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THE EFFECT OF GROWTH STIMULANTS ON THE ROOTING OF CUTTINGS OF PLANTS OF THE GENUS *COTONEASTER* MEDIC. ON DIFFERENT SUBSTRATES

Tetiana KOPYLOVA, Volodymyr HRABOVYI, Olha POROKHNIAVA, Yuriy RUMIANKOV, Alla KONOPELKO, Larisa NOVAK

National Dendrological Park 'Sofiyivka' of the National Academy of Sciences of Ukraine, 12a Kyivska Str., Uman, Ukrain

Corresponding author email: kt.pyracantha@gmail.com

Abstract

The results of studies on the regeneration ability of green and semi-woody cuttings of plants of the genus Cotoneaster Medic. for obtaining high-quality planting material are presented. The effect of plant growth stimulants (Heteroauxin, Epin +, Kornevin, Charkor) on rooting and biometric indicators of cuttings in protected soil conditions in different substrates peat + sand 2:1 (pH 4.8), sand (pH 5.7), peat substrate Mixkar MKS-10-6 (pH 5.2-6) was analyzed. The object of the study was represented by five species of Cotoneaster - Cotoneaster ascendens Flink & B. Hylmö, Cotoneaster hjelmqvistii Flinck & B. Hylmö, Cotoneaster horizontalis Decne., Cotoneaster nan-shan M.Vilm. ex Mottet, Cotoneaster dammeri C.K.Schneid, which are characterized by high decorativeness and are in demand, which requires maximum efficiency of vegetative propagation and cultivation in the conditions of the Right-Bank Forest-Steppe of Ukraine. Therefore, finding new technologies and improving existing ones for vegetative propagation of species of genus Cotoneaster is an extremely urgent task that requires a scientific solution.

Key words*: vegetative propagation, cuttings, biometric indicators, growth regulators, substrate.*

INTRODUCTION

The polymorphic genus *Cotoneaster* (Medic.) Bauhin contains 175 taxa, according to Flinck and Hylmö (1966). In his work "Sinopsis der Gattung Cotoneaster Medicus I", Klotz (1982) included 230 taxonomic units in this genus (Grevtsova, 1999). Recently, Plants of the World Online (POWO) accepted 268 species in the world flora (POWO, 2025).

The range of most species is located in the mountainous regions of Central Asia, Iran, Afghanistan, India, Mongolia, and China. In Western European countries, they have been used in landscaping since 1825 (Dickoré et al., 2010). Three species of *C melanocarpus*, *C. integerrimus* and *C. horizontalis* occur naturally in Ukraine (Grevtsova & Drabinyuk, 2020). *Cotoneaster* cultivars are diverse plants in terms of decorative characteristics, which helps create a desirable composition in gardens, parks, and home areas. They differ in the variety of habit, height, shape, leaf arrangement, abundance of flowering and fruiting, autumn leaf color, and are able to tolerate pruning well (Meng et al., 2021; Fryer & Hylmö , 2009; Grevtsova, 1999). *Cotoneasters* are of particular value as highly decorative plants in the autumn period, when plantings lack bright colors. At this time, their bushes are covered with orange, purple, dark red, black, pear-shaped, rounded fruits, which are placed on the shoot singly, in pairs, or as a raceme. They are used in border plantings, alpine gardens, as ground cover plants, and green fences. The largest collection in Ukraine was created in the O.V. Fomin Botanical Garden of the Taras Shevchenko National University of Kyiv, which consists of 200 taxa (Grevtsova et al., 2016; Grevtsova et al., 2017). The introduction of plants of the genus *Cotoneaster* in the National Dendrological Park "Sofiyivka" of the NAS of Ukraine began in 1959, and currently the collection is represented by 20 taxa.

Currently, the reproduction, growth, and use of deciduous and evergreen shrubs is extremely relevant and is discussed in the works of scientists in various fields of activity: biologists, dendrologists, ecologists etc.

In Ukraine, studies of the influence of cutting timing and growth stimulants on the rooting of green and semi-woody cuttings of ornamental shrubs using various substrates were conducted by various researchers.

In particular, Grevtsova and Kazanskaya (1997) studied the propagation of green, semi-woody and woody cuttings in cold greenhouses of the most decorative *Cotoneaster* species. Experiments conducted by the authors on the propagation of *C. megalocarpus, C. lucidus, C. przewalskii, C. roseus* by green cuttings on a substrate of sand + peat revealed differences between species and treatments. Maximum yield of rooted cuttings of *C. megalocarpus* was 40%, when using dimethyl sulfoxide (DMSO) 0.001%, same as the control; 100% at *C. lucidus* when using maleic acid hydrazide (HMA) 0.001%, compared to 64% in the control; 84% at *C.przewalskii* when using dimethyl sulfoxide (DMSO) compared to 60% in the control and 84-86% at *C. roseus* when using HMA and DMSO, compared to 38-48% in the control. Semi-woody cuttings were also rooted better when stimulants were used.

