, талданды. Сонымен, Алматы қаласы және Алматы облысының агроклиматтық жағдайлары мен топырақтың агрохимиялық көрсеткіштері *Paulownia* ағаш өсімдігін жерсіндіруге қолайлы.

Түйін сөздер: *Paulownia Siebold & Zucc,* абиотикалық факторлар, жерсіну, бейімделу.

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Анализ абиотических факторов, влияющих на древесное растение *Paulownia Siebold & Zucc*

В статье делается анализ факторов среды т.е. абиотические условия адаптации и интродукции древесного растения *Paulownia Siebold & Zucc*, произрастающего в местных условиях Казахстана. В естественных условиях *Paulownia* (Павловния) произрастает в Китае. В настоящее время выращивается и в других странах мира. Известно около 9 природных видов, а также моножество гибридов. Область применения *Paulownia* широка, это агролесомелиорация, целлюлозная промышленность, добыча биотоплива и биомассы, фиторемедиация, рекультивация, лесопродукция и др. В Казахстане, последние 5-6 лет *Paulownia* адаптируется и культивируется в южных, юго-восточных регионах Казахстана. В условиях Казахстана выращивается впервые и поэтому в местных экологических условиях биологически-экологические исследования не проводились. Исследования в нашей работе проводятся в городе Алматы и Жамбылском районе (с. Бериктас, с. Узынагаш) Алматинской области.

Целью исследования является оценка местных абиотических факторов на гибридные виды рода *Paulownia*. Были рассмотрены и проанализированы климатические и эдафические факторы изучаемого региона и проведена предварительная оценка. С учетом агроклиматических условий и агрохимических показателей почв г. Алматы и Алматинской области делаем вывод, что *Paulownia* является благоприятной зоной для интродукции. В статье представлены предварительные результаты этих исследований.

Ключевые слова: *Paulownia Siebold & Zucc,* абиотические факторы, интродукция, адаптация.

Introduction

Paulownia (Paulownia) is a deciduous tree belonging to the *Paulowniaceae* family, which naturally grows in China. Some species are also cultivated in Japan, Southeast Asia, Europe, North, South, and Central America, and Australia. There are nine species: *P. tomentosa, P. albiphloea, P. catalpifolia, P. elongata, P. fargesii, P. fortunei, P. australis, P. kawakamii, and P. taiwaniana*, as well as numerous natural hybrids known for their wood quality and biological properties [1-4].

Paulownia species from China have been used for over 2600 years as agroforestry and reclamation trees due to their numerous positive properties and versatile uses. This species was named after Queen Anna Pavlovna of the Netherlands (1795-1865), the daughter of Russian Tsar Paul I. It is also known as the «princess tree» or «kiri tree» [5]. Paulownia has been cultivated as an ornamental tree in Northwestern Europe since the early 1800s, but it was not considered a commercial species until recent years. Research results based on data collected from existing sites, as presented by Jensen (2016), indicate that Paulownia species and hybrids can be successfully grown as a commercial agroforestry crop in Northwestern, Southern, and Eastern Europe [6-9]. *Paulownia* can be propagated by seeds, roots, or microclonal methods [10,11]. The wood was introduced to the United States in the mid-1800s as packing material for decorative porcelain [12-14].

Paulownia trees are characterized by a wide range of applications. The purpose of planting *Paulownia* is land restoration, utilization of livestock waste, and rapid biomass production for paper manufacturing [15,16]. *Paulownia* is an ideal tree for short-term cultivation due to its rapid growth, ability to regenerate from stems and roots, and the diverse uses of its wood and fibers. *Paulownia* does not require replanting after cutting, as it regenerates from stem and root shoots. The wood of *Paulownia* is used to make many products due to its attractive appearance, strength, light weight, and good physical-mechanical properties. A *Paulownia* tree that is 8-10 years old produces 100 kg of leaves per year [17,18]. The leaves and flowers of *Paulownia* are rich in nitrogen and other nutrients, making them an excellent natural fertilizer. Additionally, *Paulownia* leaves are nutrient-rich and can be used as a forage crop [19,20]. The plant analyzed in this article is characterized by very rapid growth (trunk diameter reaches 50-70 cm in 8-10 years), low temperature tolerance (down to -27°C), a robust root system, and large leaves (up to 60 cm in width) [21-23].

