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**RESEARCH ON THE PRACTICAL USE OF  
PAULOWNIA SP., OXYTREE, AS AN  
ELEMENT OF CLIMATE-ADAPTIVE  
AGROFORESTRY SYSTEMS**

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*The article summarizes current approaches to the practical use of paulownia (*Paulownia* sp., *Oxytree*) as an element of climate-adaptive agroforestry systems. The aim of the work is to assess the prospects for integrating paulownia into the structure of agricultural landscapes and to determine its potential role in increasing the ecological stability and productivity of agroecosystems under conditions of increasing climate risks (drought, uneven precipitation, erosion processes). The methodological basis was the analysis and systematization of literary sources, a comparative analysis of the biological, ecological, and economic characteristics of *Paulownia* spp., and an assessment of the possibilities for using the species in tree-field, agroforestry, and bioenergy schemes.*

*The key properties that determine the suitability of paulownia for agroforestry plantations are considered: high growth rates at a young age, intensive biomass accumulation, the ability to regrow after cutting (important for short-rotation plantations), as well as the potential for the formation of microclimatic and anti-erosion effects as part of field protection plantations. Special attention is paid to the technological prerequisites for effective cultivation: light-loving, dependence of productivity on moisture supply, requirements for soil conditions (preference for well-drained soils), the feasibility of optimizing planting schemes (4×4, 5×5 m or wider row spacing) for combination with growing crops in the row spacing and ensuring mechanized care.*

*The efficiency of using paulownia varies significantly depending on the species or clone and the cultivation technology (feeding, irrigation, shaping), and also requires consideration of limitations (frost risks, sensitivity to moisture deficiency) and biosecurity aspects, in particular the invasive potential of individual taxa in certain regions. The integration of *Paulownia* sp. (*Oxytree*) into climate-adaptive agroforestry systems can optimize the use of land resources, increase the ecological stability of agrolandscapes and form an additional source of wood biomass and wood products, provided that the implementation is controlled and scientifically sound.*

**Keywords:** *Paulownia, agroforestry systems, climate-adaptive technologies, agroforestry reclamation, sustainability of agrolandscapes.*

**Table 2., Fig 2., Ref. 19.**

**Problem statement.** Modern climate changes, manifested in an increase in average annual temperatures, an increase in the duration of dry periods and an uneven distribution of precipitation, significantly affect the productivity of agricultural landscapes and the stability of ecosystems. In these conditions, there is a growing need to find new approaches to agricultural and forestry management aimed at increasing the resilience of agroecosystems to adverse climatic factors.

One of the promising areas is the formation of climate-adaptive agroforestry systems, which involve the integration of tree plantations with agricultural crops. Such systems provide a comprehensive ecological effect, in particular, improving microclimatic conditions, reducing the intensity of erosion processes, increasing soil fertility and optimizing the use of land resources [1, 2].



Of particular interest in this context are fast-growing tree species that are capable of forming significant amounts of biomass in a short time. One such species is paulownia (*Paulownia* sp., *Oxytree*), which is characterized by intensive growth, high regeneration capacity, and significant potential for adaptation to various soil and climatic conditions.

**Analysis of recent research and publications.** Paulownia is a fast-growing tree native to Asia. The genus *Paulownia* (Paulowniaceae) includes nine species, the most commonly mentioned in plantation cultivation are *P. tomentosa*, *P. elongata*, *P. Fortunei*, which are intensively used and studied [3,4]. Hybrids of Paulownia can combine, for example, *Paulownia tomentosa* x *elongata* or *Paulownia elongata* x *Paulownia fortunei* [5]. In Europe, the most studied clones are *Paulownia in vitro* 112 – *Oxytree* [6], BIO 125 or *Cotevisa* 2 [7].

