AGROTECHNIQUE OF GROWING ROOT PLANTED PLANTING MATERIAL OF DECORATIVE SPECIES OF PLANTS

Tokman Volodymyr, k. a. s. as. prof.

Sumy National Agricultural University,Ukraine

Green plantings are one of the main factors in the landscape organization of the territory, in its sanitary and hygienic improvement, which gives originality to the salinity points. They are an integral part of settlements' landscaping, provided by development projects [1, 3, 7].

In their vast majority various forms of greenery are used in landscaping.

Green plantations can perform a number of functions, among which the most important are improving microclimatic conditions, cleaning and humidifying the air and enriching it with oxygen, high volatile activity, improving the architectural and artistic appearance of new buildings, preventing adverse climatic factors [2, 6].

Relevance of the issue. The introduction of ornamental plants in the improvement and landscaping of settlements, requires improvement of growing methods. At the same time, an extremely important problem is the development of new and improvement of existing technologies for growing of planting material of ornamental plants. This will create conditions for increasing the species diversity of garden phytocenoses and for the increase of their resistance to adverse environmental factors.

Analysis of recent research and publications. With the increasing demand for planting material of ornamental plants, the need to improve existing seedling technologies, taking into account biological characteristics, arises. A number of elements of technology for growing rooted seedlings of ornamental species are still insufficiently studied.

Materials and methods of research. Experimental work was performed in 2020-2021 in the "Landscape Design" training laboratory of the Department of Horticulture and Forestry.

The research was conducted in eight experiments:

1. To analyze the influence of the time of grafting (*Ligustrum vulgare*) on the rhizogenic activity of micro-shoots (cuttings).
2. To identify the effect of substrate on the rhizogenic ability of *Tahis bassata* cuttings.
3. To determine the effect of the reaction of the soil environment on the regenerative capacity of *T. baccata* stem cuttings.
4. To identify the influence of metamerism of cuttings on rhizogenic ability and quality of planting material (*L. vulgare and Spiraea vanhouttei*).
5. To consider the influence of micropod planting scheme on the growth and development of *L. vulgare* plants.
6. To study the influence of the time of soil mixture usage on the process of coregenesis in cuttings and other biometric indicators of *L. vulgare* plants.

7. To identify the influence of exogenous auxin-like compounds on the rooting process of microshoots of *L. vulgare and S. vanhouttei*.

8. To analyze the influence of the transplantation time of rooted cuttings (*T. baccata*) on their survival.

Factor A - grafting time: 1) control (10.04); 2) 10.07; 3) 10.09. Factor B - substrate type: 1) control (peat + humus (1: 1)); 2) peat + sand + humus (1: 1: 1); 3) peat + sand (1: 1). Factor C - the reaction of the soil: 1) control + sand + peat (pH 4.0), 2) sand + peat (pH 6.0). Factor D - metamerism of cuttings: 1) control (single-node or single-bud); 2) two-node or two- bud; 3) three-node or three-bud micro shoots. Factor E - planting scheme: 1) control (15 X 10 cm); 2) 8 X 4 cm. Factor F - soil mixtures of differentusage term: 1) control (single use); 2) reusable. Factor G - auxin compounds: 1) control (water); 2) *Ukorzeniacz DDS*; 3) *Stekpoeder pokon*; 4) topsin-M; 5) *Rhizopon AA* powder; 6) charkor. Factor H - terms of transplanting plants: 1) control (20.09), 2) 25.04.

Micro-shoots were harvested from 7-8-year-old mother plants growing on the territory of the university (Fig. 1).

Fig. 1. Procurement of cuttings of L. vulgare [Own photo]

A greenhouse box covered with glass 4 mm thick was used for rooting cuttings. It housed ridges 0.8 m wide and 6.0 m long.

Soil mixture for rooting cuttings included peat "*DOMOFLOR*" (pH 6.0) and river sand.