In recent years, interest in species belonging to the *Paulownia* family has been growing in the CIS countries – Ukraine, Uzbekistan, Kyrgyzstan, Russia, and Kazakhstan. Currently, entrepreneurs in these countries have shifted to commercial planting operations for timber production. In the processes of adaptation to environmental conditions, different elements of environmental factors affect various, primarily hybrid species belonging to the *Paulowniaceae* family in different ways. Most of the territory of these countries is located in the temperate zone, and due to higher temperature amplitudes to the north, *Paulownia* is cultivated and grown only in the southern regions. For example, *Paulownia* is very popular in Ukraine, where it is grown and developed for various purposes across much of the country. It was adopted there earlier than in other CIS countries. Ukraine has a moderately continental climate, with continental influences increasing towards the east. Except for the northeastern part of the country, the regions are ideal for growing *Paulownia*, which benefits from warm, moist air masses coming from the Atlantic [24]. In Uzbekistan, *Paulownia* has been localized and developed over the past 7-8 years. The country's predominantly subtropical climate provides favorable conditions for *Paulownia* species [25, 26]. In the Issyk-Kul region of Kyrgyzstan, *Paulownia* was initially cultivated for timber and biomass production. Due to the adverse effects of abiotic factors, it is now grown in a park-like environment for landscaping purposes [27]. Hybrid species of *Paulownia* are transplanted and grown in southern Russia – specifically in the Krasnodar, Sevastopol, Crimea, and Rostov regions. Research is also being conducted in Kazakhstan to determine the microclonal propagation, regeneration, adaptation conditions and medicinal properties of the plant [28-31].

In Kazakhstan, *Paulownia* has been cultivated and developed in the southern regions since 2016-2017. To obtain timber and wood materials for commercial purposes, private individuals grow it in plantation conditions, sell seedlings, and contribute to the greening of the southern regions. Since *Paulownia* has been recently introduced and transplanted in Kazakhstan, biological and ecological studies of the plant in local environmental conditions have not yet been conducted. For commercial purposes, various hybrids of the *Paulownia* family are grown. The adaptation and introduction of *Paulownia* to the local environment are being carried out in Almaty City and in the Zhambyl and Talgar districts of the Almaty Region..

The **aim of this research** is to evaluate the abiotic factors of the area on the growth of hybrid species of the *Paulownia Siebold & Zucc* family.

Changes in abiotic factors can significantly impact organisms, either positively or negatively, and sometimes even lead to their death. Abiotic factors shape the habitat of animals and plants, greatly influencing physiological processes and life cycles of organisms. Abiotic factors include the physical and chemical conditions of the environment. Broadly, the environment encompasses the collection of material bodies, phenomena, and energy that affect living organisms.

Materials and Methods

The study examines hybrid *Paulownia Siebold & Zucc* species, focusing on abiotic factors in Almaty City (Al-Farabi Kazakh National University garden plot and Abai Kazakh National Pedagogical University campus) and the Almaty Region (Beriktas village land plot, Zhambyl District), using meteorological observations and chemical-analytical soil composition methods. Soil Analysis Instruments: Specord 210 PLUS (for determining heavy metals in soil); Ionometer I-160 MI (for measuring pH and soil salinity); Plasma photometer FLAFO-4 (for determining various chemical elements in soil). Soil Analysis Methods: Total humus – RK MSC 3477-2019 with Tyurin; Mobile N – Tyurin-Kononov; Mobile P, K – GOST 26205-91; pH – GOST 26423-85; Water separation – GOST 26423-85-26428-85; Granulometric composition – GOST 12536-2014.