However, they are now widely cultivated in Asia, Africa, North and South America, Europe and Australia as fast-growing timber species [8]. Among them, the woolly paulownia *Paulownia tomentosa* (Thunb.) Steud. is cultivated in many regions of Japan primarily for its wood, which is traditionally used for making furniture, musical instruments and other household items [9]. Historically, in Japan, this species was not considered a typical forestry species, but rather a special-purpose tree, respectively. At the same time, in recent decades, a number of well-known areas for growing and harvesting *P. tomentosa* timber have experienced a decline due to a decrease in demand for traditional products in modern life. Expanding the use of *Paulownia tomentosa* as a forestry species, with a focus on wood for construction and interiors, as well as biomass for energy needs, has the potential to combine the sustainability of wood production with the preservation of the cultural heritage associated with paulownia wood [10].

In recent decades, there has been a growing interest in agroforestry plantations of paulownia for industrial use in Europe. As a result, the ecological footprint of paulownia wood from Asia is reduced by eliminating shipping costs. Paulownia plantations help reduce soil hazards by intercropping trees on agricultural land and fields. For example, intercropping with wheat increases production rates, similar to the increase in ginger production. It is recommended to intercrop paulownia with winter crops and vegetables, given that the trees will not compete for water and nutrients during the cold season during their dormant period [11]. Paulownia protects systems from erosion, flooding or wind damage, reduces soil degradation (by absorbing heavy metals), reduces air pollution (by purifying the air of harmful gases thanks to its large leaves) and improves the microclimate.

**Research objective.** The research objective is to assess the prospects for using paulownia as an element of climate-adaptive agroforestry systems and to determine its role in increasing the ecological sustainability and productivity of agrolandscapes.

**Materials and research methods.** The research process used a generalization of literary sources, a comparative analysis of the biological and economically valuable properties of the species, as well as an assessment of the possibilities of integrating paulownia into the structure of agrolandscapes.

Additionally, the results of research on the use of fast-growing tree species in agroforestry systems and bioenergy production were taken into account.

Presentation of the main material. Modern climate changes, manifested in an increase in air temperature, uneven distribution of precipitation and an increase in the frequency of dry periods, require the introduction of new approaches to agricultural and forestry management. One of the promising areas is the formation of climate-adaptive agroforestry systems that combine the cultivation of woody vegetation with agricultural crops and contribute to increasing the ecological sustainability of agricultural landscapes. In this context, fast-growing tree species are of great interest, capable of forming a significant amount of biomass in a short period of time and effectively adapting to different soil and climatic conditions [1,4].

One such species is paulownia (*Paulownia sp.*, *Oxytree*), which is characterized by intensive growth, high regeneration capacity and significant potential for biomass accumulation. At a young age, paulownia is capable of achieving significant height gains, which makes it promising for use in short-rotation plantations. Paulownia wood is characterized by lightness, sufficient strength and wide possibilities of use in the woodworking industry, as well as as a source of energy biomass [6].

An important feature of paulownia is its well-developed root system, which helps to improve soil structure, increase its aeration and activate biological processes in the soil environment. Paulownia leaves have a significant leaf surface area and contain a significant amount of organic matter, which after falling contribute to the enrichment of the soil with organic mass. Thanks to these properties, paulownia can perform an important phyto-ameliorative function in agricultural landscapes [12].

From an agronomic point of view, paulownia can be successfully integrated into agroforestry systems. The most common are tree-field systems, in which rows of trees are combined with the cultivation of agricultural crops in the inter-rows. Depending on the cultivation technology and the intended purpose of the plantations, various planting schemes are used, in particular 4×4 m, 5×5 m, or wider inter-rows, which allow for mechanized soil cultivation and field crop cultivation. In the first years after planting, the inter-rows can be used for growing cereals, fodder, or legumes, which increases the efficiency of land use.

The use of paulownia in agroforestry plantations also has significant potential. Thanks to their rapid growth and large leaf surface area, the trees can contribute to the formation of a favorable microclimate, reduce wind speed, and decrease the intensity of erosion processes. As part of field-protecting forest strips, paulownia can serve as a fast-growing component, contributing to the rapid formation of the protective effect of the plantings.

