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Technology of green cuttings of woody plants for landscaping arctic cities

Natalia V. Saltan[1, 2] ✉, Ekaterina A. Sviatkovskaya[1], Marina S. Zavodskikh[1], Maria V. Korneykova[2]

[1]Avrorin Polar-Alpine Botanical Garden-Institute, Kola Science Centre of the Russian Academy of Sciences, *Apatity, Murmansk region, Russian Federation*
[2]RUDN University, *Moscow, Russian Federation*
✉ saltan.natalya@mail.ru

Abstract. For landscaping of northern cities, requirement for ornamental plants resistant to urban conditions is increasing, so there is a need to find a solution for multiplication at commercial scale. A technology of green cuttings of woody plants (*Syringa josikaea* and *Spiraea media*) has been developed as one of the promising methods of vegetative propagation of deciduous ornamental species in the Arctic region. The terms of cuttings (at the beginning of shoot lignification) have been established: for *Spiraea media* — July 1–10; for *Syringa josikaea* — July 10–25. A positive effect of the growth stimulator IBA 1000 ppm on the development of the root system and the above-ground part of the cuttings was determined with 6-hour and 12-hour treatment. It was shown that a longer treatment period (12 hours) was more effective. The length of the roots of *Syringa josikaea* exceeded the control with a 6-hour treatment by 52%; at 12 hours by 89%; in *Spiraea media* — by 27% and 42%, respectively. In both species the number of roots increased by 32–34% with a longer exposure. The treatment of cuttings for 12-hour significantly increased the formation of leaves on the cuttings of *Syringa josikaea* ($r = 0.87$ ($p < 0.001$)) and *Spiraea media* ($r = 0.89$ ($p < 0.001$)). The results revealed that the cuttings treated with IBA 1000 ppm (12h) registered maximum survival percentage of rooted cuttings of *Syringa josikaea* (95.1%) and *Spiraea media* (75.2%).

Keywords: vegetative reproduction, *Syringa josikaea*, *Spiraea media*, IBA treatment, biometric parameters, Murmansk region

Author's contribution: Saltan N.V. — experimental design, analysis, systematization, and interpretation of the obtained data, writing the manuscript; Svyatkovskaya E.A. — conceptualization of the study goal, data processing,

writing the manuscript; Zavodskikh M.S. — conducting the experimental observations; Korneykova M.V. — statistical processing of the results. All authors have read and approved the final version of the manuscript.

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Introduction

With increasing urbanization, climate change, and other global environmental processes, the quality and level of green infrastructure in urban ecosystems are becoming increasingly important [1–3]. With economic growth, improving the quality of life for the population is becoming increasingly important, especially in Arctic cities with extreme natural conditions [4]. It is well known that green spaces improve the microclimatic conditions of an area and have a positive effect on the psycho-emotional and physical well-being of people [5–7].

New public spaces and landscaped areas are being created in northern cities, resulting in an increased demand for planting material for various types and forms of ornamental plants. Due to the inability to meet the increased demand with local resources, many plants are imported from southern regions. Since the plants are not adapted to the conditions of the Far North, they have lower decorative value and aesthetic appeal.

The Polar-Alpine Botanical Garden-Institute has been conducting introduction trials of a large number of woody and herbaceous plants and developing propagation methods since its founding in 1931. For a long time, preference was given to seed propagation, with material obtained from expeditions and seed collections from mother plants growing within the Garden. With this type of propagation, the period for trees and shrubs to achieve ornamental value is longer (2–3 years) than with vegetative propagation. Furthermore, almost 40% of species do not produce high-quality seeds, or seed procurement is extremely difficult. Due to the high demand for woody planting material in the region, the development of a cost-effective technology for vegetative propagation of trees and shrubs has become necessary.

Green cuttings are the most suitable method for solving such problems. This method of propagation allows plants to retain beneficial characteristics and properties of the crops, fully reproducing features (color, shape, and size) of the mother plant. The rooting ability of cuttings and the success rate of cuttings depend on many factors, such as age of mother plant, date of collection, length and type of cutting, nutrient level in cutting, climate conditions, subsequent care, etc.

Plant growth regulators are often used to accelerate root formation and shoot growth in cuttings. The most reliable rooting hormone is synthetic auxin indole butyric acid (IBA), as it is non-toxic to plants and can be used in a wide range of concentrations [8–10]. Treatment with IBA at a concentration of 1000 ppm has been shown to be superior across most parameters of vegetative growth and propagation rate of plant cuttings [11, 12].