Soil samples from four locations investigated in October 2022 (A – the Al-Farabi Kazakh National University apple orchard; B – the campus area of Abai Kazakh National Pedagogical University; C – the uncultivated Paulownia land in Beriktas village, Zhambyl District, Almaty Region; D – Almaty Region, Zhambyl District, Paulownia-planted land in Beriktas village winter) were delivered to the accredited laboratory of LLP «Chemical Analysis» according to the standards of the Kazakh Scientific Research Institute of Soil Science and Agrochemistry named after Ospanov. Chemical-analytical analyses were conducted on soil samples collected from the 0-30 cm soil depth layer at these four research sites.

Results and Discussion

The combination of abiotic factors affecting the tree *Paulownia*, the subject of this study, necessitates the following favorable environmental conditions for its growth [5,13,32,33].

Table 1 – Complex of abiotic factors favorable for *Paulownia* tree

№	Abiotic factors:	Favorable environmental conditions:
1	Soil edaphic conditions	Paulownia grows well in clay-loam, light-textured, and moderately moist soils. However, with improved agroecological conditions, it can also thrive in lower-quality soils.
2	Hydrogeological factors (groundwater)	Groundwater should be located at a depth of 1.5-5 meters, as the area is prone to overmoisture. If the groundwater level is less than 1.5 meters, the site is unsuitable for growing Paulownia. The deep roots of Paulownia need to be provided with adequate water at depths up to 5 meters. If the root system does not reach the groundwater, the soil must have sufficient water-holding capacity. In clayey areas, the soil retains adequate moisture even during prolonged droughts. If the soil has low water retention capacity, irrigation or a drip irrigation system is recommended.
3	pH	pH Range 5.0–8.5: Soil pH, indicating acidity or alkalinity, is a crucial factor affecting plant growth and development. Paulownia grows well in calcium-rich soils, and optimal growth is achieved across a wide acidity range from pH 5.0 to approximately 8.5. Adjustments can be made as needed to maintain suitable conditions for rapid and productive growth.
4	Terrain	Location – Southern Slope or Open Areas: Paulownia optimally utilizes sunlight with its very large leaves. As a heat-loving plant, it thrives best on southern slopes. This orientation extends the growing season due to the rapid spring warming, promoting year-round growth of the trees.
5	Precipitation	Precipitation > 800 mm or Use of Irrigation: In the initial years, abundant irrigation is necessary. Thanks to its deep root system, Paulownia can generally meet its water needs from groundwater. If precipitation is insufficient, additional irrigation should be provided.
6	Temperature	Temperature Range: Paulownia grows well in temperatures ranging from 24-26°C and can tolerate temperatures up to 45-47°C.
7	Wind	Early Growth and Development: Paulownia’s very large leaves are sensitive to wind, which can cause damage. However, the plant’s excellent regenerative ability allows it to quickly compensate for this damage, though growth rates may temporarily slow down. In mature plants, leaf size decreases, and sensitivity to wind is reduced
8	Nutrients	Nutrient Requirements in Early Growth: In the early years, Paulownia requires a significant amount of nutrients. The large leaves of Paulownia absorb substantial quantities of nitrogen and potassium. Targeted addition of essential nutrients enhances the growth and development of young saplings and lays the foundation for healthy, robust trees throughout their lifespan. However, the composition of the fertilizer, correct dosage, and timing of application are crucial. Excessive nitrogen application late in the growing season can negatively impact lignification and, consequently, winter hardiness. For instance, potassium improves the tree’s winter hardiness. Regular potassium fertilization throughout the summer enhances water use efficiency and supports safe growth even during drought periods.

Abiotic factors represent a collective group that has a decisive impact on plant life compared to other forms of life. These factors play a crucial role in the morphological, anatomical, physiological, and reproductive development of plants.

Ecological conditions for adaptation of *Paulownia Siebold & Zucc* hybrid species in local conditions of Kazakhstan: This involves evaluating environmental factors, including agroclimatic conditions of the Almaty region and the city of Almaty, and the diversity of climatic features.