In addition, the integration of paulownia into the structure of agricultural landscapes contributes to increased biodiversity and improved ecological conditions in the areas. The significant leaf surface area of the trees contributes to the active absorption of carbon dioxide and the accumulation of organic matter in the form of biomass, which is important in the context of mitigating the effects of climate change.

Table 1

**Annual diameter growth rate of paulownia hybrids, cm/year**

Hybrid	Year 1	Year 2	Year 3	Average growth
Cotevisa 2	2-4	4-6	4-6	4-5
<i>P. elongata</i> x <i>P. fortunei</i>	2-4	3-5	4-6	3-5
<i>P. tomentosa</i> × <i>elongata</i>	3-5	5-7	7-8	4-6
Oxytree	3-5	4-6	6-8	4-6
BIO 125	2-4	4-6	6-7	3-5

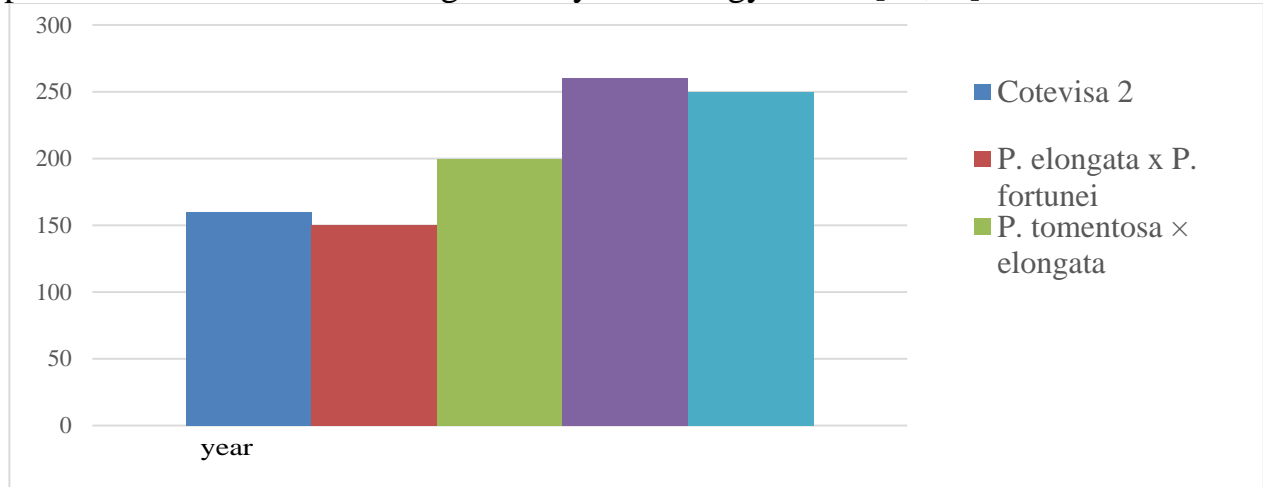
Source: based on own research

Table 1 shows the rate of diameter growth (cm/year) for five Paulownia hybrids during the first three years of cultivation, with the average values summarised, enabling an assessment of their production potential during the early stages of trunk formation. The general trend indicates an increase in diameter growth with age: in the first year, the figures are predominantly 2-5 cm/year; in the second year, 3-7 cm/year; and in the third year, for some genotypes, they reach 6-8 cm/year. *P. tomentosa* × *elongata* demonstrates the most intense growth dynamics (3-5 cm/year in the first year; 5-7 cm/year in the second; 7-8 cm/year in the third), reflecting a high potential for rapid trunk growth. Oxytree exhibits a similar, though somewhat less pronounced, trend (3-5; 4-6; 6-8 cm/year) with an average of 4-6 cm/year. BIO 125 is also characterised by an increase in growth (2-4; 4-6; 6-7 cm/year), although the average is generally estimated at 3-5 cm/year. Cotevisa 2 and the *Paulownia elongata* × *Paulownia fortunei* hybrid demonstrate more stable values ranging from 2-4 cm/year in the first year to 4-6 cm/year in the second and third years (average growth of 4-5 and 3-5 cm/year respectively), indicating that growth rates stabilise from the second year onwards. Such early growth rates are important from a practical point of view, as the use of paulownia is linked to the potential for producing various types of products: the timber may be in demand in the furniture industry, construction and the manufacture of panel materials, as well as serving as a raw material for bioenergy. High growth rates and the ability to regenerate after felling create the conditions for establishing short-rotation plantations, which ensure a relatively rapid and stable supply of woody biomass and improve the efficiency of land use [13, 14].