The aim of this study was to develop a technology for green cuttings of woody plants in the Arctic region for the commercial production of planting material.

Materials and methods

The study was conducted in 2024 at the Polar-Alpine Botanical Garden-Institute, located in Kirovsk, Murmansk Region (Fig. 1). Ornamental flowering shrubs *Syringa josikaea* Jacq. fil. and *Spiraea media* Franz Schmidt., widely used for landscaping in northern cities, were selected for the experiment. These species were included in the regional landscaping assortment in 1941 [13].

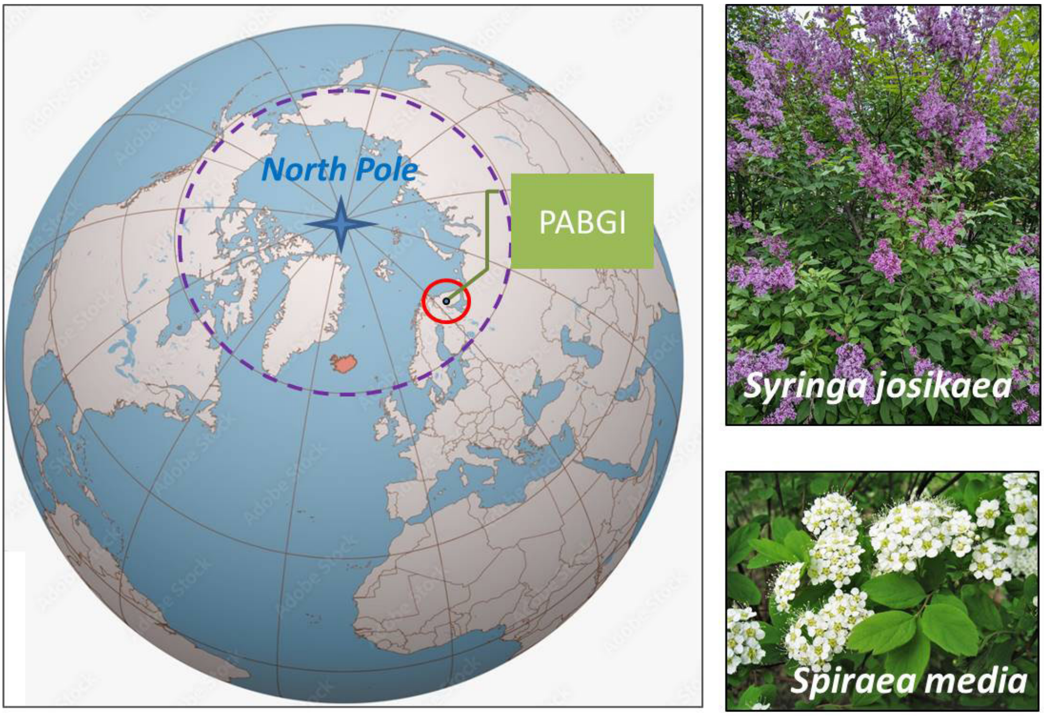

Fig. 1. Description research area and objects
Source: plant photo — N.V. Saltan.

Syringa josikaea was first brought to the PABSI for introduction trials in 1936 from the Leningrad Botanical Institute as 2–3-year-old seedlings. In 1940, this species was first used for landscaping parks and squares in Murmansk and Monchegorsk. In its native Carpathian flora, it is considered a rare species [14]. *Syringa josikaea* is the most common dendro-introduced plant, found in every city and accounting for 1 to 30% of all introduced species [15].

Syringa josikaea is an ornamental shrub growing up to 5 m tall. The leaves are green above, with a glaucous bloom beneath, elongated, and fairly large. The inflorescences are loose, erect, and pyramidal, with well-defined tiered branches. The flowers are lilac-violet, long, tubular, and have a pleasant, faint aroma. It is a good honey plant. Depending on weather conditions, it blooms from early to mid-July for two to three weeks. Fruit is set annually but rarely ripens. At the end of July, the shoots finish growing and have time to become woody by winter. The leaves retain a fresh green color until snowing [16]. Its ornamental value lasts up to 60 years with regular care.

