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Prospects for the use of Walnut and Poplar in agroforestry of Polissya and Forest-Steppe of Ukraine

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Abstract. Climate changes actualise the need for the transition of Ukraine's agricultural business to agroforestry systems not only in the steppe but also in the northern regions of the country. The purpose of the study is to examine the features of creating protective stands of Walnut (*Juglans regia* L.) and Poplars (*Populus* × *euramericana*) in Polissya and in the Forest-Steppe of Ukraine. Experimental plantings of Walnut were created by one-year-old seedlings on sod-podzolic sandy loam soils of Zhytomyr Polissya and on carbonate soils of the Western Forest-Steppe, and the analysis of the survival rate of Poplar plantings was conducted on chernozems of the Right-Bank Forest-Steppe. It was established that on sod-podzolic soils, five-year-old plants of Walnut had an average height of 91.8 cm. At the age of 4, some of them bore fruit. The fruit-bearing trees had higher indicators of average height of 13.4% and a diameter of 71.5% compared to the rest. On carbonate soils, the trees showed substantially better growth in height, which is explained by the calciphile nature of the nut. It is determined that an effective way to increase the survival

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rate of one-year-old seedlings of Poplar varieties Dorskamp, Robusta and I-45/51 is to plant them without trunks. In all the examined varieties, during the first two years, the highest survival rate of seedlings was in the variant without a trunk – from 57.0 to 68.9%, while in seedlings with a trunk – from 50.3% to 68.1%. In 2022, due to irrigation, the survival rate ranged from 74.4% to 88.9%. The average height was mostly also higher in plants that grew from seedlings without a trunk. It was the largest in plants of the Dorskamp clone – 188.6 to 209.3 cm. In uncut plants of this variety, it ranged from 174.0 to 197.2 cm. The practical importance of the study lies in the possibility of developing new forms of Walnut and Poplar and improving technologies for creating forest lands with their involvement, which can be used in Polissya and Forest-Steppe conditions.

Keywords: forest-field lands; *Juglans regia* L.; *Populus × euramericana*; seedlings; plantings; survival rate; average height; fruiting

Introduction

At the present stage of development of world agricultural production, it becomes clear that the existing management systems in agriculture are not viable in the long term, and excessive use of chemicals to increase the yield of field crops and protect them from weeds, pests, and diseases creates a serious danger to the environment. Food and Agriculture Organisation (FAO) (n.d.) recognises that complex, multi-faceted issues, including sustainable land use, require cross-sectoral approaches. The agenda in the field of sustainable development for the period up to 2030 not only defines the goals in sustainable development but also proposes the means to achieve them (Burgess & Rosati, 2018; Moreno *et al.*, 2018). In the context of increasing global competition, uncertainty and increasing risk of crisis factors both at the national and global levels, special emphasis in the process of land management is placed on the issues of their effective use. The complexity and lack of a unified approach to solving this problem has led to the need to develop scientific foundations for determining effective land use areas and modelling agri- and economic processes (Rigueiro-Rodriguez *et al.*, 2009; Smith *et al.*, 2013).

V.Yu. Yukhnovsky *et al.* (2019), I.D. Ivaniuk *et al.* (2022) argue that an extremely high risk to

European farming systems in the coming years is climate change, with steady warming, and an increase in the occurrence of unpredictable weather events, which negatively affects the development of the global economy. G. Moreno *et al.* (2018) note that optimising agricultural production is essential for obtaining the necessary amount of food and improving the resilience of European agricultural systems to current challenges.

An alternative area for the development of sustainable and rational use of land resources can be agroforestry – simultaneous cultivation of conventional crops and woody plants on agricultural land. Research M.L. Augère-Granière (2020) indicates the ability of larger or smaller groups of woody plants to improve, stabilise the environment, and control the negative impact of adverse natural phenomena and anthropogenic impacts. The authors note that agroforestry is a type of environmentally oriented agriculture that combines woody vegetation with objects of agricultural activity (agricultural crops or animals) to increase the economic and ecological efficiency of agricultural landscapes.

It can provide an increase in biomass production per hectare by an average of 40%, due to an increase in the leaf surface area per 1 ha,

which provides higher efficiency in the use of solar energy, compared to areas without trees (Mosquera-Losada *et al.*, 2012a; 2012b).