Thus, Paulownia can be regarded as a promising component of climate-resilient agroforestry systems. The combination of high productivity, ecological flexibility and the ability to be integrated into various types of agricultural landscapes creates the conditions for its widespread use in sustainable agricultural and forestry systems.

Characterizing at Fig. 1, it can be noted that paulownia is also characterised by rapid growth rates, which, under favourable conditions, can reach up to 2 m in height per year when the trees are young. As a result, it is capable of producing significant volumes of woody biomass within a short period of time.

Paulownia wood is noted for its lightness, sufficient strength and wide range of applications in the woodworking industry and energy sector [15,16].



**Fig. 1.** Average height growth (during the growing season) of Paulownia hybrids, cm/year

Source: based on own research

Characterizing Table 2, it can be noted that *Paulownia sp.*, *Oxytree* are distinguished by high growth rates and significant potential for biomass formation, which makes them promising for agroforestry systems under the condition of sufficient light, heat supply and moisture supply.

The effectiveness of the use of paulownia significantly depends on the selection of the species, soil and climatic conditions and cultivation technology (location scheme, care, irrigation, nutrition). At the same time, during implementation, it is necessary to take into account possible limitations (frost risks, sensitivity to moisture deficiency) and biosecurity aspects, in particular the invasive potential of certain species, which requires controlled use and monitoring.

Figure 2 clearly shows that the ability of different genotypes to withstand winter conditions varies significantly. Cotevisa 2 and Oxytree received the highest scores (4 points each), distinguishing them as the most adapted to the cold season among the varieties tested. *The Paulownia elongata* × *Paulownia fortunei* hybrid and BIO 125 (3 points each) demonstrate a moderate level of winter hardiness, occupying an intermediate position and potentially requiring more careful site selection and agronomic practices in areas with an increased risk of frost. The lowest score was recorded for *P. tomentosa* × *elongata* (2 points), highlighting its relative sensitivity to winter stress within the scope of this assessment. Overall, the diagram forms a clear gradation of winter hardiness from 4 to 2 points, highlighting that the success of paulownia cultivation under contrasting winter conditions is largely determined by the choice of hybrid or clone.

An analysis of literary sources and the results of practical cultivation of paulownia indicates its high growth rates at a young age. In favorable soil and climatic conditions, the growth of trees in the first years can be more than 2-3 m per year.