Overall, the climate of the region is continental, but in the foothills of the Zailiyskiy Alatau, there is sufficient humidity, with moderately warm summers and mild winters. The plain areas are characterized by significant diurnal and annual temperature fluctuations, cold winters, and long, hot, and dry summers. January is the coldest month, with temperatures ranging from -11 to -13°C in the north and northeast, -6°C in the south, and up to -13°C in the mountains. July is the warmest month, with temperatures reaching 25°C in the north, 18°C in the southern mountains, and 26°C on the slopes. The region is characterized by pronounced temperature inversions, where temperature decreases with altitude. The warm period with average daily temperatures above 0°C ranges from 240 days in the northern plains to 220 days in the southern highlands. Annual precipitation varies from 125 mm in the north to 900 mm in the south, with 50-75% of the annual precipitation occurring during the warm period from April to October [34-38].

The city of Almaty and the Zhambyl district of the Almaty region, where our research is conducted, are characterized by favorable climatic factors. Meteorological data related to climate and weather were obtained from the database of the RMC «Kazhydromet» for assessing the abiotic factors of the areas where hybrid species of *Paulownia Siebold & Zucc* are found. The climatic and atmospheric conditions of the studied areas, i.e., 2 sites (A and B) in the city of Almaty and 2 sites (C and D) in the Zhambyl district of the Almaty region, were considered, including air and soil surface temperature, average relative humidity, cloud cover, wind speed, average atmospheric pressure, average precipitation, number of days with snow cover, duration of sunlight, and soil temperature.

Temperature affects plants at all stages of their development, with different stages requiring different thermal conditions; thus, variations in air and soil temperatures significantly influence physiological processes in plants. Three-year average temperature data for the study areas, obtained from monitoring stations in Almaty and Uzyngach, show: Almaty – January: +4.6°C, July: +24.4°C, annual: +11.9°C; Beriktas – January: -8°C, July: +23°C, annual: +9.5°C. Absolute maxima: Almaty +39.2°C, Beriktas +40°C; Absolute minima: Almaty -15.9°C, Beriktas -22.2°C. Frost days: Almaty – 149, Beriktas – 157; frost-free days: Almaty – 188, Beriktas – 182. Average soil temperature (0-80 cm): Almaty +11.4°C, Beriktas +12.3°C. Duration of periods with mean daily temperatures above 10°C: Almaty 160 days, Beriktas 170 days. Accumulated mean daily temperatures above 10°C: Almaty 3400°C, Beriktas 3600°C. Total heat resources during the growing season: Almaty 3400°C, Beriktas 3600°C [34, 35].

Air humidity is a crucial environmental indicator; its decrease reduces plant yield and negatively affects the survival and reproduction of certain organisms. Humidity determines the periodicity of active life, influences seasonal dynamics of life cycles, and impacts development and mortality. In natural conditions, relative humidity in vegetation areas is not constant throughout the growing season. Humidity increases as plants grow and develop, reaching a maximum of around 85-90% by the end of the growing season. As plants mature, evaporation decreases, leading to a drop in relative humidity (76% and below). Average relative humidity: Almaty 58%, Beriktas 66%. Maximum relative humidity in January: Almaty 79%, Beriktas 84%. High humidity is generally observed in winter and autumn due to precipitation. Minimum humidity recorded in July: Almaty 36%, Beriktas 46% (Table 1) [34,35].

Light: Solar radiation is fundamental to life on Earth. Plants require constant light for the vital process of photosynthesis. Light not only participates in photosynthesis but also shapes plant development, affecting flowering, fruiting, and seed germination. The annual sunlight duration was calculated in hours: Almaty – 2,343 hours, Beriktas – 2,389 hours [38]. Cloud Cover: Number of clear days: Almaty – 239, Beriktas – 218. Number of cloudy days: Almaty – 119, Beriktas – 85 (Tables 2,3) [34,35].

