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Improving propagation technology of *Ligustrum L.* planting material for greening urbanised areas

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Abstract. The relevance of the study is due to the need to improve the quality of planting material and expand the range of ornamental plants for landscaping urbanised areas. The aim of the study was to improve the technology of privet propagation, taking into account the biological characteristics and factors affecting the rooting process, such as the use of root formation stimulants and the choice of substrates. Comparison of rooting of green and lignified cuttings revealed different efficiency depending on the substrates and root formation stimulants used, in particular, Rizopon, Heteroauxin super and Grandis. The experiments showed that the most effective root stimulant was Rizopon, which increased the percentage of rooting of cuttings by 5-10% compared to the control. The highest rooting rates were observed in *Ligustrum vulgare* L. and its cultivars 'Atrovirens' and 'Aurea', reaching 96 %. The substrate based on peat and river sand (2:1) was the most optimal for most species, while for *Ligustrum ibota* 'Musli' the use of pure river sand was more effective. The results of propagation by lignified cuttings showed an order of magnitude higher percentage of rooting for most of the studied plants, in particular, *L. vulgare* L., and its cultivars, the percentage of rooting ranges from 86-96%, while rooting by green cuttings – from 85-90%. In the case of *L. ovalifolium* Hassk. These indicators were somewhat lower but satisfactory, lignified cuttings 75-92%, green cuttings 74-90%. *L. ibota* 'Musli' and *Ligustrum japonicum* 'Green Century' have mediocre rooting results both with lignified and green cuttings, *L. ibota* 'Musli' when propagated by lignified cuttings had a result in the range of 12-14%, and lignified cuttings 66-68%. *L. japonicum* 'Green Century' had a higher percentage of rooting when propagated by lignified cuttings 47-62%. The results of the study can be used to increase the efficiency of privet propagation and improve the technology of growing high-quality planting material resistant to the conditions of the urbanised environment. These studies serve as an informational scientific basis for improving the systems of ornamental seedling production

Keywords: ornamental nursery; vegetative propagation; green plantings; substrate; rootability; urban environment; morphometric indicators

Introduction

Plants play an important role in creating a comfortable and healthy climate in urban landscapes. In general, they have a positive effect on both the psycho-emotional state of a person and air quality, reducing the level of pollution and preserving the ecological integrity of urban ecolandscapes. When planning urban green spaces at the macro and regional levels, it is extremely important to study plant species of urban green spaces and introduce new species taking into account climatic conditions environmental pollution.

J.C. Fisher *et al.* (2022) described the importance of plants in urban environments, demonstrating that an increase in the number of

flowering plants in cities positively affects people's mental wellbeing, highlighting the role of urban biodiversity in enhancing the quality of life in cities. This is complemented by the research of S. Ghafari *et al.* (2020) and T. Blanusa *et al.* (2019), who assess plant species for urban green spaces. They emphasized the importance of selecting appropriate plant species, particularly for hedges, that contribute to urban biodiversity and the well-being of residents. O. Strashok (2022) also examined the significant role of urban plants in shaping the microclimate of modern cities, along with their recreational and aesthetic functions. The study highlighted the impact of climate change and

temperature variability on plant growth and development, focusing on the adaptive potential of plants in the urban environment, particularly in Kyiv.

An important element of urban green spaces is privet (*Ligustrum*). This is determined not only by its aesthetic qualities but also by its ability to adapt to various growing conditions, including care practices, as noted by H.B. Lukashchuk (2020). S.I. Kuznetsov *et al.* (2020) and J. Dong *et al.* (2021) described common privet as a highly winter- and drought-resistant plant, undemanding to soil, tolerating slight soil salinity, and thriving well in urban environments, particularly in conditions of air pollution. Special attention is given to its resistance to dust and gas, as highlighted by T. Tkachenko *et al.* (2023). With the increasing popularity of this plant, there is a need to provide high-quality planting material.

As stated by V.M. Maurer (2019), to obtain uniform seedlings, including privet (*Ligustrum*), the vegetative propagation method was most often used, namely, cuttings, since it allowed to preserve the genetic features of the mother plant and obtain material that corresponds to the specified characteristics, for example, the colour of the leaves, or crown shape. However, the propagation process requires the improvement of scientific and agrotechnical methods to improve the quality and efficiency of growing privet (*Ligustrum*) planting material and its cultivars.

The study of factors affecting the root-forming ability of shoots and the subsequent growth of these plants is a key aspect for improving cultivation technology. As noted by E. Kentelky *et al.* (2021), biological features of the taxon, parameters of the physiological state of plants, rooting conditions and the use of various drugs can affect the reproduction process. In particular, E.M. Badawy *et al.* (2020) in their study described the process of reproduction of *Ligustrum ovalifolium* L., where the main

emphasis was placed on the timing of cutting material harvesting, as well as the effect of auxins on the quantity and quality of root formation. P. Basuchaudhuri (2021) researched the effect of auxins on the rooting ability of the cutting material, in particular, the most popular and most reliable hormone for rooting is IBA – indolylbutyric acid, although NAA – naphthylacetic acid was also used. H. Chen *et al.* (2023) investigated the effect of different concentrations of indole-3-acetic acid (IAA), indole-3-butyric acid (IBA) and indene-naphthaleneacetic acid (ABT-1) on rooting and dynamic changes in endogenous hormone content in cuttings. Additionally, I. Karakaş & B. İzci (2024) explored the application of auxins (IBA 2000 ppm and NAA 1000 ppm) for the rooting of lavender cuttings. In turn, K. Chinnasamy *et al.* (2024) analysed the effects of auxin at various concentrations, specifically IBA and NAA (1000, 2000, 3000, 4000, and 5000 ppm), on the rooting of *Morus indica* L. cuttings. The effect of auxins on the rooting of cuttings was also investigated by V.R. Fursa & A.P. Pinchuk (2024), in particular the use of the following stimulants was described: Rhizopon AA (1%) (powder, 3-indolylbutyric acid (IBA), 1-Naphthylacetic acid (NOA) and 3-Indoleacetic acid (IC)), succinic acid and potassium humate. Certain aspects of the technology of growing privet (*Ligustrum*), in particular *Ligustrum ovalifolium*, *Ligustrum ibota* and *Ligustrum japonicum*, remain under studied by researchers and require a deeper study.

The aim of this study was to improve the technology for cultivating planting material that preserves the ornamental traits of the parent privet (*Ligustrum*) plants and their cultivars, taking into account all aspects of their biological characteristics and factors affecting propagation. To achieve this goal, the following tasks were outlined: to assess the reproductive capacity of cuttings and to develop scientific recommendations for optimal cutting practices

for these plants. This approach to the research will support the improvement of privet (*Ligustrum*) cultivation methods and contribute to the development of more effective strategies for producing high-quality, uniform planting material that can be used in urban landscaping.