Tokman (2020) researched and developed measures and techniques for accelerated propagation of *Ligustrum vulgare* based on stem cuttings in the conditions of the northeastern Forest-Steppe of Ukraine. The optimal period for harvesting cuttings coincides with the dormant period of plants, when the rooting rate was 97%. Optimal for vegetative propagation of *Ligustrum vulgare* are three- and four-node cuttings, which significantly outperform two-node cuttings in terms of growth and development. An effective stimulator of regeneration processes in *Ligustrum vulgare* cuttings was Rhizopon AA powder (the rooting rate was 97%).

Kovalchuk et al. (2021) determined the percentage of engraftment and growth rates of the most common evergreen trees and shrubs in the Volyn region that are propagated by cuttings. Among the studied forms of evergreen plants, the highest percentage of rooting was observed in *Thuja occidentalis* 'Ericoides' (92%), *Thuja occidentalis* 'Aurea' (89%), *Buxus sempervirens* L. (94%) and *Thuja occidentalis* 'Globosa' (83%). The lowest percentage of rooting was observed in *Thuja occidentalis* 'Columna' (65%). Among trees, the greatest growth of the underground part was observed in *Picea pungens* 'Glauca' (26 cm) and among shrubs, in *Juniperus communis* L. (17 cm) and *Juniperus sabina* L. (13 cm).

Kopylova (2021) performed vegetative propagation of plants of the genus *Pyracantha* by rooting green, semi-woody, and woody cuttings, grafting, and also by the method of horizontal burial of shoots in the soil. The best indicators of cuttings' rooting were obtained in fine moisture conditions when planting semi-woody cuttings in a peat substrate KST (2:1:1) and green cuttings using heteroauxin 100 mg/l. Omelyanova and Kotovska (2021) conducted experiments on rooting cuttings of various types of citrus crops on such substrates as peat, sand, coconut substrate, vermiculite, peat with the addition of sand, coconut substrate with the addition of vermiculite. According to the results the highest percentage of survival was observed when growing plants in coconut substrate with the addition of vermiculite (85–98%). Planting material obtained by green cuttings using coconut substrate with the addition of vermiculite or vermiculite alone showed high rooting results.

Mikulich et al. (2023) experimentally investigated the effect of phytohormonal preparations on the rooting of cuttings and the effect of irradiation with red and blue lasers on cuttings of *Buxus sempervirens.* According to the results the positive effect was provided by complex irradiation with red and blue lasers with the longest duration of irradiation. All growth stimulants used during the study had a positive effect on the processes of root formation, but the greatest effect was achieved by "Heteroauxin" - 90%.

Pantsyreva et al. (2024) studied the rooting of green cuttings of the Viburnum 'Velikoplodna' variety. The rooting and subsequent growth and development of rooted three-node cuttings significantly outweigh the similar indicators of two- and one-node cuttings. Three-node cuttings harvested from the apical part showed the best rooting – 53.5%.

Poşta and Bernardis (2018) carried out research on vegetative propagation of *Cotoneaster dammeri* 'Skogholm' This study had as object the simultaneous influence of both nutritive mixture and foliar fertilizers on the growth and development of the seedlings The general conclusion was that vigorous *Cotoneaster dammeri* 'Skogholm' seedlings were obtained by using a nutritive sublayer composed of 30%

manure; 20% peat; 50% sand and Lithovit as foliar fertilizer product.

Ersoy et al. (2016) studied the rooting of green apical cuttings of *Cotoneaster horizontalis* using IBA and air humidity. The highest root number was obtained from 4000 ppm dose application (28.90 number/cutting) and the longest root (5.39 cm) was obtained from 1000 ppm IBA hormone dose application. Also, the highest rooting area lenght was found 5000 ppm hormone dose (13.26 cm).

The selected species of the *Cotoneaster* genus as objects of the present research are promising for landscaping in our climatic conditions, therefore the features of their reproduction and cultivation require further scientific justification. Scientific advances in previous years have shown that *Cotoneaster* cuttings have good rooting ability. Our work complements these studies with documented and analyzed material that tracks the rooting percentage and development of these species under the influence of modern growth regulators and using inexpensive substrates in conditions of fine-dispersed moistening. Our research will improve propagation technology, as well as reduce production costs and ensure the planned quantity and quality of planting material.

MATERIALS AND METHODS

Studies of the influence of growth stimulants and substrates on the rooting of cuttings of *C. ascendens, C. hjelmqvistii, C. horizontalis, C. nan-shan, C. dammeri* were conducted in greenhouse, with mist irrigation in the experimental and production nursery of the National Dendrological Park "Sofiyivka" of the NAS of Ukraine.