Wind: Air movement significantly impacts plant life. Wind acts as a carrier for seeds, spores, and fruits, playing a crucial role in plant pollination. However, wind also depletes moisture from plants by replacing moist air with dry air, although it brings in fresh carbon dioxide. Average wind speed: Almaty – 0.6 m/s, Beriktas – 1.0 m/s; Maximum wind speed: Almaty – 18 m/s, Beriktas – 30 m/s (Table 1) [34,35].

Table 2 – Weather forecast for 2021-2023

Study area	Air temperature						Average relative humidity, %	Cloudiness		Wind speed, m/s	
	Aver . t	Max. t	Min. t	Abs max.t	Abs. min.t	Number of frosty days		clear	Cloudy	Aver.	Max.
Weather indicators for 2021											
Almaty	11,5	17,6	-6,7	39,7	-17,2	165	55	239	119	0.6	18
Beriktas	9,2	17,2	-2,3	40,6	-23,4	180	64	218	85	1.0	30
Weather indicators for 2022											
Almaty	12	17.6	-7.3	39.3	-13.9	138	59	214	135	0.6	13
Beriktas	9.9	17.0	-3.4	40.9	-19.1	137	67	221	134	1.1	28
Weather indicators for 2023											
Almaty	12,4	18,1	-9.9	38,5	-16,6	143	59	243	115	0.5	8.4
Beriktas	9,5	17,2	-2,9	38,5	-24	153	68	229	101	1.1	18.6

Pressure: Average atmospheric pressure: Almaty – 920.2 hPa, Beriktas – 925.1 hPa (Table 3) [35].

Precipitation: Precipitation is crucial for the water cycle, influencing surface and subsurface runoff, evaporation, and water distribution among plants. Average annual precipitation: Almaty – 630 mm, Berikbash – 436 mm. Snow cover days: Almaty – 64, Beriktas – 51 (Table 3). [34,35].

Table 3 – Weather forecast for 2021-2023

Study area	Average atmospheric pressure, Pa	Average precipitation, mm	Number of days with snow cover	Duration of sunshine, in hours – annual data	Soil temperature, degrees, 0-80 cm
Weather indicators for 2021					
Almaty	920,5	673	53	2343	11,2
Beriktas	925,4	488	38	2389	12,3
Weather indicators for 2022					
Almaty	919,9	640.3	52	1729.4	11.7
Beriktas	924,8	410.4	50	2225.8	12.5
Weather indicators for 2023					
Almaty	847,3	575,4	88	1978,6	11,4
Beriktas	844,5	407,9	65	2238.5	12,0

Soil is one of the components of terrestrial ecosystems and the natural basis for their activity, while vegetation is an important factor in soil formation. The soil substrate serves as the medium for plant attachment, water supply, and mineral nutrition. In the agro-climatic and soil resource zoning of the city of Almaty and the Almaty region, the studied areas in the city of Almaty are classified as part of the mountain-steppe zone at an altitude of 700-1000 meters. The soil cover of this region consists of various types of soils with different mechanical compositions. The best soils are the mountain black soils with a granular structure, moderately humic, and low humic rainfed soils. The mountain black-chestnut soils occupy the zone of dry grass and feather grass steppes. The elevated steppes located at the top are characterized by poorly developed coarse-grained soils, while black-chestnut and light chestnut soils on the slopes are found along the edges of cones.

The studied areas in the Zhambyl district of the Almaty region are part of the irrigated agricultural zone in the desert-steppe zone on the slopes of the mountains. The region is located at an altitude of 450-700 meters above sea level and represents a major reserve of irrigated land. The soils in the area include light chestnut soils, black soils, and meadow-serozem soils. The humus content in the upper horizon ranges from 1.1% to 2.5%. In the peripheral parts of the plains on the mountain slopes surrounding the mountain formations, light chestnut and serozem soils covered with gravel are widespread. The soil profile is characterized by a significant distribution of unutilized serozems [36,37].

For plants, the physical, chemical, and biological properties of the soil, as well as its water, air, and thermal regimes, the pH, and the chemical composition of the soil solution are of significant ecological importance. The main soil indicators affecting plants include: granulometric composition, salinity, moisture level, soil temperature, structure, humus content, agrochemical indicators, microelement composition, and others.