Materials and Methods

Studies on vegetative propagation of species and cultivars of the genus *Ligustrum* were conducted during the period 2022-2024. During the study,

ethical standards outlined in the following were adhered to Convention on Biological Diversity (1992) and Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

The research used species of the genus *Ligustrum* L. and their cultivars, in particular: *Ligustrum vulgare* L., *L. vulgare* 'Atrovirens', *L. vulgare* 'Aurea', *Ligustrum ovalifolium* Hassk., *L. ovalifolium* 'Aureum', *L. ovalifolium* 'Green Diamond', *L. ovalifolium* 'Vicaryi', *Ligustrum ibota* 'Musli', *Ligustrum japonicum* 'Green Century' (Fig. 1).

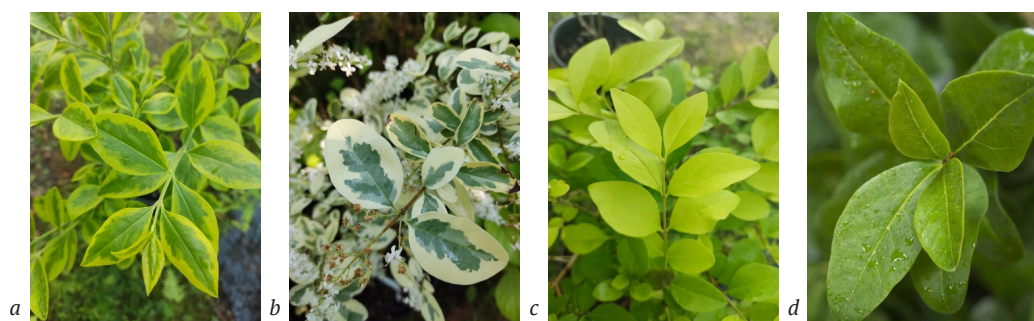


Figure 1. Decorative qualities of leaves of mother plants of certain cultivars of the *Ligustrum* L. **Note:** a – *L. ovalifolium* 'Aureum', b – *Ligustrum ibota* 'Musli', c – *L. ovalifolium* 'Vicaryi', d – *L. ovalifolium* 'Green Diamond'

Source: photos made by the authors

In general, such an assortment of species and cultivars was due to a wide range of shapes and colours of leaves, their most frequent use in landscaping, and the availability of these plants in garden centers and nurseries of Ukraine. All the mentioned plants grow both in open ground and in container culture, in particular *Ligustrum ibota* 'Musli', *Ligustrum japonicum* 'Green Century', in the nursery of the Educational-scientific-production laboratory of tree nursery, reproduction of forests and land reclamation of the department of reproduction of forests and forest land reclamation of the National University of Life and Environmental Sciences of Ukraine.

Mother plants, from which cuttings were taken, were aged from 3 to 5 years. There were no signs of damage by pests or diseases. As for

growing conditions, these plants grew on soils of medium fertility and moisture in partial shade. Propagation of experimental plants was carried out by two methods, lignified – winter, and green – summer cuttings (Maurer, 2019), in greenhouse conditions.

The method of propagation by lignified and green cuttings was carried out according to the methods used by the botanical garden of the National Academy of Sciences of Ukraine (Kolesnichenko et al., 2008), however, the main methods of propagation were adapted in the author's modification, taking into account the characteristics of the species and cultivars of the studied plants. In the process of reproduction by lignified cuttings from mother plants during the rest period, at the end of February,

the beginning of March, shoots were pre-cut, from which cuttings of 8-10 cm size were subsequently formed, approximately 3-4 buds, such cuttings were 5-8 mm in diameter, the upper section is straight, the lower one at an angle of 45°. In the process of planting, the cuttings were deepened by 50-60% of the total length.

When propagating with green – summer cuttings, cuttings from the current year's shoots were used, which actually finished or are finishing their growth and did not have time to become woody, in particular, the period was chosen from the end of July to the beginning of August. The length of the cuttings was on average 5-8 cm, with one or two internodes (however, in the case of *Ligustrum ibota* 'Musli', the number of internodes was 4-5, due to the peculiarity of the shoot structure). Accordingly, the upper cut was made 1 cm above the leaf petiole, and the lower one 1-3 cm below the petiole. Also, in order to prevent excessive evaporation of moisture, the leaf plates were cut in half. The temperature regime in this method was 25-30 °C and air humidity – 85-95%.

For rooting, clean river sand (II in the table) and a mixture of river sand with neutral peat in a ratio of 1:2 (I in the table) was used as a substrate. As an auxiliary factor for improving rooting indicators, powdered preparations (powder) that stimulate the formation of roots were also used. Accordingly, the content of the active substance in these preparations is indicated by the manufacturers as follows, Rizopon AA Proszek 1% – 5-(3-indolylbutyric acid) 9.9 g/kg, Heteroauxin Super – indolyl-3-acetic acid potassium salt 50 g/kg, Grandis-Indolyl-3-butyric acid 6 g/kg.

The peculiarity of the use of these drugs was to apply the powder to the lower section of the cuttings, for both methods, the same length of 1-1.5 cm. Measurement results were presented as mean \pm standard error ($\bar{x} \pm SE$). The significance of the difference ($p < 0.05$) between the obtained data was determined by the method of variance analysis (one-way ANOVA) using Tukey's a posteriori test in the XLSTAT program.

Results and Discussion

When carrying out a comprehensive analysis of the influence of propagation methods, type of substrate and the use of stimulators on the rooting of green and lignified cuttings of various species and cultivars of privet (*Ligustrum*), special attention was paid to the comparisons between the different stimulators of root formation and their rooting conditions.

The obtained results indicate a significant variability of rooting percentages depending on the applied methods and rooting conditions. It was found that some types of privet responded better to certain stimulants and conditions, while others were less sensitive to the changed factors and showed a mediocre rooting result.

When propagating by lignified cuttings, the rooting of all studied cultivars and species is partially different (Table 1). Thus, under control conditions, that is, without the use of drugs, the highest rooting rate of 90.2-92.0% is in *Ligustrum vulgare* L. and its cultivars 'Atrovirens', 'Aurea' (Fig. 2), in the first (peat+sand) substrate, when using the second (sand) substrate, rooting is somewhat less, and varies in all plants differently.