Experimental work to improve the technology of growing planting material was carried out in accordance with the method of reproduction of ornamental trees of the Botanical Garden of NULES of Ukraine [5].

Research results and their discussion. The intensification of the system for the production of planting material is especially important due to the high demand for planting material. The results of research by Ukrainian and foreign scientists prove that harvesting micro-shoots in optimal periods creates the conditions for managing vital processes occurring in the plant body, as well as significantly affect the efficiency of root production of planting material [10, 17].

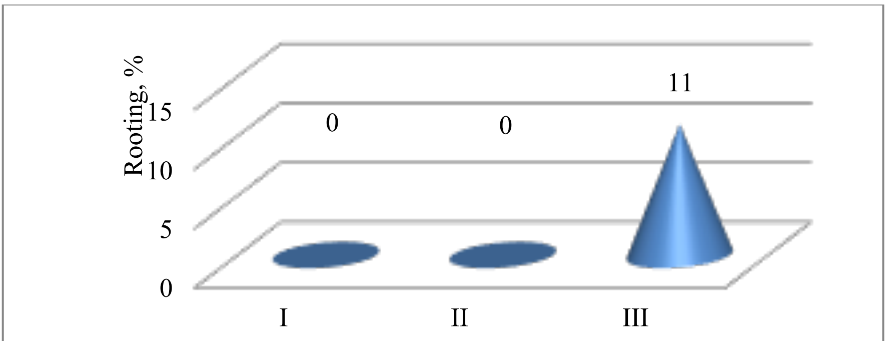
Table 1. Influence of the period of *L. vulgare* grafting on the reproductive capacity of micro-shoots

Harvest time of micro-shoots	Reproducibility,%	± to control
10.07	0	- 98
10.09	12	- 86
Control (10.04)	98	-
SSD (the smallest significant difference) $_{05}$	7.38	

The results of laboratory studies (Table 1) convincingly show that the highest rate of reproductive capacity (rooting makes 98 %) is observed when harvesting *L. vulgare* micro-shoots in April. Harvesting of micro shoots of this taxon after swelling and flowering buds provides low rates of rooting.

To obtain a homogeneous planting material rootstock propagation by stem grafting is widely used [8].

During the vegetative propagation of ornamental plants and their forms, *T. baccata* in particular, it is advisable to create conditions for the processes of callus and cargenesis [10]. An important condition for the intensive root-forming ability of cuttings is the soil mixture with optimal agrophysical and agrochemical properties (Fig. 2).



I - peat + humus, II - peat + sand + humus, III - sand + peat

Fig. 2. The effect of substrate on the root-forming ability of cuttings

At the stage of rooting cuttings do not absorb nutrients from the substrate. However, they are very sensitive to both the lack and excessive concentration of cations of hydrogen, aluminum, iron, manganese, sodium in the soil solution.

One of the important factors in the effective regeneration of the root system is the optimally selected acidity of the soil mixture. In this case, the inconsistency of the reaction of the soil environment to the characteristics of the species adversely affects the process of reproductive capacity of stem cuttings (Table 2).

Table 2. Influence of reaction of environment on rhizogenic activity of stem cuttings

Substrate type	A variant of the experiment	*T. baccata*	
		Rooting, %	± to control
Control (sand + peat) (pH 3.5)	Water	0	-
	Ukorzeniacz DDS	1	+ 1
Sand + peat (pH 6.0)	Water	8	-
	Ukorzeniacz DDS	35	+ 27

According to the results of experimental work, it was found that the root-forming ability of cuttings (*T. baccata*) is influenced by the acidity of the soil environment. At the same time, in the control the reproductive capacity of stem cuttings was minimal, and at the acidity of the substrate pH 6.0, it was 8-35 %.

In the course of the study it was convincingly proved that the concentration of hydrogen ions and other elements in the soil mixture can significantly affect the processes of adventitious rhizogenesis in the *T. baccata* stem cuttings. In addition, we found out that in the case of root reproduction of the mentioned species, it is best to use peat with a weakly acidic or neutral reaction of the soil environment.