Spiraea media was introduced to the PABSI in 1936. It was first used in landscaping in the city of Polyarny in 1944. It is found in landscaping throughout the cities of the Murmansk region. Its share of introduced species ranges from 0.5 to 18.0%. It is widespread in public gardens in Monchegorsk (a public garden in the Yuzhny district) and Snezhnogorsk (a public garden on Oktyabrskaya Street). It has been observed in street plantings in the cities of Apatity and Murmansk [17].

This is a highly branched, tall (up to 1.8 m) shrub with a dense crown. It blooms for two weeks in June. The flowers are white, gathered in multi-flowered umbels, and densely spaced along the entire shoot. It is winter-hardy and responds well to pruning. In urban areas, it can retain its decorative appearance for 40–50 years, depending on growing conditions.

Spiraea media и *Syringa josikaea* cuttings were taken early in the morning from 25–50 cm long lateral shoots of the current year. 5- to 15-year-old specimens, placed in a well-lit location, were used as mother plants, as the experimental crops are sun-loving. Before propagation, the selected plants were carefully inspected for pest and disease damage. Leaf blades should be flat, not curled, and not too large.

Cuttings were taken at the initial stage of shoot lignification (brown blotches on a green background) from July 1 to 10 for *Spiraea media* and from July 10 to 25 for *Syringa josikaea*. Cuttings were taken from the middle and upper parts of the shoots with vegetative buds, making an oblique cut at the basal end and a transverse cut at the apex of each cutting. *Syringa josikaea* cuttings were 5–10 cm long (1–2 internodes); the lower 1 or 2 leaves were removed, and the upper leaves were trimmed by 1/3 or 50%, which is necessary to reduce moisture evaporation in the absence of a root system. Leaves with a small surface area were left unchanged. *Spiraea media* cuttings were cut 10–15 cm long (4–5 internodes). The leaves of this species are small, so they were not trimmed, and the lower two internodes were completely removed. Depending on the length of the cut shoot, 2–4 cuttings were obtained for *Syringa josikaea* and 2 or 3 for *Spiraea media*.

Cuttings were treated with 1000 ppm IBA. The experiment was set up with three replications per one factor: exposure time. Each factor contained three treatments: distilled water (T1); 1000 ppm IBA, exposure time of 6 hours (T2); and 1000 ppm IBA, exposure time of 12 hours (T3). The solution at the indicated concentration was prepared by dilution in distilled water, and the pH was maintained at 7.0 using 0.1 N KOH or HCl using a digital pH meter. Each replication included 30 cuttings.

The treated cuttings were rinsed with water and planted in a greenhouse in pre-prepared containers filled with a layered soil substrate. The bottom layer (2–3 cm) consisted of expanded clay for drainage; the second layer (8–10 cm) consisted of fertile soil with pH of 6.3 and ammonium nitrogen of 3.34, nitrate nitrogen of 4.03, and P_2O_5 of 258.4 mg/100 g; the third (top 2 cm) layer consisted of river sand. Before planting, the substrate was watered generously and left covered with plastic film for 24 hours.

When planting, the cuttings were buried 1.5–2.0 cm deep, so that the lower cut was in the sand or at the sand-soil boundary. The distance between the cuttings was maintained from 3 to 4 cm to prevent the leaves from touching each other. The cuttings were placed in the substrate at an angle and firmly secured in the soil. To create a greenhouse effect, the containers with the cuttings were covered with plastic film, which was removed only for watering during the first 2–3 weeks, and subsequently at night for better adaptation to air environment. All cuttings were watered regularly. Relative humidity in the greenhouse was maintained at ≥ 85%, and the temperature was 20–26 °C.

Further observations were conducted on various shoot and root parameters: number of roots per cutting; root length (cm); shoot growth (cm); number of leaves formed on cuttings; survival rate (%). Measurements were taken on the 50th day (early September).

Statistical analysis. The significance of differences in experimental data was assessed using a one-way analysis of variance with Turki's test. To establish statistically significant differences between treatments and plant biometric parameters, principal component analysis was performed using the FactoMineR and factoextra packages in R (R 4.3.3).

Results and Discussion

Twenty days after planting, a reconnaissance inspection of the *Syringa josikaea* cuttings revealed that those treated with the growth stimulant for 12 hours were in better condition. They had fewer dry leaves, and new buds appeared on 50% of the plants. When removing individual cuttings, callus and small root formation were observed. New buds were detected on 30% of plants treated with the growth stimulants for 6 hours, compared to 20% of the control plants.