Table 1. Indicators of the percentage of rooting of lignified cuttings, with the use of root formation stimulators

No.	The name of the plant	Control, %		Type of rooters					
				Rizopon, %		Heteroauxin super, %		Grandis, %	
		Substrate	I	II	I	II	I	II	I
1	<i>Ligustrum vulgare</i> L.	90.2 ^{±1.48}	89.6 ^{±1.14}	95.4 ^{±0.55}	91.4 ^{±1.34}	92.4 ^{±1.52}	89.8 ^{±0.45}	93.6 ^{±0.55}	90.4 ^{±0.55}
2	<i>L. vulgare</i> 'Atrovirens'	93.6 ^{±0.89}	88.8 ^{±2.17}	96.2 ^{±1.64}	93.8 ^{±0.84}	92.2 ^{±1.64}	91.0 ^{±1.00}	94.4 ^{±2.07}	92.6 ^{±1.67}
3	<i>L. vulgare</i> 'Aurea'	91.8 ^{±2.28}	85.0 ^{±1.58}	94.6 ^{±1.14}	91.2 ^{±1.10}	91.6 ^{±0.55}	86.4 ^{±0.89}	91.0 ^{±1.22}	89.6 ^{±1.52}
4	<i>L. ovalifolium</i> Hassk.	89.4 ^{±1.95}	85.8 ^{±1.64}	92.2 ^{±1.30}	91.0 ^{±1.00}	92.0 ^{±1.22}	90.0 ^{±0.71}	89.8 ^{±1.48}	88.2 ^{±1.30}
5	<i>L. ovalifolium</i> 'Aureum'	65.6 ^{±0.89}	59.6 ^{±1.52}	84.8 ^{±0.45}	78.8 ^{±1.30}	85.0 ^{±0.71}	77.2 ^{±0.84}	82.8 ^{±0.45}	75.6 ^{±1.14}
6	<i>L. ovalifolium</i> 'Green Diamond'	82.5 ^{±1.56}	73.8 ^{±1.30}	84.4 ^{±0.55}	77.8 ^{±1.30}	80.0 ^{±1.58}	75.0 ^{±1.00}	80.2 ^{±1.79}	77.2 ^{±0.84}
7	<i>L. ovalifolium</i> 'Vicaryi'	92.0 ^{±1.58}	82.4 ^{±1.34}	91.3 ^{±1.16}	88.2 ^{±1.64}	90.4 ^{±0.89}	84.4 ^{±1.14}	91.0 ^{±0.71}	84.8 ^{±1.30}
8	<i>Ligustrum ibota</i> 'Musli'	12.4 ^{±2.06}	9.8 ^{±0.84}	13.1 ^{±1.14}	14.0 ^{±1.4}	14.4 ^{±2.07}	12.6 ^{±2.30}	13.2 ^{±2.05}	12.0 ^{±1.58}
9	<i>Ligustrum japonicum</i> 'Green Century'	67.1 ^{±0.51}	55.0 ^{±2.45}	66.2 ^{±0.84}	62.8 ^{±0.45}	47.0 ^{±2.35}	54.2 ^{±1.64}	51.4 ^{±1.67}	56.2 ^{±1.30}

Note: the significance of the difference $p < 0.05$

Source: developed by the authors

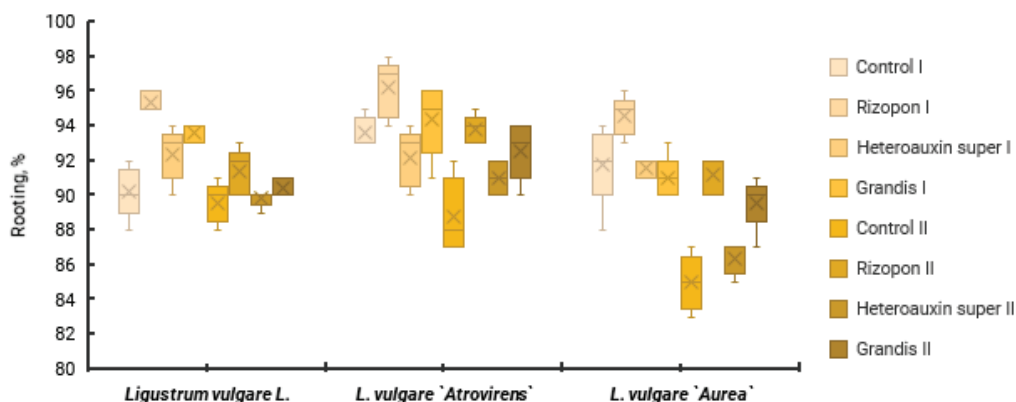


Figure 2. Results of rooting of lignified cuttings of *Ligustrum vulgare* L. and cultivars 'Atrovirens', 'Aurea'

Source: developed by the authors

In particular, *Ligustrum vulgare* L. cultivars, as well as two plants of *L. ovalifolium* Hassk, showed relatively good results and *L. ovalifolium* 'Vicaryi'. In turn, *L. ovalifolium* 'Aureum' and

Ligustrum japonicum 'Green Century' showed mediocre results of rooting, and amounted to no more than 65-67%. *Ligustrum ibota* 'Musli' had the worst rooting rates in the control

conditions, namely 9.8%, although the use of the first substrate had a more positive effect on its rooting, and is 12.4%.

According to the results of the use of root formation preparations, it is possible to see positive dynamics in the rooting of almost all experimental privet plants. The most optimal

variant of the stimulator was Rizopon, %, in contrast to the control, the percentage of rooting increased on average by almost 5% for all plants. *Ligustrum vulgare* L. has the highest indicators – 95.4%, *L. vulgare* ‘Atrovirens’ – 96.2% (Fig. 3) in the first substrate, and 93.8% in the second.

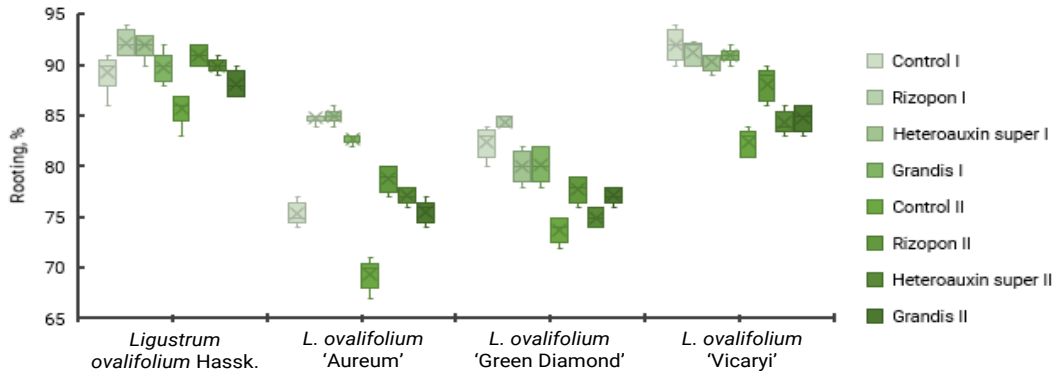


Figure 3. Results of rooting of lignified cuttings of *Ligustrum ovalifolium* Hassk. and its cultivars ‘Aureum’, ‘Aurea’, ‘Green Diamond’, ‘Vicaryi’

Source: developed by the authors

In the case of *L. ovalifolium* ‘Aureum’, ‘Vicaryi’ (Fig. 3), the use of rooting drugs generally has a positive effect on the formation of roots, and an increase in results up to almost 20% is observed in fact for all drugs, which cannot be said for *Ligustrum japonicum* ‘Green Century’ (Fig. 4) when using stimulants, there was no desired increase in rooting rates. *Ligustrum ibota* ‘Musli’ (Fig. 4) reacted positively to the use of drugs, but still the percentage of rooting is extremely small, and is 14.4%, when using Heteroauxin super. Comparing the rooting results of all three drugs, the most optimal for use was Rizopon, and to a lesser extent Grandis, in relation to Heteroauxin super, a positive rooting dynamics is observed, but it differs from the control conditions by a not very large percentage. As in the control conditions, the first substrate (peat+sand) is the best for rooting almost all

plants, but the rooting of *Ligustrum japonicum* ‘Green Century’ in the second substrate (sand) turned out to be an order of magnitude higher under the condition of using rooting preparations, on average this percentage was 4%-7%, which is not observed in control conditions.