The obtained results provided the proof for a significant effect of substrate acidity on the rate of adventitious rhizogenesis in *T. baccata* stem cuttings.

Thus, for the optimal root-forming ability of cuttings, it is important to create and maintain the appropriate concentration of hydrogen and aluminum ions in the nutrient medium, which meets the biological requirements of the species under study.

In production conditions, grafting is used in order to grow large volumes of rootstock planting material. Vegetative propagation of plants by micro-shoots (cuttings) is a fairly simple and affordable way. This method creates the preconditions for obtaining planting material that identically retains the phenotypic characteristics and properties of the parent forms [8, 10. 12].

The rhizogenic capacity of *S. vanhouttei* micro-shoots depends on the metamerism of the cuttings (Table 3).

The yield of planting material from single-bud micro-shoots, which were harvested from the apical part, was 1 %, which is 2-3 times less compared to the medial and basal micro-shoots.

The use of double-bud cuttings influenced the process of their rooting (the percentage of rooted micro-shoots increased compared to single-bud ones). The yield of rooted double-bud cuttings from the medial part of the shoot was 12 %, and single-bud ones made 3 %.

Table 3. Influence of metamerism of cuttings on rooting and indicators of root system development

Part of the shoot	Number of buds, pieces	Yield of rooted cuttings,%.	In anticipation of a cutting	
			number of roots, pieces	length of roots, cm
Apical	1(control)	1	1.2	2.1
	2	4	2.0	4.3
	3	8	3.0	5.1
Medial	1(control)	3	1.9	2.5
	2	7	3.3	5.2
	3	12	3.8	6.3
Basal	1(control)	2	1.4	2.4
	2	6	1.9	4.2
	3	9	3.2	5.9

Rooting of three-bud cuttings dominated significantly, regardless of the part of the shoot which they were harvested from. Rooting of cuttings from the apical part of the shoot was 8 %, which was 1.5 and 1.12 times less compared to the medial and basal ones.

In the experimental variants, the number of roots formed in two- and three-bud cuttings was significantly higher compared to the control (single-bud one). For example, three-bud cuttings from the apical part of the shoot formed 3.0-pieces roots, which is 250 % more than single-bud ones.

The maximum number of roots was formed on the cutting material from the medial part of the shoot.

The total length of roots in single-bud apical cuttings was 2.1 cm, while in double-buds this figure was 4.3 cm. The length of roots was the smallest on cuttings from the apical part of the shoot. It was found that the maximum number and total length of roots is characteristic of three-bud cuttings.

The results of the influence of shoot type on some morphometric parameters of planting material are shown in Fig. 3 and 4.

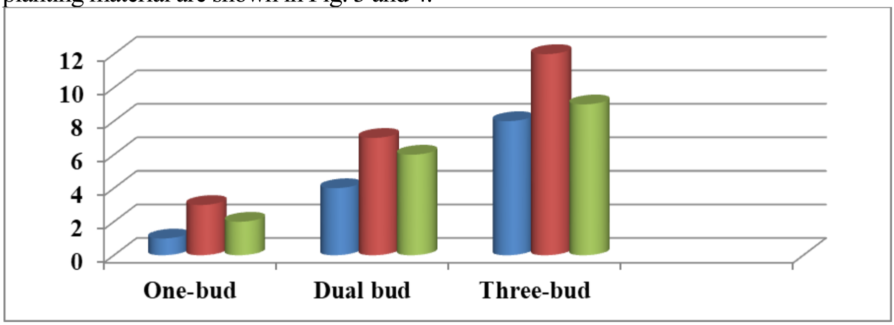


Fig. 3. The dependence of the rooting rate of S. vanhouttei microshoots on the number of buds on cuttings,%