Number of roots per cutting. The highest number of roots was reliably found in *Syringa josikaea* cuttings treated with IBA for 12 hours (9.9, $p = 0.009$), while the value was slightly lower for the 6-hour period (9.1, $p = 0.016$), Fig. 2, 3. In the control, the number of roots was minimal (7.4). In *Spiraea media*, the number of roots was also higher after 12-hour treatment (11.2, $p < 0.01$), and this indicator exceeded the similar value for *Syringa josikaea*. It was noted that in both species, compared to the control, the number of roots increased by 19…21% after 6-hour exposure, and by 32…34% after 12-hour exposure. IBA is the most widely used growth regulator for stimulating root formation in cuttings due to its high rooting stimulating ability and low toxicity [18, 19].

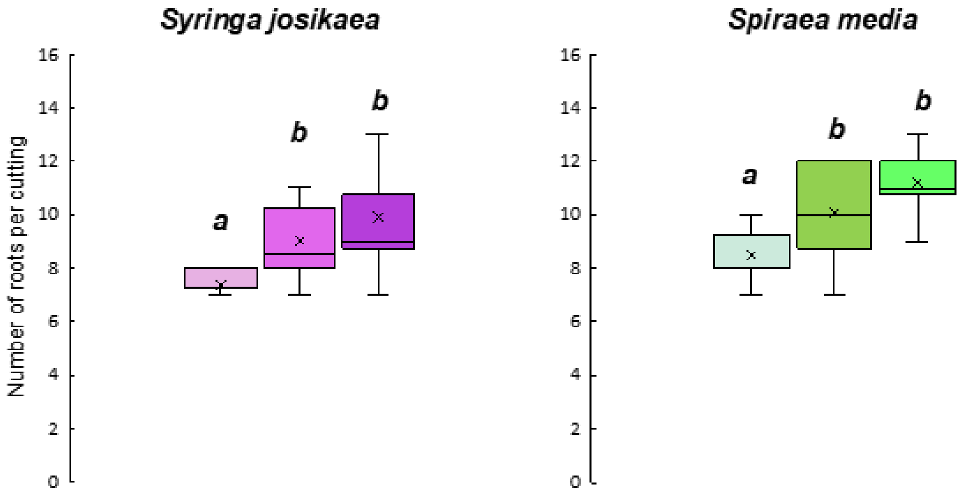

Fig. 2. Effect of IBA growth regulator on number of roots per cutting of *Syringa josikaea and Spiraea media*. Values with different letters differ significantly ($p < 0.05$) for different treatments (ANOVA, Tukey's test).

Source: compiled by N.V. Saltan.

Keeping the cuttings in the stimulator for a longer period of time contributed to better root formation.

Root length. IBA treatment also resulted in increased root length in cuttings of the studied species, but growth dynamics varied (Fig. 3, 4). In *Syringa josikaea*, maximum root length was significantly observed in the T3 treatment (16.6…20.0 cm; $p < 0.05$), and in *Spiraea media* — also in the T3 treatment (9.8…15.7 cm; $p < 0.05$). Overall, compared to the control, root length in *Syringa josikaea* was 52% longer after 6 hours of treatment and 89% longer after 12 hours. These values were significantly lower in *Spiraea media*: 27% longer after 6 hours of exposure and 42% longer after 12 hours.

The increase in root length may be associated with early callus formation, cell differentiation, greater cell elongation, and vascular tissue differentiation, which in turn promoted root growth. Shenoy showed that increase in root length in *Rosa damascena* compared to the control may be associated with enhanced carbohydrate hydrolysis, metabolite accumulation, and auxin-induced cell division [20]. These results are consistent with the findings of Singh et al. for *Cestrum nocturnum* [21] and Keerthivasan et al. for new jasmine genotypes [22].