According to K. Kovács & A. Vityi (2019) and S. Fahad *et al.* (2022), one of the main types of agroforestry is silvoarable – growing agricultural (garden) crops in the aisles of tree alleys of a certain width. Therewith, wood and tree fruits are additional products that increase economic indicators, without substantially reducing the main crop yield.

The stable trend towards climate warming in Ukraine actualises the need to switch to agroforestry systems of agricultural business not only in the steppe but also in the Forest-Steppe regions of the country and in Polissya. The results of the studies by Ya.D. Fuchylo *et al.* (2022; 2023), and data from the State register of plant varieties suitable for dissemination in Ukraine (2022) confirm that under these conditions, woodlands using Walnut (*Juglans regia* L.) can be effective – mainly for the production of fruits and Euro-American hybrids of the Black Poplar section (*Populus* × *euramericana*) for the production of wood and energy biomass.

The purpose of the study was to examine the features of creating field-protected Walnut stands (*Juglans regia* L.) and Poplars (*Populus* × *euramericana*) in Polissya and in the Forest-Steppe of Ukraine.

The objectives of the study were to evaluate the effectiveness of the creation of agroforestry facilities in the Forest-Steppe and Polissya of Ukraine, using the two most effective systems of forest land (silvoarable): 1 – growing woody plants for the purpose of obtaining fruit and 2 – for growing high-quality wood.

Materials and Methods

The objects of the study were Walnut plantings created by one-year-old seedlings grown from seeds of fast-fruited, lateral, low-growing

forms, which can be considered the third generation of selection by L.S. Shugin (Skrypchuk, 2020; Shugins hazelnuts, n.d.). In the Rivne region, Walnut seedlings were planted in the fall of 2019 in pits with the addition of 9 litres of vermicompost, and on the grounds of the Malyn Vocational College – in the spring of 2020 using a similar technology. Due to the low moisture capacity of sandy loam sod-podzolic Polissya soils, drip irrigation and careful soil care were conducted during the first two years. After the end of each growing season, studies were conducted on the survival rate of seedlings, their growth, and fruit yield. The study of 4-year-old Walnut plantations were conducted in 2022 (Ivaniuk *et al.*, 2022). This study presents 5-year examination of these plants. During the study, the Convention on Biological Diversity (1992) standards were observed.

The study of the features of creating agroforestry objects using one-year-old seedlings of Poplar was conducted at the Experimental Field of the Institute of Bioenergy Crops and Sugar Beets of the National Academy of Agrarian Sciences of Ukraine. Three Poplar varieties were used in the studies: Dorskamp, Robusta and I-45/51. Seedlings of these varieties were grown from one-year-old seedlings and planted in the spring of 2020, 2021, and 2022. Rooting of plants, their safety, and growth were determined according to conventional methods in crop production (Fuchylo *et al.*, 2018).

Results and Discussion

Considering that after the completion of the first vegetative period, the seedling survival rate at Malyn Vocational College was 100%, and no plant losses were observed during the subsequent years. The height of the aboveground part of the seedlings at the time of their planting was 10.4 ± 0.64 cm, after the end of the fourth growing season (plant age – 5 years), their average height increased to 91.8 ± 6.49 cm (Table 1).

Table 1. Morphometric characteristics of Walnut seedlings

Morphometric indicators	one-year-old seedlings	Age of Walnut plants / calendar year			
		2/2020	3/2021	4/2022	5/2023
Height, cm	10.4±0.64	25.4±2.39	47.6±3.77	65.5±5.36	91.8±6.49
Height increase, cm	10.4	15.0	22.2	17.9	26.3
Root neck diameter, cm	0.8	1.2	1.8	2.3	2.9
Increase in the diameter of the root neck, cm	0.8	0.4	0.6	0.5	0.6

Source: compiled by the authors

The diameter of the root neck grew almost synchronously with the height, reaching 2.3 cm in four-year-old plants and 2.9 – in five-year-old ones. After the first year, the average increase in diameter was 0.4 cm, after the second – 0.6 cm, and after the fifth – 0.6 cm, that is, it was approximately the same in recent years. The relatively cold winter of 2020-2021

and spring with strong late frosts led to the complete freezing of the aboveground part of 56.3% of plants. Over the next two years, the nut trees were not damaged by low temperatures. Studies have shown that the average height of three-year-old seedlings affected by frost was 50.4±4.68 cm, and resistant to cold – only 44.0±6.31 cm (Table 2).