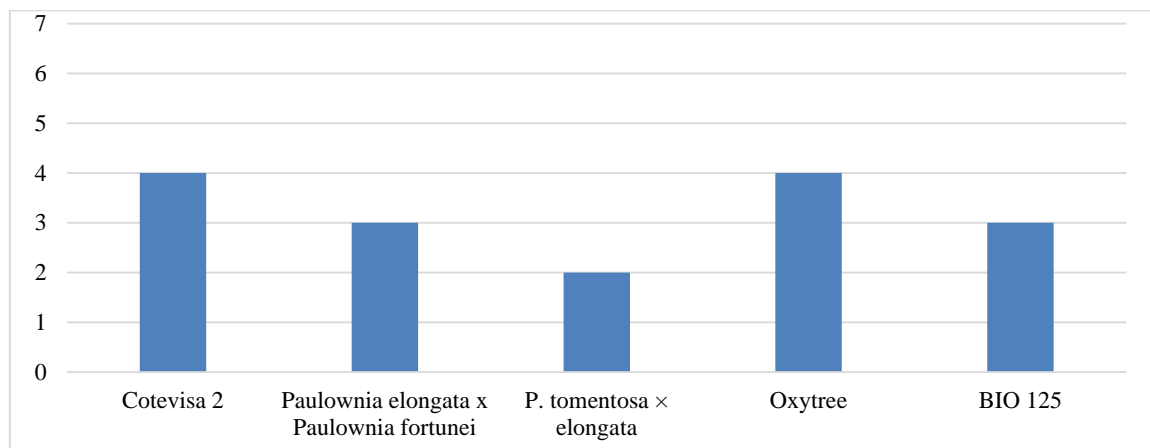
Table 2

**Biological and ecological characteristics of *Paulownia sp.*, *Oxytree* for agroforestry systems**

Feature	Characteristics
Taxonomy, origin	The genus <i>Paulownia</i> includes deciduous fast-growing trees; species, interspecific hybrids, and clones are widely used in production systems.
Life form, morphological traits	Intensive vegetative growth, large leaves, and high transpiration rate; morphological parameters vary significantly depending on species or clone and growing conditions.
Light requirements	Generally a light-demanding species; in mixed agroforestry systems it requires optimization of row spacing and row orientation to minimize shading of crops.
Heat requirements and frost resistance	Realizes its growth potential better in warmer conditions; in colder regions young plants may be damaged by frost; the level of resistance depends on the species and clone.
Water supply	Sensitive to moisture deficit; irrigation and water-saving technologies are important for high productivity in arid and semi-arid conditions.
Soil conditions	Grows best on well-drained soils; waterlogging or soil compaction suppresses growth and reduces productivity.
Nutrition(response to fertilization)	Productivity strongly depends on the level of mineral nutrition; fertilization systems should be planned according to soil analysis and target production.
Regeneration and regrowth after cutting	For short-rotation systems, the ability to regenerate after cutting and restore growth is important; efficiency depends on the clone and cultivation technology.
Productivity (biomass, volume)	Growth rate, stock, and biomass yield vary significantly depending on clone, planting density, water availability, and agricultural practices.
Ecosystem services in agricultural landscapes	Potentially contributes to agro-landscape structuring, wind protection, microclimate regulation, erosion control, and diversification of production.
Carbon effect	May contribute to carbon sequestration in above-ground biomass and wood products; accurate assessment requires allometric models, plantation age, and growing conditions.
Wood properties and use	Wood is characterized by specific physical and mechanical properties that determine its areas of use; quality depends on age, diameter, growth conditions, and processing technology.
Biosafety and invasive potential	Some species may show invasive potential in certain regions; for hybrids and plantations preventive measures are important (control of self-seeding, origin of planting material, monitoring).

Source: based on own research

Rapid growth and the ability to intensively accumulate biomass make paulownia promising for use in bioenergy production systems, as well as in agroforestry and land reclamation plantations.



**Fig. 2.** Assessment of the winter hardiness of paulownia hybrids

Source: based on own research

As part of tree-field agroforestry systems, such plantations can perform both a productive and protective function, contributing to the improvement of the microclimate and the increase of the ecological stability of agricultural landscapes[4].

In the first years after planting, the inter-rows can be used for growing grain, fodder, or leguminous crops. This approach allows for more efficient use of land resources and provides additional economic benefits for agricultural enterprises.

Paulownia can also be used in agroforestry plantations, particularly in field protection forest belts. Thanks to their rapid growth, the trees are able to quickly form a protective effect, reducing wind speed, decreasing the intensity of deflation processes, and promoting moisture accumulation in the soil. This is particularly important for regions with insufficient moisture and an increased risk of soil erosion.