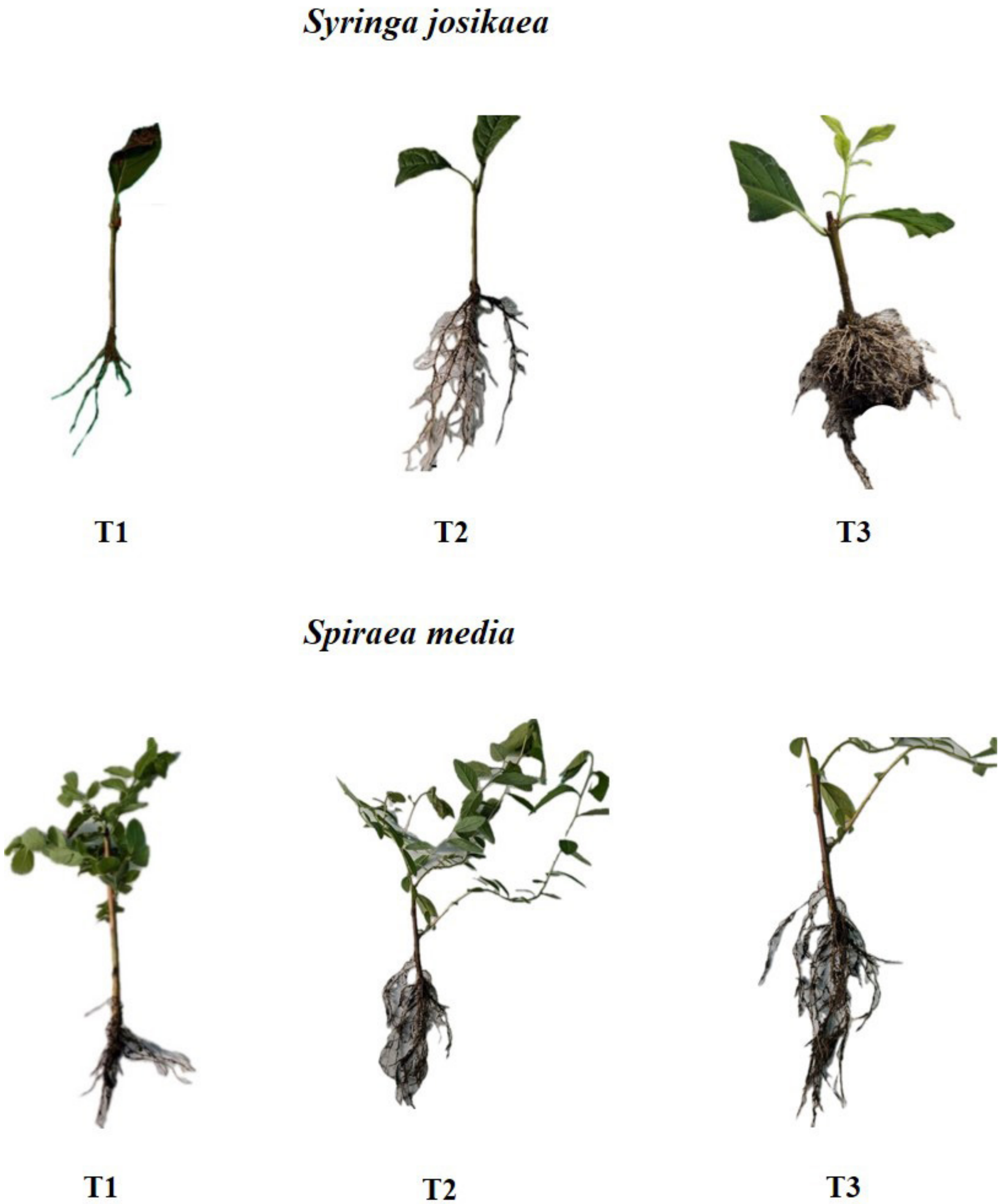

Fig. 3. Development of adventitious roots in plant cuttings
Source: compiled by N.V. Saltan.

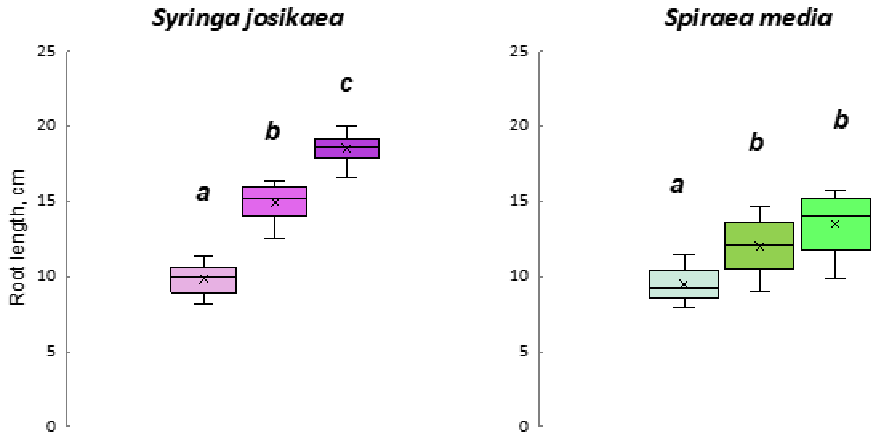

Fig. 4. Effect of IBA treatment on root length of *Syringa josikaea* and *Spiraea media*. Values with different letters differ significantly ($p < 0.05$) for different treatments (ANOVA, Tukey's test)

Source: compiled by N.V. Saltan.