Table 2. Morphometric characteristics of groups of four-year-old Walnut seedlings that differ in cold resistance

Cold resistance	Morphometric parameters of seedlings	
	average height, cm	average diameter of the root neck, mm
2021 (three-year-old plants)		
Non-cold resistant	50.4±2.39	21.4±1.63
Cold-resistant	44.0±2.31	14.1±1.44
Difference, %	14.5	51.8
2022 (four-year-old plants)		
Non-cold resistant	59.6±2.90	26.0±2.71
Cold-resistant	83.3±8.94	23.1±2.82
Difference, %	-39.6	12.6
2023 (five-year-old plans)		
Non-cold resistant	78.7±6.48	31.0±3.64
Cold-resistant	109.4±12.45	26.1±2.91
Difference, %	-39.0	18.8

Source: compiled by the authors

Over the next 2 years, cold-resistant forms grew much more intensively and after the growing season of 2023 exceeded the indicators in non-cold-resistant plants by 39.0%. Seedlings exposed to frosts had a larger diameter of the root

neck during the study period. In 2021 – by 51.8%, in 2022 – by 12.6%, and in 2023 – by 18.8%. During the growing season of 2022, 22.7% of plants formed fruits in the amount of 3 to 17 pcs., or 6.6 pcs. on average, on one plant (Fig. 1a).

During the spring season of 2023, in the period of the flowering and pollination of nuts (in April), there was cold and rainy weather, which negatively affected the fruit set. Fruiting was

observed on the same trees where it was in the previous year, but not on all – the number of plants with fruits decreased to 18.2%. The average number of fruits was 5.0 pcs. per plant (Fig. 1b).

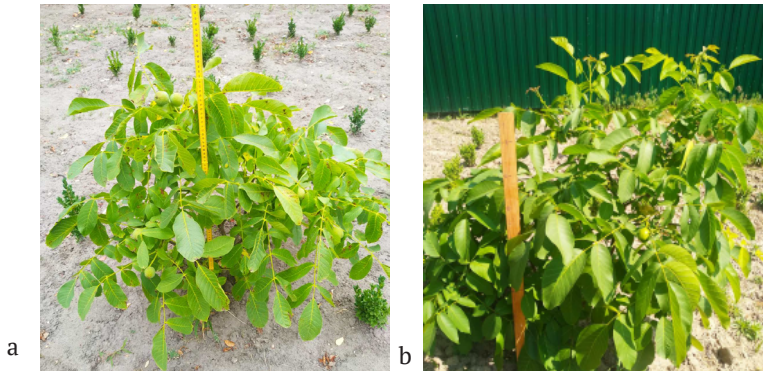


Figure 1. Fruiting of a Walnut in the conditions of Zhytomyr Polissya

Note: a – 2022; b – 2023

Comparison of morphometric indicators of trees that entered the fruiting stage and other trees (Table 3) showed that plants with fruits had higher indicators of average height (by 27.4% at 4 years of age and by 13.4% at

five years of age) and diameter – by 61.4% and 71.5%, respectively. The obtained data indicate that one of the markers of early fruitfulness of Walnut plants can be a larger diameter of the root neck and partially – a larger height.

Table 3. Morphometric characteristics of Walnut seedlings that differ in the beginning of fruiting

Fruit availability	Morphometric indicators	
	average height, cm	average diameter of the root neck, mm
Four-year-old plants		
With fruits	78.6 ± 4.51	32.6 ± 2.50
Without fruits	61.7 ± 5.22	20.2 ± 1.51
Difference, %	27.4	61.4
Five-year-old plants		
With fruits	101.0 ± 12.97	42.2 ± 4.85
Without fruits	89.1 ± 7.56	24.6 ± 1.78
Difference, %	13.4	71.5

Source: compiled by the authors

In the western Forest-Steppe zone, Walnut plantations grew and developed much more intensively. The growth of trees in 2020 ranged from 0.4 to 0.90 m. Some individuals

had fruit ovaries (0.5% of trees). In 2022, the growth of shoots ranged from 0.7 to 1.1 m. 48.5% of trees entered the fruiting stage (Fig. 2).