To assess the edaphic factors of the area where the Paulownia Siebold & Zucc is transplanted and cultivated, studies were conducted on the soil's granulometric composition, total humus content, total and available nitrogen content, pH level, salt content, and concentration of major heavy metals. Samples for the study were taken from a depth of 0-30 cm. Regarding the soil indicators for the four studied points:

1. *Soil moisture* – the amount of water per unit mass of absolutely dry soil, where the lowest is 2.06 (point A – KazNUU, apple orchard, i.e., less moist); low moisture – 1.14 (point C – winter, non-cultivated land in the village of Beriktas, i.e., assessed as arid) [37].

2. *Granulometric composition* obtained with three percentage fractions of absolutely dry soil:

sand (coarse 1.0-0.25 mm, fine 0.25-0.05 mm), silt (coarse 0.05-0.01, crushed 0.01-0.005, fine 0.005-0.001), clay (<0.001), mud (<0.01). Analysis (Table 4.) [38]:

1) Large amount of coarse sand 15.668 mm – point B; small size 0.526 mm – point C. Large amount of fine sand 37.819 mm – point A; small size 22.193 mm – point C;

2) Highest amount of coarse silt 40.057 mm – point C, lowest amount 20.829 mm – point A. Large amount of fine silt 13.757 mm – point C, small amount 11.844 mm – point A.

3) Large amount of clay 10.210 mm – point B, small amount 11.002 mm – point C.

4) Large amount of mud 38.454 mm – point D, small amount 34.230 mm – point B.

Table 4 – Granulometric composition of the soil

№	Location of choice	Depth, cm	A.C.H % H2O	% of fractional composition for absolutely dry soil						
				Fraction sizes, mm						
				Sand		Silt			Clay	Mud
				1,0-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	Fractions < 0,01
1. A	KazNUU, apple orchard	0-30	2,06	4,595	37,819	20,829	14,703	11,844	10,210	36,757
2. B	KazNPU, campus area	0-30	1,84	15,668	26,059	24,042	11,002	12,225	11,002	34,230
3. C	Beriktas v., wintering site, non-cultivated	0-30	1,14	0,526	22,193	40,057	15,780	13,757	7,688	37,224
4. D	Beriktas v., wintering site, cultivated	0-30	1,18	0,830	22,667	38,049	17,001	12,548	8,905	38,454

3. *Agrochemical indicators* – Agrochemical indicators of soil fertility are a set of properties that characterize the soil's ability to supply plants with nutrients and maintain an optimal feeding regime. In our case (Table 4) [38]:

1. Maximum amount of total humus – Point B – 1.86%, minimum – Point C – 0.65%. Humus content is low at all points.

2. Available nitrogen (N), mg/kg, obtained from two points, highest – 47.6%, Point D; lower – 44.8%, Point C. High values indicate the nitrogen (N) status of the cultivated area of Paulownia Siebold & Zucc, suggesting that nitrogen-fixing microorganisms are active and that the humus formation process has started. It can be said that *Paulownia* trees may fertilize the soil and enhance its fertility. Although the studies cover a short period, the trend may already be underway.

3. pH values: high 9.25 – Point C, low – 8.20, Point A. All indicators point to a high degree of alkalinity. The soil is classified as alkaline [38].

4. *Salt content*. The salts present in the studied soil were determined by separating absolutely dry soil from water. High salt content – Point C with 0.139%, Point B with a lower value – 0.086%. At all points, salinity is within the range of 0.50-1.00%, indicating that the soil is considered moderately saline (Table 6) [38].