Shoot growth. The maximum shoot growth (14.9 cm) was recorded in *Spiraea media* cuttings treated with IBA for 12 hours (T3), while the minimum (1.3 cm) was recorded in the control (T1) (Table). This parameter in *Syringa josikaea* cuttings varied within a lower range of values than in *Spiraea media*, but the trend identified for it was maintained. For both plant species, the effect of auxin treatment on cuttings was increased shoot growth compared to the control, especially with 12-hour treatment. Increased shoot growth in cuttings may be due to active root growth and a larger number of roots per cutting, which in turn increases the absorption of water and nutrients. In IBA-treated cuttings, auxin increased cell division, cell elongation, and protein synthesis, which could lead to increased healthy vegetative growth. Similar results were also obtained by Kumaresan et al. for *Jasminum multiflorum* [19] and Mohammed et al. for some rose cultivars [23].

Effect of growth regulator treatment time on shoot parameters

Growth regulator		Shoot growth, cm		Number of leaves per cutting	
		Syringa josikaea	*Spiraea media*	*Syringa josikaea*	*Spiraea media*
T1	Control	**1.59** 1.10–2.30	**3.41** 1.30–5.10	**2.67** 2.0–4.00	**13.83** 10.00–17.00
T2	IBA -1000pm (6h)	**2.91** 1.50–4.50	**4.83** 2.20–7.30	**3.17** 2.00–4.00	**21.5** 15.00–27.00
T3	IBA -1000pm (12h)	**3.59** 1.60–6.30	**7.72** 3.20–14.90	**5.33** 3.00–7.00	**37.17** 30.00–42.00

Note. above the line bold — mean; below the line — min–max.

Source: compiled by N.V. Saltan.

Number of leaves per cutting. In *Spiraea media*, a significant increase in the number of new leaves (37.17) was reliably observed with a longer treatment with IBA (T3) (see Table). In the control, new leaves were formed in cuttings, but in smaller quantities (13.83). In *Syringa josikaea*, which is characterized by larger leaves and long internodes, this indicator is much lower than in spirea. However, a 12-hour treatment with auxin was more effective than a 6-hour one and better stimulated leaf formation, which may be associated with an increase in plant height and the number of shoots. It was shown that under the influence of exogenous auxin, the number of leaves per cutting increases due to callus cell division, cell expansion and protein synthesis, which leads to increased growth of roots and shoots and, thus, to an increase in the number of leaves [24, 25].

Interactions between factors. Principal component analysis of *Syringa josikaea* revealed that the first component (64.9%) was associated with root length, root number, shoot growth, and leaf number per cutting (Fig. 5). The highest values for parameters characterizing effectiveness of growth stimulator were observed for the number of roots per cutting. Overlapping ellipses for T1 and T2 indicate little difference between IBA treatments for 6 and 12 hours.

In *Spiraea media*, the maximum contribution to variance is due to the first component (69%), which includes parameters such as root length and number, shoot growth, and number of leaves per cutting. In this plant species, the treatment types formed isolated ellipses, where the effect of a 12-hour treatment with a growth stimulator was the best, especially on shoot growth.

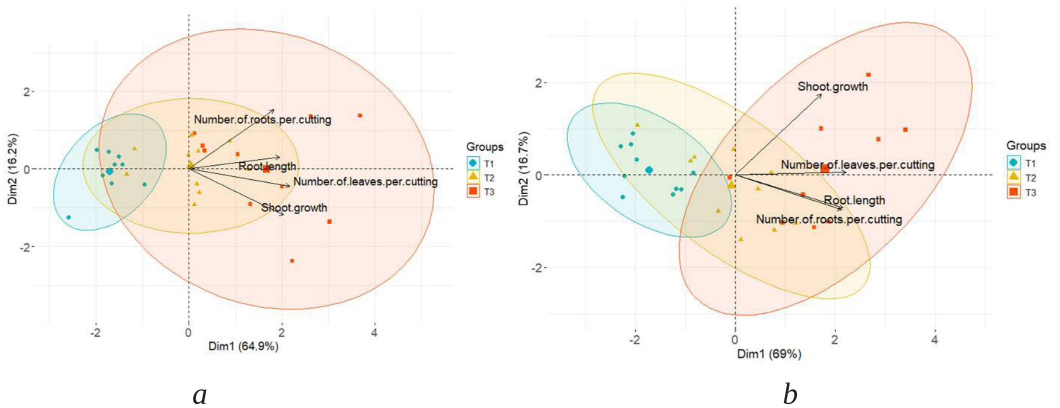

Fig. 5. Contribution of variables on principal component: *a — Syringa josikaea; b — Spiraea media*