Figure 2. Fruiting of a four-year-old Walnut in the conditions of the Western Forest-Steppe
Source: photographed by the P. Skrypchuk (2020)

About 9% of the fruit had a cluster shape and a second flowering. According to the stage of development, about 15% of trees had later signs of development (budding, leaf colour, fruit development). Trees are characterised by different crown shapes: conventional (45%), cup-shaped and low-growing (up to 2%), and vertical (18%). The remaining trees are not structured and need to be formed in subsequent years.

P. Skrypchuk (2020), I.D. Ivaniuk *et al.* (2022), selected and analysed the morphological features of more than 80 varieties of Walnut in Rivne, Volyn, Khmelnytsky, Vinnytsia, Lviv, Kyiv, Kherson, Poltava, and other regions of Ukraine in recent years. The variety Soyka has been created and introduced into the State register of plant varieties suitable for dissemination in Ukraine (2022). It provides high indicators of stability and yield of trees in the northern and western parts of Ukraine.

There is a large difference in the size and reproductive characteristics of nuts selected by L. Shugin, which were grown in the Forest-Steppe and Polissya, is largely determined by soil conditions because Walnut needs calcium, and on the soils of Zhytomyr Polissya that are poor in calcium compounds, it grows and

develops worse, which should be considered when creating its plantings in this region.

Due to the lowering of the groundwater level on the territory of Ukraine, the use of Walnuts in the agroforestry system will increase due to its deep root system. In particular, a study of Chinese researchers W. Wu *et al.* (2022), showed that Walnut trees growing on the semi-arid Loess Plateau of China, compared to peach and apple trees, are characterised by a more stable response to dry periods due to their deep root system, which makes their use in these conditions more cost-effective.

It is advisable to continue research in the area of investigating morphometric and other characteristics of plants of fast-fruited forms of Walnut to identify new promising forms suitable for obtaining fruits and performing agroforestry functions.

European researchers K. Kovács & A. Vityi (2019), V.-N. Nicolescu *et al.* (2020), M. Báder *et al.* (2023) considering the agroforestry systems of different European countries, the types of trees used, the quality of wood produced in these systems, and analysing the current goals of support and practices of the European Union for agroforestry, indicate that agroforestry

projects are important and can lead to the spread of agroforestry systems in Europe. They play an important role in reducing wood scarcity. Therewith, Black Walnut and Poplar are considered among the most important tree species in the European agroforestry.

Unlike Walnut, Poplar plantings are practically not created by seedlings since most Poplars reproduce well vegetatively, and the planting material for creating their plantings is most often stem plantings and cuttings. The latter, as a rule, are grown for one year, while the average height of varieties taken for the study on leached chernozems of the Right-Bank Forest-Steppe is from 144 to 181 cm (Fuchylo *et al.*, 2022; 2023). The advantage of such planting material is that it already exceeds the height of

adjacent agricultural crops at the stage of creating forest lands. In particular, Indian researchers N. Sharma & R. Singh (2012) emphasise this, investigating wheat woodlands with American Black Poplar (*Populus deltoides* Marsh.).

The watering is usually used to increase the survival rate of cuttings, although this does not always contribute to the high survival rate of plants due to the substantial xerification of climatic conditions in recent years. In this regard, it has become necessary to search for new ways to ensure the high survival of one-year-old seedlings, in particular, the use of seedlings with the trunk removed as planting material. Studies have shown that such seedlings take root better and form trunks in one year that are taller than seedlings with an undivided trunk (Table 4).

Table 3. Survival rate of Poplar seedlings depending on varietal characteristics and type of planting material, %

Cultivar name	One-year-old seedlings	Years of the study		
		2020	2021	2022
Dorskamp	with a trunk	60.3 ± 2.40	68.1 ± 2.71	81.1 ± 4.15
	without a trunk	63.3 ± 2.92	71.5 ± 3.30	82.2 ± 4.05
Robusta	with a trunk	50.3 ± 2.40	56.8 ± 2.71	88.9 ± 3.33
	without a trunk	57.0 ± 3.01	64.4 ± 3.40	74.4 ± 4.62
I-45/51	with a trunk	57.1 ± 2.12	64.5 ± 2.39	77.8 ± 4.41
	without a trunk	61.0 ± 2.57	68.9 ± 2.90	75.6 ± 4.55

Source: compiled by the authors according to Ya.D. Fuchylo *et al.* (2023)

As can be seen from the above data, all the examined varieties during the first two years had higher survival rates of one-year-old seedlings in the variant with the cut aboveground part – from 57.0 ± 3.01 to 68.9 ± 2.90%.