The condition of the root system for all studied species and cultivars of privet is good, although the intensity of branching in individual cultivars was much greater, and even the average number of roots in rooted cuttings differed. Thus, *Ligustrum vulgare* L. (Fig. 5a), *L. vulgare* ‘Atrovirens’ (Fig. 5b) and *L. vulgare* ‘Aurea’ (Fig. 5c) had a more branched root system. The formation of roots was observed along the entire length of the cutting, starting from the soil surface, that is, the roots of these plants were formed not only from the lower section of the cutting, but also from

lentils, which are characteristic of this species and its cultivars. The average number of roots for *Ligustrum vulgare* and cultivars was about 12-15 sproutings. Also, intensive branching of secondary roots was observed in these plants, which was not observed in other plants. Root formation in *L. ovalifolium* Hassk., *L. ovalifolium* 'Aureum' (Fig. 5d), *L. ovalifolium* 'Green Diamond' (Fig. 5e) and *L. ovalifolium* 'Vicaryi' (Fig. 5f) occurred only from the lower section

of the cuttings, since this species and its cultivars do not have such an intensive formation of lentils on the shoots, or according to observations, they are absent at all. In general, root formation in all cultivars, including the species plant, is similar. The average number of roots also ranges from 8 to 11 sproutings. In contrast to *Ligustrum vulgare*, intensive formation of second-order roots was not observed in these plants.

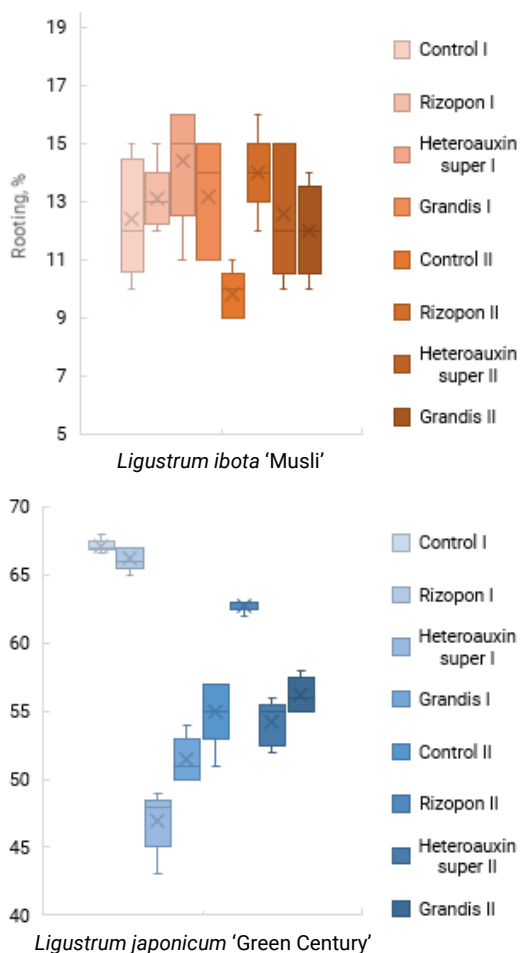


Figure 4. Results of rooting of lignified cuttings of *Ligustrum ibota* 'Musli' and *Ligustrum japonicum* 'Green Century'

Source: developed by the authors

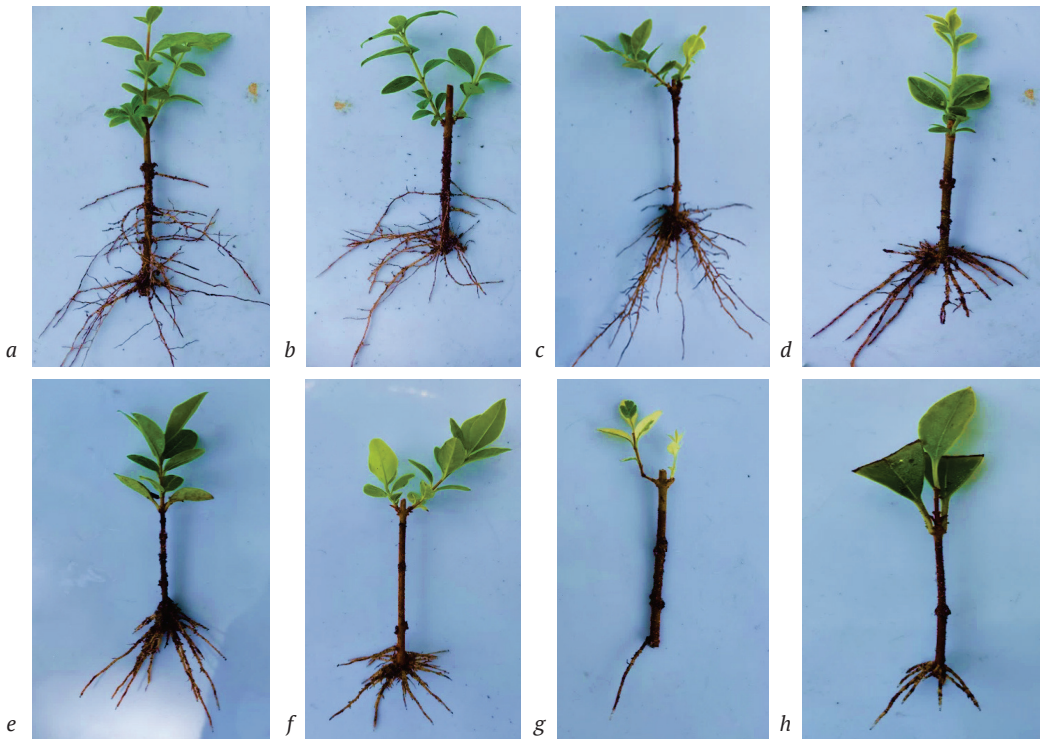


Figure 5. The nature of the development of the root system by lignified cuttings of privet species and cultivars, when using the stimulator Rizopon

Note: a – *Ligustrum vulgare* L, b – *L. vulgare* ‘Atrovirens’, c – *L. vulgare* ‘Aurea’, d – *L. ovalifolium* ‘Aureum’, e – *L. ovalifolium* ‘Green Diamond’, f – *L. ovalifolium* ‘Vicaryi’, g – *Ligustrum ibota* ‘Musli’, h – *Ligustrum japonicum* ‘Green Century’

Source: photos made by the authors

The character of the development of the root system in *Ligustrum japonicum* ‘Green Century’ (Fig. 5h) is not bad, however, unlike *L. vulgare* and *L. ovalifolium*, the intensity of root growth in this plant is somewhat slowed down. The average number of roots was 4-6 sproutings. A characteristic feature of this plant is that the formed roots, although not long, have a comparatively greater thickness, approximately 1.5-2 times greater than those of other cultivars

and species. *Ligustrum ibota* ‘Musli’ (Fig. 5g) has the lowest rooting rates among experimental plants (Table 1). In general, the development of roots in this plant is also not satisfactory, since the number of roots on all rooted cuttings was mostly 1-2 sproutings.