Source: compiled by N.V. Saltan, M.V. Korneykova.

Survival rate. The proportion of rooted plants without the use of growth substances (T1) varied from 60 (*Syringa josikaea*) to 65% (*Spiraea media*) (Fig. 6). In cuttings of both species, which were in the growth stimulator for 6 hours, rooting was 70%. Treatment for 12 hours increased the survival rate for spirea to 75, and for lilac to 95. Thus, a 12-hour exposure to the growth stimulator had the greatest effect on the rooting of green cuttings of *Syringa josikaea*, for *Spiraea media* it was less significant. In both plants, very thin cuttings cut from the upper part of the shoots did not root.

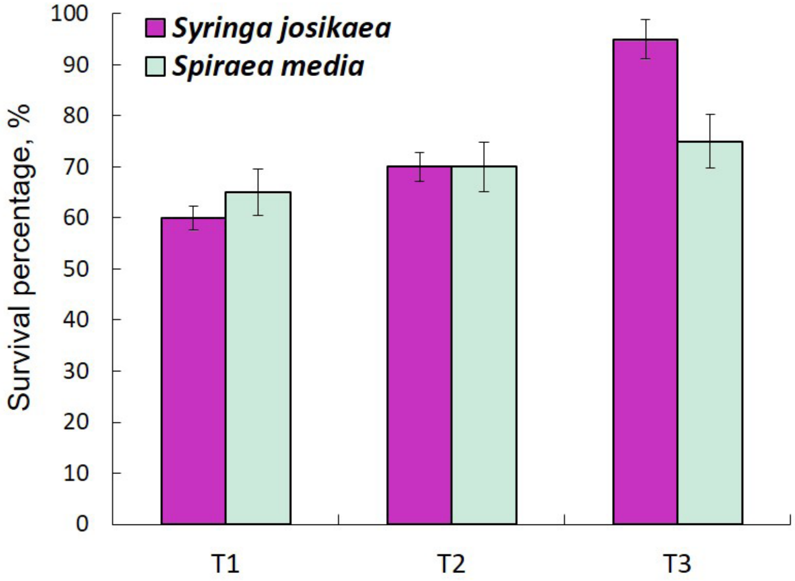

Fig. 6. Effect of growth regulator on survival percentage of green cuttings
Source: compiled by N.V. Saltan.

Conclusion

Based on the accumulated knowledge on green cuttings for more southern regions, we adjusted the technology for Arctic regions. Regional timing for cuttings was established, depending on the time of plant flowering and the onset of shoot lignification. The development and flowering periods of the experimental plants varied. *Spiraea media* is an earlier-flowering species than *Syringa josikaea*, and accordingly, cuttings were taken almost 10 days earlier.

Analysis of rooting results from cuttings revealed positive effect of growth stimulant treatment on the development of root system and aboveground part. An increase in root length was noted in cuttings from experimental plants: in *Syringa josikaea*, compared to the control, this figure was 52% higher with a 6-hour treatment, and 89% higher with a 12-hour treatment; in *Spiraea media*, this figure was 27% higher and 42% higher, respectively.

A 12-hour treatment of the experimental species with the growth stimulant also proved more effective than a 6-hour treatment for leaf formation. In *Syringa josikaea*, which is characterized by larger leaves and long internodes, this indicator was much lower than in *Spiraea media*. In the control, new leaves formed on the cuttings, but in smaller numbers.

A 12-hour treatment with a growth stimulant had the greatest impact on rooting of green cuttings: 95% for *Syringa josikaea* and 75% for *Spiraea media*, while a 6-hour treatment increased the rooting rate to 70% for both species. The percentage of rooted plants without the use of growth stimulants ranged from 60% (*Syringa josikaea*) to 65% (*Spiraea media*).