In seedlings with an aboveground part, the survival rate ranged from 50.3 ± 2.40% to 68.1 ± 2.71%. During the growing season of 2022, due to irrigation, the highest survival rates of seedlings were obtained – from 74.4 ± 4.62% for the Robusta variety with removed trunks to 88.9 ± 3.33% for the same variety with trunks. Therewith, in the remaining clones examined, the survival rate of both variants of planting

material was approximately the same. In plants of the Dorskamp variety, it was 81.1 ± 4.15 and 82.2 ± 4.05%, respectively, and in I-45/51 – 77.8 ± 4.41 and 75.6 ± 4.55.

It was also established that in 2020, the average height was mostly higher in plants grown from seedlings without a trunk. The plants of the Dorskamp clone had the highest height – 189.5 ± 3.45 cm. In uncut plants of this variety, it was 174.0 ± 7.69 cm. Therewith, the height increase in seedlings with a trunk was very small and ranged from 4.6 to 17.7 cm.

The results of similar studies that were conducted during the growing season of 2021

showed that the indicators of preservation and height were slightly higher, but in general, the overall trend observed in 2020 continued. The growth of seedlings with trunks in 2021 was higher compared to 2020 – from 17.8 cm for the variety Robusta to 31.1 cm for Dorskamp. Accordingly, their average heights were also higher. Therewith, in the case of the Dorskamp variety, seedlings with trunks were slightly higher – 190.4 ± 7.93 cm against 188.6 ± 4.15 cm for using seedlings with the trunk removed.

The 2022 study generally confirmed the conclusions made in previous years. The highest height indicators at the end of the growing season in 2022, as in previous years, were established in plants of the Dorskamp variety. When using seedlings with trunks, the height was 197.2 ± 6.61 cm, and without trunks – 209.3 ± 5.62 cm.

The weather conditions of 2022 were the least favourable for the growth of plants of the I-45/51 variety. Their average height at the end of the growing season was 134.1 ± 4.31 cm when using seedlings with trunks, and 135.9 ± 4.94 cm without trunks.

In plants of the Robusta variety, the average height of plants from seedlings with trunks in 2022 for the first time in years of research was slightly higher than that of seedlings without trunks (160.1 ± 5.09 and 155.6 ± 5.91 cm, respectively), which is associated using irrigation.

In conclusion, it is important to highlight some positive aspects of the forest component of agroforestry, which are emphasised by a number of researchers investigating this problem. In particular, most of them (Szigeti & Vityi, 2019; Bayala & Prieto, 2020; Nicolescu *et al.*, 2020) indicate its high efficiency in terms of improving conditions for successful agricultural crops growth. Especially important is the role of tree stands in stabilising the moisture content of territories and reducing the temperature of the environment during the hottest parts of the

growing season. A study by North American researchers J. Ansari *et al.* (2023) showed high efficiency of absorption of inorganic nitrogen introduced with fertilisers from the soil by tree roots in agroforestry systems (forest pastures, field protection strips and alleys), which substantially reduces emissions of N_2O in the atmosphere. In this way, agroforestry maximises the efficiency of using N and simultaneously minimises nitrate pollution of air and drainage of water.

S. Fahad *et al.* (2022) indicate that planting trees on arable land substantially increases the content of organic carbon and nutrients in the soil, including nitrogen, phosphorus, metabolic potassium, etc. This reduces the need for fertilisers.

Thus, the conducted studies indicate a generally higher efficiency of using seedlings without trunks when creating forest fields and other Poplar plantings, compared to seedlings that were planted with trunks. In addition to higher survival rates of plantings and higher average plant height, this option releases a substantial number of one-year-old trunks, which can be used for harvesting high-quality seedlings to create other plantings, or growing cuttings.

Conclusions

The trend towards xerification of the climate of Ukraine actualises the need to switch to agroforestry systems of agricultural business not only in the Steppe, but also in the Forest-Steppe regions of the country and in Polissya. Under these conditions, wooded areas using Walnut can be effective (*Juglans regia* L.) – mainly for the production of fruits and hybrid Poplars – for the production of high-quality wood and energy biomass.