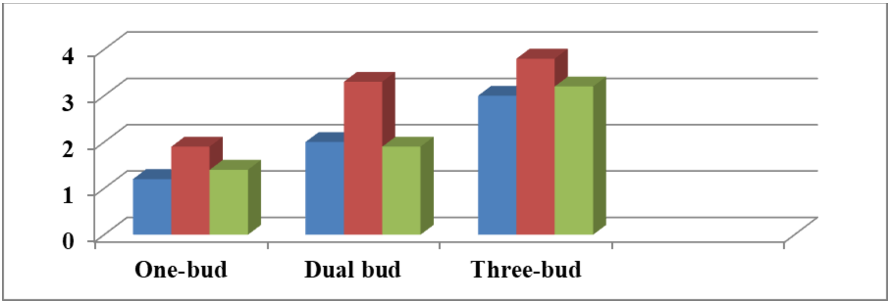


Fig. 4. The average number of roots formed on the micro-shoots depending on the number of buds on the cuttings, pcs.

In the course of experimental research it was proved that the type of the shoot significantly affects not only the rhizogenic ability of microshoots, but also the number of roots formed on them. The number of roots formed on the cuttings of the control variants was smaller compared to the experimental variants. The results of research convincingly show that with root propagation of *S. vanhouttei,* it is desirable to harvest cuttings from the medial and basal part of the shoot, and the cuttings should have at least 2-3 buds.

The production of standard seedlings is the final stage of the agro-technological process of cultivation (Table 4).

There was a significant difference in the reproducibility of the cuttings. The highest rate of regenerative capacity was observed under the conditions of using two and three-node cuttings, and the lowest - in the control.

Table. 4. Influence of metamerism of micro shoots on qualitative indicators of planting material

Experimental variant	Regenerative capacity,%	Plant height, cm	± to control
Single-node (control)	89	12.3	-
Dual nodes	100	23.9	+ 11.6
Three-node	100	42.1	+ 29.8
SSD (the smallest significant difference) $_{05}$	4.45	3.85	

The length of plants in the first variant was 12.3 cm, which is 11.6 and 29.8 cm less than in other variants (SSD_{05} was 4.45).

During the laboratory tests, a significant difference was found in the options (SSD_{05} 4.45 and 3.85). Under the conditions of scientific work, we found out that in the experimental variants the planting material has better biometric performance than in the control one.

Experimentally, it was found that the metamerism of the shoot affects not only the root productivity of cuttings and *L. vulgare* plant height, but also the formation of phytomass (mass of the aboveground part and root system) (Table 5 and Fig. 5).

Table 5. Influence of metamerism of micro shoots on the mass of planting material

A variant of the experiment	Mass, g			
	aboveground part	± to control	the root system	± to control
Single node	6.8	-	19.5	-
Dual nodes	14.1	+ 7.3	31.5	+ 12.0
Three-node	21.5	+ 14.7	43.2	+ 23.7
SSD$_{05}$		1.22		1.98

Fig. 5. The influence of metamerism of cuttings on the growth of the root system [Own photo].

The mass of the aboveground part of plants formed in single-node micro-shoots was 6.8 g, which was 7.3 and 14.7 g less than in the experimental variants, where two- and three-node cuttings were used. Mathematical processing of the obtained indicators proved a significant difference between the options (SSD$_{0,5}$ was 1.22).

The weight of the root system of plants ranged from 19.5 to 43.2 g (SSD$_{0,5}$ was 2.48). The highest value of this indicator was observed in the experimental version, which used three-node cuttings and was 43.2 g.

In particular, it was found out that the number of nodes on the micro-shoots significantly affects the further growth and development of the studied cultivar. Thus, 2- and 3-node micro shoots had the opportunity to form a more branched root system.

In the process of performing the tasks of scientific work, attention was paid to the influence of the scheme of planting cuttings on the morphometric parameters of planting material (Table 6).