Thus, green cuttings of woody species, in particular *Syringa josikaea* and *Spiraea media*, are the most effective way to obtain planting material in the Arctic zone.

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About the authors:

Saltan Natalia Vladimirovna — Candidate of Biological Sciences, Senior Researcher, Laboratory of Decorative Floriculture and Landscaping, Avrorin Polar-Alpine Botanical Garden-Institute — Subdivision of the Federal Research Centre 'Kola Science Centre of the Russian Academy of Sciences', 18a Academgorodok microdistrict, Apatity, Murmansk Region, 184209, Russian Federation; e-mail: saltan.natalya@mail.ru
ORCID: 0000-0002-5905-9774 SPIN-code: 6405–0697

Sviatkovskaya Ekaterina Aleksandrovna — Researcher, Laboratory of Decorative Floriculture and Landscaping, Avrorin Polar-Alpine Botanical Garden-Institute — Subdivision of the Federal Research Centre 'Kola Science Centre of the Russian Academy of Sciences', 18a Academgorodok microdistrict, Apatity, Murmansk Region, 184209, Russian Federation; e-mail: sviatkovskaya@mail.ru
ORCID: 0000-0002-4069-7020 SPIN-code: 3143–2491

Zavodskikh Marina Sergeevna — Junior Researcher, Laboratory of Decorative Floriculture and Landscaping, Avrorin Polar-Alpine Botanical Garden-Institute — Subdivision of the Federal Research Centre 'Kola Science Centre of the Russian Academy of Sciences', 18a Academgorodok microdistrict, Apatity, Murmansk Region, 184209, Russian Federation; e-mail: mar.umanets@yandex.ru
ORCID: 0000-0002-5702-3858 SPIN-code: 1064–2792
Korneykova Maria Vladimirovna — Candidate of Biological Sciences, Senior Researcher, Center for Smart Technologies for Sustainable Development of the Urban Environment under the Global Change, Deputy Director for Research, Agrarian and Technological Institute, RUDN University, 6 Miklukho-Maklaya st. Moscow, 117198, Russian Federation; e-mail: korneykova.maria@mail.ru
ORCID: 0000-0002-6167-1567 SPIN-code: 8258–4976

Технология зеленого черенкования древесных растений в Арктическом регионе

Н.В. Салтан[1, 2] ✉, Е.А. Святковская[1], М.С. Заводских[1], М.В. Корнейкова[2]

[1]Полярно-альпийский ботанический сад-институт им. Н.А. Аврорина — обособленное подразделение Федерального государственного бюджетного учреждения науки Федерального исследовательского центра «Кольский научный центр Российской академии наук», *г. Апатиты, Российская Федерация*
[2]Российский университет дружбы народов, *г. Москва, Российская Федерация*
✉ saltan.natalya@mail.ru

Аннотация. Для озеленения северных городов возрастает потребность в декоративных растениях, устойчивых к условиям обитания, в связи с этим возникает необходимость найти решение для их размножения в промышленных масштабах. Разработана технология зеленого черенкования древесных растений (*Syringa josikaea* и *Spiraea media*) как одного из перспективных способов вегетативного размножения лиственных декоративных пород в арктическом регионе. Установлены сроки черенкования (после цветения, в начале одревеснения побега): для *Spiraea media* — 1–10 июля; для *Syringa josikaea* — 10–25 июля. Определено положительное влияние стимулятора роста ИМК 1000 ppm на развитие корневой системы и надземной части черенков при 6- и 12-часовой обработке. Показано, что эффективным способом является более длительный период обработки 12 часов. Длина корней у *Syringa josikaea* превышала контроль при 6-часовой обработке на 52 %; при 12 часовой — на 89 %; у *Spiraea media* — на 27 и 42 % соответственно. Выявлено также, что у обоих видов на 32…34 % увеличивалось количество корней при более продолжительном воздействии. Отмечено, что 12-часовая обработка достоверно увеличивала образование листьев на черенке *Syringa josikaea* ($r = 0{,}87$ $p > 0{,}001$) и *Spiraea media* ($r = 0{,}89$ $p > 0{,}001$). Результаты показали, максимальный процент приживаемости укоренившихся черенков имели *Syringa josikaea* (95,1 %) и *Spiraea media* (75,2 %) при обработке ИМК 1000 ppm в течение 12 часов.

Ключевые слова: вегетативное размножение, *Syringa josikaea*, *Spiraea media*, обработка ИМК, биометрические параметры, Мурманская область

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