Table 5 – Soil Agrochemical Indicators

№	Determined Indicators				
	Sampling Location	**Total Humus %**	**Mobile Nitrogen Mg/kg**	**Total nitrogen %**	**pH**
1. A	KazNUU, apple orchard	1,65	-		8,20
2. B	KazNPU, campus area	1,86	-		8,61
3. C	Beriktas v., wintering site, non-cultivated	0,65	44,8	0,070	9,25
4. D	Beriktas v., wintering site, cultivated	1,48	47,6	0,168	9,08

Table 6 – Salt separation indicators by water

№	For Absolutely dry soil $\frac{\%\%}{м.экв.}$ **volumetric separation by water**								
	Salt Content, %	Alkalinity		Cl’	SO_4''	Ca^{++}	Mg^{++}	Na^+	K^+
		General HCO_3^-	Composition of CO_3 from common carbonates						
KazNU, apple orchard	0,107	0,034		0,000	0,048	0,014	0,010	0,001	0,001
		0,56		0,00	0,99	0,70	0,79	0,03	0,03
KazNU, apple orchard	0,086	0,024		0,001	0,040	0,010	0,008	0,001	0,002
		0,40		0,04	0,83	0,50	0,69	0,03	0,04
Beriktas v., wintering site, non-cultivated	0,126	0,034	0,002	0,012	0,044	0,004	0,008	0,018	0,005
		0,56	0,08	0,33	0,92	0,20	0,69	0,80	0,13
Beriktas v., wintering, non-cultivated	0,139	0,039		0,004	0,056	0,010	0,005	0,020	0,006
		0,64		0,11	1,16	0,50	0,39	0,85	0,16

5. *Micronutrient composition*. The study analyzed four types of mobile forms of micronutrients found in significant quantities in urban soil: zinc (Zn), copper (Cu), cadmium (Cd), and lead (Pb). This group of heavy metals is widespread in the soil and negatively impacts natural processes in the environment. In our research (Table 7) [38]:

- High levels of zinc at point B – 45.6 mg/kg; low levels – 1.90 mg/kg; normal levels – Point C.
- High levels of copper at point C – 1.80 mg/kg; low levels – 1.10 mg/kg; normal levels – Point B.
- High levels of cadmium at point B – 1.20 mg/kg; low levels – 0.80 mg/kg; normal levels – Point A.
- High levels of lead at point B – 1.00 mg/kg; low levels – 0.60 mg/kg; normal levels – Point D.

According to the analysis, at point B, which is KazNPU, campus area, there are high levels of three elements – Zn, Cd, Pb. This situation indicates that the land plot planted with trees is located near street intersections (Kazibek bi and Sh. Ualikhanov), and consequently, these levels are elevated.

Table 7 – Micronutrient composition in soil

№	Sampling location	Available forms of micronutrients, mg/kg			
		Zn	Cu	Cd	Pb
1. A	KazNU, apple orchard	4,40	1,20	0,80	0,80
2. B	KazNPU, campus area	45,6	1,10	1,20	1,00
3. C	Beriktas v., wintering, non-cultivated	1,90	1,80	1,10	0,80
4. D	Beriktas v., wintering, cultivated	2,80	1,30	1,00	0,60

Environmental factors affect the growth and development of *Paulownia* trees to varying degrees: low temperature has a primary influence, while high temperature has a secondary, weaker effect. Additionally, these factors can impact specific aspects of plant development. The response of *Paulownia* trees to changes in environmental conditions is reflected in their ability to exhibit resilience, which manifests in the flexibility of structures and functions and the development of adaptive changes in structure and life processes. Three years of phenological observations from the conducted localization work have shown good results in growth and adaptation of *Paulownia* trees in the city of Almaty and the Almaty region, as shown in Table 8.