Table 6. Biometric indicators of *L. vulgare* rooted microshoots

Version of experiment	Length of growth, cm	± to control	Weight, g	
			root system	± to control
Control (15 X 10)	9	-	1.4	-
8 X 4	5	- 4	0.6	- 0.8

The increase in the experimental variant was 5 cm, which was 166.7 % less than in the control variant. In particular, the increase in the feeding area of micro-shoots had a positive effect not only on the height of planting material, but also on the weight of the root system.

In the experimental work, we drew attention to the relationship between the service life of the soil mixture and some biometric indicators of planting material (Table 7).

Table 7. Influence of the term of soil mixture use on plant quality indicators

Version of experiment	Reproducibility, %	Length gain, cm	Weight, g	
			aboveground part	± to control
Control (disposable)	100	11	3,91	-
Reusable	63	6	2,72	- 1,19

The regenerative capacity of micro-shoots in the experimental variants was 63 %, which was 37 % less than in the other variant.

In the variant where a single use of the substrate was performed, the length of growth was 11 cm, which was 1.83 times longer than with repeated use.

The results of laboratory studies show that the duration of use of the soil mixture can affect not only the height of the plants, but also the peculiarities of the formation of the aboveground part.

In laboratory studies, the weight of the aboveground part of plants was in the range of 2.72 - 3.91 g.

It was found out that the highest morphometric indicators of *L. vulgare* plants are characteristic of the variant where the substrate was used only once. Probably, these data can be explained by the fact that plants have the ability to emit toxic substances (colenes), which adversely affect the growth and development of plants in the future.

Recently, in the industrial nursery of ornamental plant species, one of the main methods of reproduction has bedome asexual one. At the same time stimulants of rooting have been used actively. Exogenous phytohormonal compounds are used to improve the regenerative ability of cuttings of ornamental plants that are relatively poorly rooted [13, 17-18].

The effectiveness of growth and development stimulants significantly depends on: the physiological state of the micro-shoot during harvesting, as well as the concentration of the active solution and the exposure of cuttings soaked in it [11].

The results of studies on the influence of exogenous regulators of growth and development of plants on the process of reproduction of the root system in *S. vanhouttei* cuttings are given in table. 8.

Table 8. Influence of exogenous growth stimulators on morphometric parameters of plants

Version	Recovery capacity,%.	Number roots of the 1st order, pcs.	Length of roots, cm.
Control (water)	12	3.8	6.3
Topsin - M	23	4.5	7.7
Rhizopon AA poeder	89	6.4	11.9
Charcor	35	5.1	9.1
SSD_{05}	4.8	0.4	0.6

The use of some exogenous growth regulators had a positive effect on the process of root system reproduction in *S. vanhouttei* cuttings. The indicator of rhizogenic ability in the experimental variants was in the range of 23-89 %, and in the control one it was 12 %. When using *Rhizopon AA poeder*, the percentage of rooting cuttings was 89, and in the control version, this figure was 7.4 times lower. Some physiologically active substances affected not only the process of rooting cuttings, but also the number of roots formed on cuttings. The number of roots of the 1st order in the control variant was 3.8 pcs. And in the experimental variants, this figure ranged from 4.5 to 6.4 pcs.

The total length of the roots of the 1st order when using topsin - M made 7.7 cm, which was 1.4 cm more compared to the control variant.

In the variant using charkor, the total length of the roots was 9.1 cm, which was 1.4 times more than in the control variant.

In the laboratory, studies were conducted on the effect of the timing of harvesting micro-shoots on the regenerative capacity of *S. vanhouttei* cuttings (Table 9).

Table 9. Influence of growth regulators on the process of rooting *S. vanhouttei* woody cuttings

Experimental variant	Grafting time		
	control	20.06	20.07
	Rooting,%		
Control (water)	8	12	10
Topsin - M	13	23	18
Rhizopon AA poeder	48	89	81
SSD_{05}	3.23	4.75	4.12

Preparation of micro-shoots for the phase of swelling and flowering buds negatively affected the process of their rooting (the minimum value of regenerative capacity was recorded in the control variant and was 8 %). The use of exogenous compounds provided an increase in the production of planting material.