In the conditions of Zhytomyr Polissya, short-fruited five-year-old plants of Walnut of the selection by L. Shugin had an average height of 91.8 cm and a root neck diameter of 2.9 cm. Some of the trees entered the reproductive stage at the age of 4 years. Comparison of morphometric parameters of fruit-bearing trees and other

trees showed that plants with fruits had a higher average height (by 27.4% at 4 years of age and by 13.4% at five years of age) and diameter – by 61.4% and 71.5%, respectively. The obtained data indicate that one of the markers of early fruitfulness of Walnut plants can be a larger diameter of the root neck and partially – a larger height.

In the Western Forest-Steppe zone, the examined Walnut forms had substantially higher growth rates. In the fourth year, their height increase ranged from 0.7 to 1.1 m. 48.5% of the trees entered the fruiting stage. A substantial difference in the size and reproductive characteristics of Walnuts selected by L. Shugin, which were grown in the Forest-Steppe and in Polissya, is largely determined by soil conditions because Walnut needs calcium and on the soils of Zhytomyr Polissya that are poor in calcium compounds, it grows and develops worse, which should be considered when creating its plantings in this region.

There were no studies of the features of creating Poplar stands with one-year-old seedlings in the Forest-Steppe in recent decades, so the results obtained have elements of scientific originality and practical importance.

The results of the study have shown that an effective way to increase the survival rate of one-year-old Poplar seedlings when creating agroforestry fields and other plantings is to plant them without an aboveground part. In addition to higher survival rates and higher average plant height, this option releases a substantial number of one-year-old shoots, which can be used as planting material for creating other Poplar plantings or growing seedlings. The research towards using various storage options, other planting dates, the use of superabsorbents, etc. should be continued to increase the survival rate of cuttings seedlings.

It is advisable to continue research in the area of investigating morphometric and other characteristics of plants of fast-fruiting forms of Walnut to identify new promising forms suitable for obtaining fruits and performing agroforestry functions.

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Conflict of Interest

The authors declare no conflict of interest.

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Перспективи використання горіха волоського та тополі в агролісівництві Полісся та Лісостепу України

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Анотація. Кліматичні зміни актуалізують необхідність переходу аграрного бізнесу України до агролісівничих систем не тільки у степових, а й у північних регіонах країни. Мета досліджень – вивчення особливостей створення полезахисних насаджень волоського горіха (*Juglans regia* L.) та тополі (*Populus × euramericana*) на Поліссі та в Лісостепу України. Дослідні насадження швидкоплідного горіха створені однорічними сіянцями на дерново-підзолистих супіщаних ґрунтах Житомирського Полісся та на карбонатних ґрунтах Західного Лісостепу, а дослідження приживлюваності живцевих саджанців тополі виконувались на чорноземах Правобережного Лісостепу. Встановлено, що на дерново-підзолистих ґрунтах п'ятирічні рослини скороплідного гріха волоського мали середню висоту 91,8 см. У віці 4 роки деякі з них запліднили. Плодоносні деревця мали на 13,4 % більшу середню висоту і на 71,5 % більший діаметр, порівняно з рештою. На карбонатних ґрунтах горіхи відзначалися значно кращим ростом за висотою, що пояснюється кальцефілією горіха. Визначено, що ефективним способом підвищення показників приживлюваності однорічних живцевих саджанців сортів тополі 'Dorskamp', 'Robusta' та 'I-45/51' є їх висаджування без стовбурів. У всіх досліджуваних сортів протягом перших двох років вища приживлюваність саджанців була у варіанті без стовбура – від 57,0 до 68,9 %, тоді як у саджанців зі стовбуром – від 50,3 % до 68,1 %. У 2022 р., завдяки проведеному поливу, приживлюваність становила від 74,4 % до 88,9 %. Середня висота переважно теж була вищою у рослин, що вирости із саджанців без стовбура. Найбільшою вона виявилася у рослин клону 'Dorskamp' – 188,6 до 209,3 см. У необрізаних рослин цього сорту вона становила від 174,0 до 197,2 см. Практичне значення дослідження полягає в можливості виведення нових форм горіха і тополі та удосконалення технологій створення лісопольових угідь за їх участі, які можуть бути використані в умовах Полісся і Лісостепу.

Ключові слова: лісопольові угіддя; *Juglans regia* L.; *Populus × euramericana*; сіянці; саджанці; приживлюваність; середня висота; плодоношення