Table 8 – Results of phenological observations

Years	Vine Height, cm (beginning/end of the growing season)					
	KazNU, apple orchard		KazNPU, campus area		Beriktas, winter site	
2021	18-22	93-105	30-38	122-220	-	-
2022	0 (technical section)	250-430	0 (technical section)	460-580	15-23	150-210
2023	0 (technical section)	260-490	420-500	570-660	0 (technical section)	170-250

The enrichment of local flora through the cultivation and transplantation of tree species has been practiced since ancient times, primarily in regions with favorable climatic conditions for growing these plants. Introduction is particularly crucial in arid regions with soil salinity, lack of moisture, and deforested areas. Enriching local flora with fast-growing, valuable woody, shrubby, and herbaceous plants that are resistant to extreme conditions, as well as high-quality products, selection, conservation, and development, is one of the pressing issues for increasing biodiversity in the Republic of Kazakhstan. Plant introduction plays a significant role in enhancing the productivity of artificially created plant communities of various purposes and their economically valuable properties. To conserve rare and endangered plant species and introduce new useful plants into local flora, it is necessary to cultivate them in dendrological gardens, botanical gardens, and experimental plots, and propagate them for reintroduction into natural conditions. Given the role that plants play in shaping the environment, and considering both natural physical-geographical conditions and anthropogenic factors related to human production activities, it is crucial to include experimentally tested plant species that are beneficial for each region into the local flora.


A – KazNU, apple orchard


KazNPU, campus area


D – Beriktas v., wintering, cultivated

Figure 1 – *Paulownia Siebold & Zucc*

This is why we analyzed and assessed the complex of abiotic factors of the local area to conduct research on the adaptation of Paulownia trees, which are the subject of our study, to increase biodiversity of the local flora, and for planting and use in various industrial and commercial purposes in the southeastern and southern regions of our country. Further study of the impact of abiotic factors on the local area will help determine indicators such as heat and cold tolerance, resistance to smoke and gas in urban conditions, and ability to withstand pests.

Conclusion

1. The study found that temperature fluctuations impact *Paulownia* growth. Suitable temperature amplitudes contributed to good development of *Paulownia* trees in Almaty, while the absolute low temperature of -22°C in Beriktas had a negative effect. The total thermal resource temperature for the growing season was: Almaty 3400°C, Beriktas 3600°C. The main abiotic factor affecting the growth of Paulownia is temperature. Its decrease has a decisive influence.

2. The high average precipitation in Almaty positively affected *Paulownia* trees, while the low level of summer precipitation in Beriktas had a negative impact. Average precipitation: Almaty – 630 mm, Beriktas – 436 mm.

3. In Almaty, the humus content in soil cultivated with Paulownia ranged from 1.65 to 1.86. In Beriktas, the humus content in non-cultivated soil was 0.65, and increased to 1.48 with Paulownia cultivation.

4. *Paulownia* adapts and grows at a pH of 8.20-8.61.

5. Among the agrochemical indicators, the amount of available nitrogen increased in the cultivated area compared to the non-cultivated winter site in Beriktas. This indicates the revival of nitrogen-fixing microorganisms and signifies that the process of soil humus formation has begun.

After analyzing the abiotic factors, we can preliminarily conclude that the city of Almaty and the Almaty region are suitable areas for planting *Paulownia* trees. However, further tasks remain to study the impact of environmental factors on the plant and the conditions for its adaptation. The agroclimatic conditions of Almaty city and the Almaty region are very favorable. The foothills of the Zailiysky Alatau are characterized by sufficient humidity, mild summers, and soft winters. The total thermal resource temperature for the growing season is around 3400-3600°C. The warm period, with an average daily air temperature above 0°C, lasts for 220-240 days. The total sunlight duration per year is 2400 hours. Soil types range from mountain chernozem to mountain black-brown, light brown, and chestnut soils. The agrochemical indicators of the soil also meet the requirements for growing *Paulownia*, and good results can be achieved through specific agronomic practices. Research shows that the set of suitable abiotic factors required for the Paulownia tree matches the established environmental factors of the city of Almaty and the region.In the southern and southeastern regions of the country, the processes of growing and transplanting Paulownia have been ongoing for several years. Currently, studies are focusing on the adaptation of *Paulownia* to local climatic conditions, as well as abiotic and biotic environmental factors affecting the plant. Moving forward, given the potential of the *Paulownia* tree for its economic value to our country and its ecological benefits for environmental improvement, comprehensive studies will be conducted on the plant's ecological and biological characteristics and adaptation processes.

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