In contrast to propagation by lignified cuttings, rooting results from green cuttings are somewhat lower, and also vary under different conditions and for different plants (Table 2).

Table 2. Indicators of the percentage of rooting of green cuttings, with the use of stimulators of root formation

No	The name of the plant	Control, %		Type of Rooters					
				Rizopon, %		Heteroauxin super, %		Grandis, %	
	Substrate	I	II	I	II	I	II	I	II
1	<i>Ligustrum vulgare</i> L.	86.8 ^{±1.10}	85.0 ^{±1.22}	91.2 ^{±0.84}	89.8 ^{±0.45}	90.2 ^{±0.45}	88.0 ^{±1.22}	91.0 ^{±2.24}	87.8 ^{±1.10}
2	<i>L. vulgare</i> 'Atrovirens'	88.8 ^{±0.44}	82.2 ^{±1.30}	91.0 ^{±0.71}	87.2 ^{±0.84}	87.6 ^{±0.55}	83.6 ^{±1.82}	89.4 ^{±1.52}	85.4 ^{±1.52}
3	<i>L. vulgare</i> 'Aurea'	83.4 ^{±0.89}	83.2 ^{±1.30}	89.2 ^{±1.92}	87.2 ^{±1.64}	87.6 ^{±2.41}	85.4 ^{±0.55}	88.4 ^{±2.41}	85.4 ^{±2.41}
4	<i>L. ovalifolium</i> Hassk.	84.2 ^{±2.39}	77.6 ^{±2.07}	88.8 ^{±0.45}	83.8 ^{±1.95}	83.6 ^{±1.67}	78.6 ^{±1.95}	86.4 ^{±2.70}	81.4 ^{±2.30}
5	<i>L. ovalifolium</i> 'Aureum'	81.0 ^{±1.04}	75.6 ^{±1.14}	94.8 ^{±1.05}	89.0 ^{±0.00}	91.4 ^{±0.55}	83.8 ^{±1.92}	89.6 ^{±1.82}	84.8 ^{±0.84}
6	<i>L. ovalifolium</i> 'Green Diamond'	74.6 ^{±0.89}	70.2 ^{±1.48}	86.6 ^{±1.14}	81.2 ^{±0.84}	83.0 ^{±1.41}	76.0 ^{±1.22}	84.2 ^{±5.05}	81.8 ^{±1.30}
7	<i>L. ovalifolium</i> 'Vicaryi'	82.5 ^{±1.39}	75.4 ^{±0.89}	83.6 ^{±0.89}	76.4 ^{±2.07}	81.4 ^{±3.78}	75.8 ^{±1.50}	83.2 ^{±2.05}	75.4 ^{±1.67}
8	<i>Ligustrum ibota</i> 'Musli'	34.9 ^{±2.43}	35.8 ^{±2.39}	66.5 ^{±1.66}	68.4 ^{±0.55}	66.2 ^{±4.60}	68.4 ^{±2.41}	66.0 ^{±2.83}	64.2 ^{±2.77}
9	<i>Ligustrum japonicum</i> 'Green Century'	21.0 ^{±2.94}	17.0 ^{±2.24}	42.8 ^{±2.86}	38.0 ^{±2.55}	41.8 ^{±2.77}	33.0 ^{±2.24}	44.0 ^{±2.65}	35.2 ^{±2.39}

Note: the significance of the difference $p < 0.05$

Source: developed by the authors

Control samples *Ligustrum vulgare* L. (Fig. 6), *L. ovalifolium* Hassk. (Fig. 7) and their cultivars mostly have similar rooting results, and the difference in the number of rooted cuttings both in the first and in the second substrates is not very different. In general, when using a substrate made of peat and sand, the quantitative indicator of rooting is 2-5% higher, in contrast to pure sand, precisely for these plants. However, considering two other species, in particular *Ligustrum ibota* 'Musli' and *Ligustrum japonicum* 'Green Century' (Fig. 8), it was

shown completely different dynamic. Thus, the percentage of rooting by green cuttings of *Ligustrum ibota* 'Musli' is actually three times higher than propagation by lignified cuttings, although in general this result is not satisfactory and is only 34-35%. *Ligustrum japonicum* 'Green Century', in contrast to the method of propagation by lignified cuttings, showed a much worse result. The percentage of rooting in the control sample in two substrates was 17-21%, which is 2.5 times less compared to lignified cuttings.

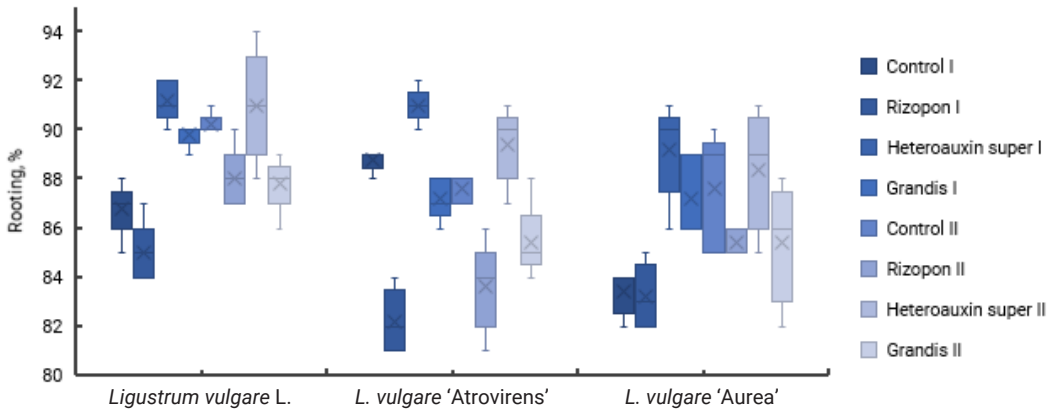


Figure 6. Rooting results of green cuttings of *Ligustrum vulgare* L. and cultivars 'Atrovirens', 'Aurea'