Grafting *Spiraea* after the flowering phase has a positive effect on the rooting process of micro-shoots. In the control variant, the percentage of rooting made 12 %, which was 1.5 times more than in the first period of grafting (before the swelling phase of the buds). The highest rate of rhizogenic activity was observed in the variant where *Rhizopon AA poeder* was used and it made 89 %.

The analysis of the results showed that the studied compounds have different effects on the processes of callus and choregenesis in micro-shoots. Treatment of cuttings with auxin-like compounds provides a more significant increase in its regenerative capacity than grafting without their use. Harvesting of *S. vanhouttei* micro-shoots should be carried out after the flowering phase of plants.

The influence of exogenous biologically active substance provides the planted cuttings with prerequisites for laying and differentiation of somatic cells, which are necessary for root system regeneration and its further growth and formation, which will ultimately affect the growth and development of the aerial part of the rooted micro-shoot in a positive way (Table 10).

Table 10. Influence of physiologically active substances on the reproduction of the root system in *L. vulgare* cuttings

Experimental variant	Rhizogenic ability,%	± to control
Control (water)	95	-
Stekpoeder Pokon	93	- 2
Ukorzeniacz DDS	98	+ 3
SSD_{05}		2.64

The analysis of experimental work showed that some exogenous compounds can significantly affect the regenerative capacity of *L. vulgare* micro-shoots. Of the studied substances, the best results were obtained using *Ukorzeniacz DDS*.

In the version with *Ukorzeniacz DDS*, the rooting rate made 98 %, which was 3 % higher than in the control one. For *Stekpoeder Pokon* cuttings, the above figure was 93 %.

Changes in the phytohormonal balance of cuttings (*L. vulgare*) under the action of certain exogenous auxin-like compounds did not affect the reproductive capacity more significantly than the cultivation of planting material without treatment with these substances.

The course of physiological and biochemical processes in plant organisms is controlled by 13 groups of hormonal compounds, in particular: salicylic, bird cherry and abscisic acids, auxin, cytokinin, ethylene, brassine and others. They have a variety of functions, control the basic physiological and biochemical processes in plants, as well as the restoration of the root system [4, 15-16].

The main role in the process of callus- and choregenesis belongs to auxins. The processes of callus- and cargenesis are significantly influenced by the ratio in plant tissues of both inhibitors and substances of auxin-like nature. The regenerative ability of micro-shoots (cuttings) is improved by stimulators of root formation, which provide better rooting of ornamental species cuttings and plant forms [9, 11].

Treatment of cuttings (*L. vulgare*) with exogenous growth regulator (*Ukorzeniacz DDS*) creates conditions for the management of regenerative processes (Table 11).

Table 11. Influence of exogenous compound on choregenesis in semi-woody cuttings of *L. vulgare*

Experimental variant	Indicator of rhizogenic ability,%	± to control
Control (water)	2	-
Ukorzeniacz DDS	49	+ 47
SSD_{05}		4.27

The results of laboratory studies convincingly show that the auxin-like substance affects certain reactions that occur in cuttings, and in particular in the version with *Ukorzeniacz DDS* treatment, the rhizogenic capacity was 49 %, which was 24.5 times more than in the control. The minimum value of rooting of micro-shoots of ornamental species was noted in the control, and it made 2 %.

In the course of laboratory studies it was found out that as a result of exposure to exogenous auxin-like compound (*Ukorzeniacz DDS*) the phytohormonal balance of *L. vulgare* micro-shoots has been changed which significantly affects the shaping processes (reproduction of the root system). Thus, the rational use of *Ukorzeniacz DDS* under the conditions of root propagation of the studied species by grafting, creates conditions for efficient cultivation of planting material.

Mathematical processing of qualitative indicators shows a significant difference between the experimental variant and control one ($SSD_{0,5}$ was 4.27).