In addition, the integration of paulownia into the structure of agricultural landscapes contributes to increased biodiversity and improved ecological conditions in the areas. Thanks to their large leaf surface area, the trees actively absorb carbon dioxide and accumulate it in the form of biomass, which is important in the context of mitigating the effects of climate change.

The practical use of paulownia is also associated with the possibility of creating short-rotation plantations. After cutting, the trees are able to regenerate from the root system, which allows for several growing cycles without replanting. This significantly reduces the cost of creating new plantations and increases the economic efficiency of their use[16].

**Conclusions and prospects for further research.** Thus, paulownia is characterized by high growth rates, significant biomass accumulation potential, and the ability to adapt to various soil and climatic conditions. The integration of paulownia into the structure of agroforestry systems contributes to increasing the ecological sustainability of agricultural landscapes, improving microclimatic conditions, and reducing the intensity of erosion processes. The use of paulownia in tree-field systems allows combining the cultivation of woody vegetation with the production of agricultural products, which ensures more efficient use of land resources.

Thanks to its ability to grow and regenerate quickly, paulownia can be used to create short-rotation plantations for the production of wood biomass and other types of products. The use of paulownia in climate-adaptive agroforestry systems is a promising direction for the development of sustainable agriculture and forestry.

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## **АНОТАЦІЯ**

### **ДОСЛІДЖЕННЯ ПРАКТИЧНОГО ВИКОРИСТАННЯ PAULOWNIA SP., OXYTREE, ЯК ЕЛЕМЕНТУ КЛІМАТОАДАПТИВНИХ АГРОЛІСОВИХ СИСТЕМ**

У статті узагальнено сучасні підходи до практичного використання павловнії (*Paulownia* sp., *Oxytree*) як елемента кліматоадаптивних агролісових систем. Метою роботи є оцінка перспективи інтеграції павловнії в структуру агроландшафтів та визначення її потенційну роль у підвищенні екологічної стійкості й продуктивності агроєкосистем за умов посилення кліматичних ризиків (посухи, нерівномірність опадів, ерозійні процеси). Методологічну основу становили аналіз і систематизація літературних джерел, порівняльний аналіз біолого-екологічних і господарсько-цінних ознак *Paulownia* spp. та оцінювання можливостей застосування породи у деревно-польових, агролісомеліоративних та біоенергетичних схемах.

Розглянуто ключові властивості, що визначають придатність павловнії для агролісових насаджень: високі темпи росту в молодому віці, інтенсивне накопичення біомаси, здатність до відростання після зрізування (важлива для короткоротаційних плантацій), а також потенціал формування мікрокліматичних і протиерозійних ефектів у складі полезахисних насаджень. Особливу увагу приділено технологічним передумовам ефективного вирощування: світлолюбності, залежності продуктивності від вологозабезпечення, вимогам до ґрунтових умов (перевага добре дренованим ґрунтам), доцільності оптимізації схем посадки (4×4, 5×5 м або ширші міжряддя) для поєднання з вирощуванням культур у міжряддях і забезпечення механізованого догляду.

Ефективність використання павловнії істотно варіює залежно від виду чи клону та технології вирощування (живлення, зрошення, формування), а також потребує врахування обмежень (морозні ризики, чутливість до дефіциту вологи) і біобезпекових аспектів, зокрема потенціалу інвазійності окремих таксонів у певних регіонах. Інтеграція *Paulownia* sp. (*Oxytree*) у кліматоадаптивні агролісові системи може забезпечити оптимізацію використання земельних ресурсів, підвищення екологічної стабільності агроландшафтів та формування додаткового джерела деревної біомаси й деревинної продукції за умови контролюваного та науково обґрунтованого впровадження.

**Ключові слова:** Павловнія, агролісові системи, кліматоадаптивні технології, агролісомеліорація, стійкість агроландшафтів.

**Табл. 2., Рис. 2., Літ. 19.**

### **Інформація про авторів**

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