Source: developed by the authors

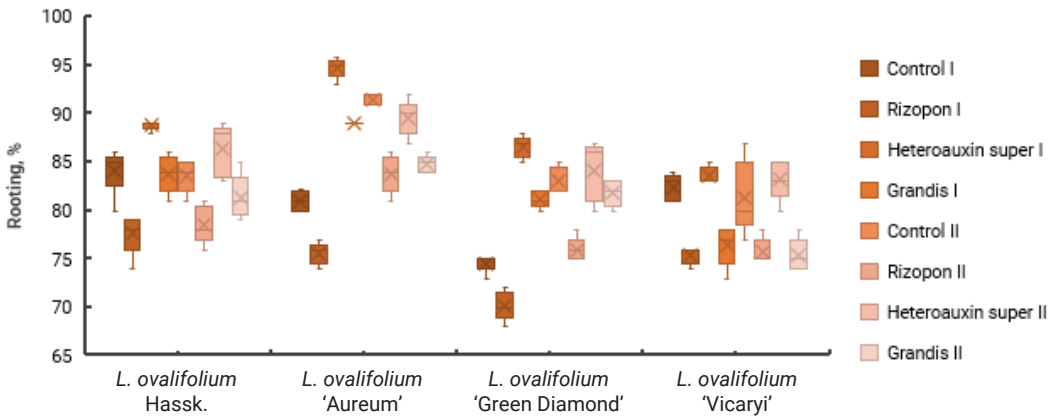


Figure 7. Rooting results of green cuttings of *Ligustrum ovalifolium* Hassk. and its cultivars 'Aureum', 'Aurea', 'Green Diamond', 'Vicaryi'

Source: developed by the authors

Rooting indicators with the use of rooting stimulants also remain relatively stable. According to the results of Table 2, it is possible to follow the same dynamics as in the case of propagation by lignified cuttings, that is, the highest percentage of rooting in all plants is observed when using Rizopon rooting agent, the quantitative indicators of rooting with its use are increased

by 3-5%. The highest rates of rooting when using this drug can be seen in the following plants: *Ligustrum vulgare* L. – 91.2%, *L. vulgare* 'Atrovirens' – 91.0% (Fig. 6) and *L. ovalifolium* 'Aureum' (Fig. 7) with the highest rate – 94.8%. In particular, these results were obtained when using the first substrate (peat + sand, 1:1), but in pure river sand the percentages are slightly lower.

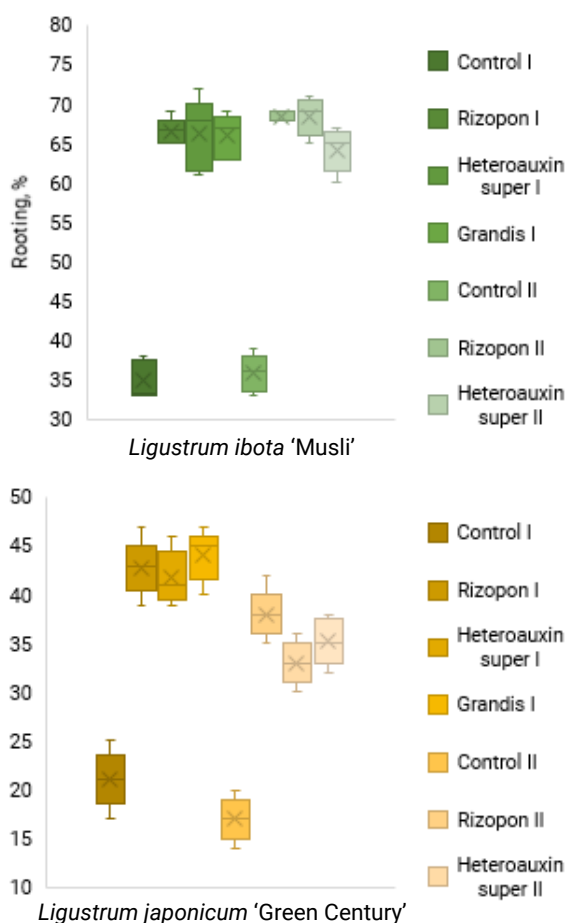


Figure 8. Rooting results of green cuttings of *Ligustrum ibota* 'Musli' and *Ligustrum japonicum* 'Green Century'

Source: developed by the authors

In turn, the percentage of rooting that exceeds 90 can also be observed with the use of other drugs, in particular with the use of "Heteroauxin super", good results are obtained in *Ligustrum vulgare* L. – 90.2% (Fig. 6), and *L. ovalifolium* "Aureum" – 91.4% (Fig. 7) while when using the Grandis stimulator, a high rate of rooting is noticeable only in *Ligustrum vulgare* L. – 91.0%, the tendency of better rooting in the first substrate usually remains.

L. ovalifolium Hassk. (Fig. 7) and its cultivars generally responded positively to the use of root-forming preparations. Thus, the rate of rooting varies between 81-88%. Using a mixture of peat and sand (1:2) as a substrate shows positive dynamics for these plants. When using *L. ovalifolium* 'Vicaryi' as pure river sand (Fig. 7), the quantitative index of rooting is significantly lower in contrast to the main substrate, and ranges from 75.4% to 76.4%,

while the use of the first substrate (peat + sand) showed 81.4%-83.6%.

It is also necessary to note the positive dynamics of rooting with green cuttings for *Ligustrum ibota* 'Musli'. Compared to the results of rooting with lignified cuttings in this case, the percentage of rooting is actually 2-3 times higher. In particular, in the control conditions, it was only 34.9-35.8% (Fig. 8), and already with the application of rooting preparations, the rooting indicators actually doubled: Rizopon – 68.4%; Heteroauxin super – 68.4%; Grandis – 64.2%. It is also worth noting that *Ligustrum ibota* 'Musli' has somewhat higher percentages of rooting in clean river sand.

Regarding the rooting of *Ligustrum japonicum* 'Green Century' (Fig. 8), it can be noted that when propagating with green cuttings, the

number of rooted cuttings is slightly less than the method of propagating with lignified cuttings. Accordingly, in the control conditions in the first substrate 21.0%, and with the use of drugs this indicator ranges from 41.8 to 44.0%.

The development of the root system when propagated by green cuttings, as in the case of lignified cuttings, differs depending on the species. The principle of root formation in *Ligustrum vulgare* L. (Fig. 9a) and its cultivars 'Atrovirens' (Fig. 9b) and 'Aurea' (Fig. 9c) is similar to lignified cuttings, i.e. root growth takes place along the entire length of the cutting, including the lower cuts and nodes. The average number of well-developed roots was 6-9 sproutings. Also, to a greater extent, the formation of roots of the second order is characteristic for a species plant, while their formation is less intense in cultivars.