Introduction into the production process of various techniques and measures, advanced achievements of science and practice necessitates the calculation of economic efficiency.

Estimation of economic efficiency of use of the perspective rooting stimulator is given in tab. 12.

Table 12. Efficiency of production of *S. vanhouttei* planting material

Types of costs	Control (water)	*Rhizopon AA poeder*
Costs (material), UAH	4204.83	7114.93
Remuneration, UAH	6419.4	7959.4
Salary accruals, UAH	2432.9	3016.6
Total costs, UAH	13057.13	18090.63
Yield of rooted cuttings, pcs.	1200	8900
Unit cost, UAH	5.0	5.0
The cost of a rooted micro-shoot, UAH	10.88	2.03
Profitability index,%	-54.04	146.1

The cost of rooted micro-shoots in the experimental version is UAH 2.03, which is UAH 8.85. less than the control. The level of profitability in the experimental version was 146.1 %. Production efficiency indicators convincingly prove that it is advisable to use exogenous auxin compound (*Rhizopon AA poeder*) for root cultivation of *S. vanhouttei*.

The set of agro-technical measures for growing the same type of planting material involves transplanting rooted cuttings for further growth. Rooted micro-shoots with a well-formed root system are transplanted in late July - early August. In the year of grafting it is advisable to transplant some ornamental species, in particular: *Cornus alba, Juniperus, Thuja*. Rooted cuttings of most breeds should be left in cultivation facilities for winter [10].

Table 13. Influence of transplantation time on the process of plant survival

Experimental variant	Survival,%	± to control
Control (25.04)	98	-
25.09	10	- 88
SSD_{05}	4.49	

According to the results of research (Table 13), the survival rate of planting material in the control was 98 %. At the same time, the minimum value of survival was recorded when transplanting was carried out in September (25.09).

In the experimental work, a probable difference in variants was noted ($SSD_{0,5}$ 4.49). At the same time, it was found out that the process of transplanting plants of the studied species should be carried out in April.

We have convincingly proved that transplanting rooted cuttings in favorable periods creates the conditions for optimizing agricultural production of *T. baccata* seedlings, as well as improving the efficiency of planting material.

Conclusions and prospects for further research.

1.The optimal substrate for plant propagation (*T. baccata*) by grafting is a mixture of sand and peat (pH 6.0) in a ratio of 1 : 1.

2. The corregenic ability of *L. vulgare* micro shoots is determined by the period of grafting. The optimal time for harvesting micro-shoots is the period before swelling and flowering buds (recovery rate is 98 %).

3. When root-own planting material (*S. vanhouttei*) is available, it is advisable to harvest micro-shoots with 2-3 buds.

4. Treatment of cuttings (*S. vanhouttei*) with auxin-like substances provides a greater effect than grafting without their use. *Rhizopon AA poeder* is a highly effective compound that stimulates the process of callus- and choregenesis in micro-shoots (cuttings) of *S. vanhouttei*. The rate of regenerative capacity in the experimental variant was 89 %, and in the control one – 12 %.

5. *L. vulgare* is desirable to propagate by root-own method (semi-woody micro-shoots) using *Ukorzeniacz DDS*. Treatment of micro-shoots (cuttings) with this compound creates conditions for the reproduction of the root system (rhizogenic capacity was 49 %).

6. The feeding area of micro-shoots (*L. vulgare*) in the cultivation facility significantly affects the quality of planting material. The optimal feeding area of rooted cuttings is 15 X 10 cm.

7. At root reproduction of *L. vulgare* in the conditions of the closed soil one-time use of soil mix is expedient.

8. The cost of planting material (*S. vanhouttei*) in the experimental variant (*Rhizopon AA poeder*) was UAH 2.03, which was 5.36 times less than in the control. The profitability of planting material production was 146.1%.

9. Transplantation of *T. baccata* rooted cuttings is best done in late April (survival rate was 98 %).

10. The use of plants of the studied taxa will create stable phytocenoses.

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