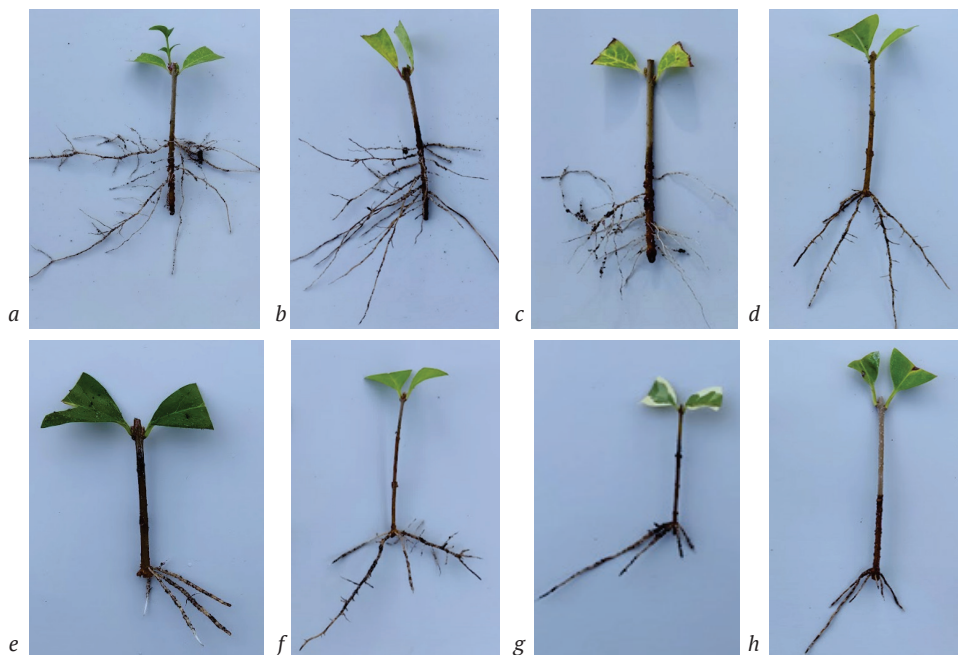


Figure 9. The character of the development of the root system, when propagating by green cuttings, species and cultivars of privet, after using the stimulator Rizopon

Note: a – *Ligustrum vulgare* L., b – *L. vulgare* 'Atrovirens', c – *L. vulgare* 'Aurea', d – *L. ovalifolium* 'Aureum', e – *L. ovalifolium* 'Green Diamond', f – *L. ovalifolium* 'Vicaryi', g – *Ligustrum ibota* 'Musli', h – *Ligustrum japonicum* 'Green Century'

Source: photos made by the authors

Formation and development of roots in *Ligustrum ovalifolium* Hassk. and cultivars 'Aureum' (Fig. 9d), 'Green Diamond' (Fig. 9e) and 'Vicaryi' (Fig. 9f) is markedly different from *Ligustrum vulgare*. In particular, root growth takes place only from the lower section of the cutting. The average number of roots for this species and cultivars is uniform for all and varies between 3-4 sproutings. It is also possible to note the formation of roots of the second order, while cuttings of *L. ovalifolium* 'Green Diamond' (Fig. 9e) did not form such roots. It is worth noting that, in general, the process of rooting and root development of *Ligustrum ibota* 'Musli' (Fig. 9g) and *Ligustrum japonicum* 'Green Century' (Fig. 9h), is much better when propagated by green cuttings. The average number of roots was 4-5 pieces, and the growth of second-order roots also began to some extent in *Ligustrum ibota* 'Musli', however, in *Ligustrum japonicum* 'Green Century' the development of such roots was not observed. The formation of roots occurred mainly from the lower part of the cuttings.

The production of high-quality planting material is always relevant, as it ultimately determines the viability and longevity of green plantings, their ornamental appeal, and aesthetic value. For this reason, the propagation of plants is a subject of study for researchers across various disciplines.

In his work, V.M. Novosad (2014) described the reproduction of *Ligustrum vulgare* L. by vegetative and generative methods. Among the main aspects of the technique that was used, the following can be noted: propagation was carried out by green cuttings in the summer, their length was 10-15 cm. In turn, propagation was carried out in open ground. Rooting rates ranged from 70 to 100%. On opinion, propagation by this method in the open ground under the condition of a constant increase in temperature every year is quite problematic, as there is a need for constant control of the rooting conditions. The author also describes the

process of propagation of *Ligustrum vulgare* L. and *Ligustrum ovalifolium* 'Aureum' using the same method, although the cuttings were planted in greenhouses during intensive growth, in particular before the flowers bloom. Thus, the results of this experiment were quite low, and in general amounted to 10-20%. On opinion, such a result was caused by failure to comply with the terms of harvesting cuttings, since during this period the shoots are just beginning to grow and do not have the potential to root. V.M. Novosad (2014) also explored the process of propagation of *Ligustrum vulgare* L. by lignified cuttings where the amount of rooted material was more than 80%. In the conclusions, the author recommended green cuttings, since the number of rooted cuttings was the highest, although the method of propagation by lignified cuttings also showed a high result. According to observations, in particular, in controlled greenhouse conditions, it will be better to use lignified cuttings.

Ligustrum vulgare L. was also propagated by A.V. Melnyk & V.S. Tokman (2023). In their research, they examined the process of propagating privet by lignified cuttings, where planting was carried out in greenhouse conditions. The main emphasis in this work was on the thickness of the cutting material. In particular, the author noted that as the thickness of the cuttings increases, there was an improvement in the biometric indicators of such material. In their work, they took shoots with a thickness of 5 mm to 8 mm. After rooting, parameters of cuttings were measured. The most productive was the material with the largest thickness – 8 mm, and the increase in above-ground and mass and mass of the root system in comparison with the thinnest cuttings – 5 mm was 215%. It was taking into account this approach to the propagation of *Ligustrum vulgare* L., however, taking into account the morphometric and biological features of the studied species and cultivars, certain corrections were made.

Propagation of *Ligustrum vulgare* was also carried out by J. Hansen & K. Kristiansen (2000). In their research, they described the rooting process of cuttings, where they paid special attention to the influence of the date of planting and the location of the experiment on the percentage of rooting. The authors noted that the percentage of rooting was significantly higher in the second year of the experiment (75%) compared to the first (60%). In addition, rooting of cuttings was found to be about 80% by September 10, after which this rate dropped sharply to 20% for planting in October. However, bud growth and plant survival were largely independent of the date of planting or location of the experiment. It was taking into account such regularities in the process of conducting the research, but made certain corrections taking into account the biological features of *Ligustrum* species and cultivars.

In their study, M.J. Monder & A. Pacholczak (2023) demonstrated the effects of biostimulants and rooting agents such as auxins on plant development processes. It is important to note that among the preparations used were powders containing 0.4% indolylbutyric acid (IBA) and 0.2% naphthylacetic acid (NAA), as well as plant extracts, in particular preparations based on seaweed and humic substances. These rooting stimulants affected the content of polyphenolic acids in plants, which may indicate their participation in rhizogenesis processes. Although changes in polyphenol content were not clearly correlated with rooting percentage or cutting quality, their effect on rooting activation was significant.

N. Aguirre-Acosta *et al.* (2023) studied the genetic diversity of *Ligustrum lucidum* (glossy privet) in fragmented habitats in Argentina. They found lower genetic diversity in fragmented populations, but age-related effects reduced fragmentation impact. Younger trees had higher diversity, suggesting multiple introduction

events. The study highlighted that bird-mediated seed dispersal maintains landscape connectivity and enhances genetic diversity.

Several studies have examined the ecological and horticultural aspects of *Ligustrum*, contributing to the improvement of propagation techniques for urban applications. Y. Wang *et al.* (2024) explored the phylogenetic diversity and interspecies competition within *Ligustrum* species, focusing on the adaptive radiated varieties. The study highlighted the impact of evolutionary processes on species diversity, which was important for selecting *Ligustrum* species suited for urban greening. The findings suggested that understanding phylogenetic relationships could guide the selection of robust cultivars with better adaptability to urban conditions.

Scientists J.J. Rycyna *et al.* (2024) evaluated three *Ligustrum* cultivars in Florida, assessing both their landscape performance and fruit characteristics. The study provided valuable insights into the ornamental and functional benefits of different *Ligustrum* cultivars for urban green spaces, particularly in terms of aesthetic appeal and ease of maintenance. The findings indicated that *Ligustrum* cultivars varied in their growth habits and resilience, which was vital when selecting the best material for urban greening projects.

Collectively, these studies contributed to a deeper understanding of the ecological, horticultural, and agronomic features of *Ligustrum*, providing a basis for improving propagation technologies. Efficient propagation methods, such as cuttings and tissue culture, were essential for producing uniform and healthy planting material, ensuring successful urban greening initiatives. In this study, rooting stimulants were also used for propagation of *Ligustrum* species and cultivars, confirming their effectiveness in increasing rooting percentage in different plant species.

Conclusions

As a result of the conducted research aimed at improving the technology for growing privet (*Ligustrum*) planting material and its cultivars for urban landscaping, it can be noted that the use of rooting stimulators is quite effective. The most positive impact on the rooting of both green and woody cuttings was observed with the Rizopon preparation, which, on average, increased the rooting percentage by 5-10% compared to the control. The highest rooting rates were observed with *Ligustrum vulgare* L. and its cultivars 'Atrovirens' and 'Aurea', reaching up to 96% rooting when using this preparation. The factor of using the substrate is also quite important, in particular, the substrate based on peat and river sand (2:1) is the most optimal for most of the studied species and cultivars, providing better rooting compared to clean river sand. As for *Ligustrum ibota* 'Musli', the optimal substrate for rooting was pure river sand.

The method of propagation by lignified cuttings is the most optimal for such species as *Ligustrum vulgare* L., *Ligustrum ovalifolium* Hassk. and most of their cultivars. The percentage of rooting compared to green cuttings is 4-6 units higher. In addition, the rooting rates of *Ligustrum japonicum* 'Green Century' are also much higher when used for propagating lignified cuttings. While *Ligustrum ibota* 'Musli' showed better results when propagated by green cuttings, here quantitative indicators of rooting were 25-40% higher. Intensive branching of the root system was also

observed in *L. vulgare* cuttings, especially when stimulants were used. In other species (for example, *L. ovalifolium* 'Aureum'), root formation was concentrated mainly in the lower part of the cuttings.

Thus, during the further cultivation of rooted cuttings, must be obtained high-quality planting material of privet species and cultivars, which can later be used in the creation of various landscaping elements. For example, the species *Ligustrum vulgare* L. and *Ligustrum ovalifolium* Hassk., due to their strong branching of the root system, will be most optimally used for creating live fences near roads. Their cultivars are more suitably used in more protected spaces, in flowerbeds, or at a certain distance from roads, when creating topiary figures or combined colour groups.

Further studies should focus on examining the long-term effects of rooting stimulators on the growth and development of plants after transplanting, as well as optimizing substrate composition to improve rootability. Research could also be aimed at improving plant care technologies after rooting to ensure their stable development and enhance the quality of planting material, which in turn will assist in the use of these plants for city landscaping.

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None.

Conflict of Interest

None.

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Вдосконалення технології вирощування садивного матеріалу рослин роду *Ligustrum L.* для озеленення урбанізованих територій

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Анотація. Актуальність дослідження зумовлена потребою у покращенні якості посадкового матеріалу та розширенні асортименту декоративних рослин для озеленення урбанізованих територій. Метою дослідження було вдосконалення технології розмноження бирючини з урахуванням біологічних особливостей та факторів, що впливають на процес укорінення, таких як використання стимуляторів коренеутворення та вибір субстратів. У результаті порівняння укорінення зелених та здерев'янілих живців встановлено різну ефективність залежно від використаних субстратів і стимуляторів коренеутворення, зокрема препаратів Rizoron, «Гетероауксин супер» та Grandis. Експерименти показали, що найбільш ефективним стимулятором коренеутворення був препарат Rizoron, який підвищував відсоток укорінення живців на 5-10 %, порівняно з контролем. Найвищі показники

укорінення спостерігалися у *Ligustrum vulgare* L. та її культиварів 'Atrovirens' і 'Aurea', досягаючи 96 %. Субстрат на основі торфу та річкового піску (2:1) був найоптимальнішим для більшості видів, тоді як для *Ligustrum ibota* 'Musli' ефективнішим виявилось застосування чистого річкового піску. Результати розмноження здерев'янілими живцями показали на порядок вищий відсоток укорінення для більшості досліджуваних рослин, зокрема, *Ligustrum vulgare* L., та її культиварів, відсоток укорінення коливався в межах 86-96 %, тоді як укорінення зеленими живцями – в межах 85-90 %. У випадку з *L. ovalifolium* Hassk. Дані показники дещо менші, проте були задовільними: здерев'янілі живці 75-92 %, зелені живці 74-90 %. *Ligustrum ibota* 'Musli' та *Ligustrum japonicum* 'Green Century' мали посередні результати укорінення як здерев'янілими так і зеленими живцями, *Ligustrum ibota* 'Musli' при розмноженні здерев'янілими живцями мала результат в межах 12-14 %, і здерев'янілими 66-68%. *Ligustrum japonicum* 'Green Century' має більший відсоток укорінення при розмноженні здерев'янілими живцями 47-62 %. Результати дослідження можна використати для підвищення ефективності розмноження бирючини та вдосконалення технології вирощування якісного посадкового матеріалу стійкого до умов урбанізованого середовища. Ці дослідження слугують інформаційною науковою основою удосконалення систем декоративного розсадництва

Ключові слова: декоративне розсадництво; вегетативне розмноження; зелені насадження; субстрат; укорінюваність; урбосередовище; морфометричні показники