Material for cuttings was selected from young plants whose branches were formed in the current and last year. Green cuttings were harvested from the second decade of June to the second decade of July and semi-woody *Cotoneaster* cuttings from the second decade of July to the second decade of August. We prepared the cuttings with hand pruners. We divided the cuttings into three fractions: from the apical, medial, and basal parts of the shoot. An important condition for selecting cuttings was well-developed axillary buds. The length of the cuttings ranged from 5 to 15 cm, depending on the length of the internode. Each variant of the experiment contained 25 cuttings in three replicates.The lower cut was made below the bud at an angle of 40°-50°, and the upper cut was made directly above the bud.

In order to increase the regeneration ability, the basal part of the cuttings was treated with biologically active substances (Table 1) at a room temperature of + 22°C.

The use of stimulants was carried out according to the manufacturers' instructions. The control cuttings were soaked in water.

Cuttings were planted at a depth of 1.5-5 cm, placed them in the substrate at a 15-25° slope, at a distance of 3–5 cm within row, and 7-10 cm inter-row spacing. According to recommendations Bilous (2005) relative air humidity was maintained around 85-100% using mist irrigation. By watering the cuttings for 1.5 months, the substrate humidity was maintained at 60-70% and the temperature at 20-30°C.

We used peat substrate Mixkar MKS-1 0-6 (pH 5.2-6) - substrate I; peat + sand 2:1, (pH 4.8) - substrate II; sand (pH 5.7) - substrate III. The regenerative ability and effectiveness of the studied preparations were determined by such criteria as: rooting percentage, the number of formed roots, their length, and shoot growth.

Table 1. Growth stimulants for cuttings

Stimulant name	Active ingredient	Concentration	Processing time (hours)
Heteroauxin	potassium salt of ß-indoleacetic acid (50 g/kg)	4 g/l	16
Epin +	solution of 24-epibrassinolide in alcohol (0.025 g/l)	1 ml/l	24
Kornevin	indolyl-3-butyric acid (5 g/kg)	dry powder	1
Charkor	2,6-dimethylpyridine-1-oxide and α-phenylacetic acid 8.3 g/l	1 ml/l	20

For quantitative analysis, at least 25 shoots were taken per experimental variant. Percentage of rooted plants and quantitative parameters of their development were defined within 45 days. Parameters of rooted plants, in particular the shoot growth, number of roots, and root system length were determined as the average of the measurements of 15 separate plants. Results were presented as mean value ($\bar{X}$) ± standard error (SE). The differences between means were tested with Tukey's HSD. Differences with $P < 0.05$ were considered significant.

RESULTS AND DISCUSSIONS

Recording and comparative analysis of the results showed that the intensity of the rhizogenesis process at the initial stages depended on growth regulators and substrate. In general, the use of stimulants had a positive effect on rooting. Green cuttings of *C. dammeri* treated with a Heteroauxin solution and planted on substrate I, had the highest rooting percentage (100%), compared to the control - 72% (Figure 1, Figure 4a).

Substrate II and the stimulants Heteroauxin and Charkor, also stimulate the rooting of all green cuttings in *C. dammeri* (Figure 2).

The lowest percentage of rooting was found in green cuttings of *C. hjelmqvistii* (49.3%) using substrate II and *C. nan-shan* (50%) using substrate III without a stimulator (Figure 3 and Figure 4b, 4c).

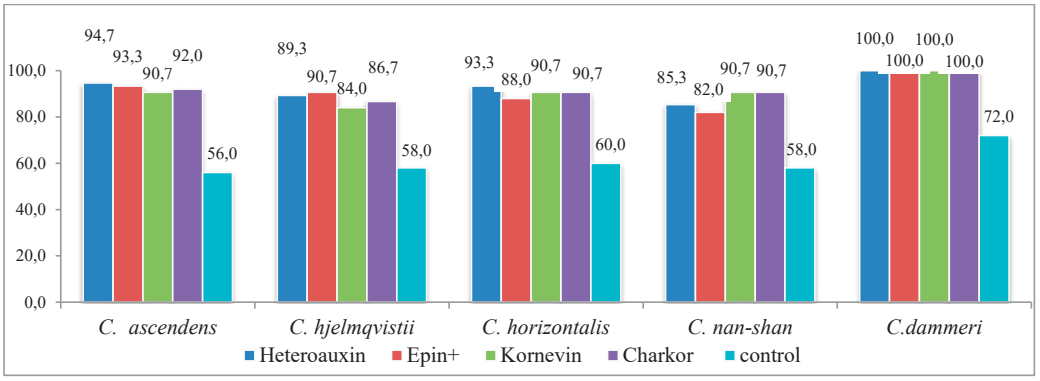

Figure 1. Effect of growth stimulant and substrate I on rooting of green cuttings (%)

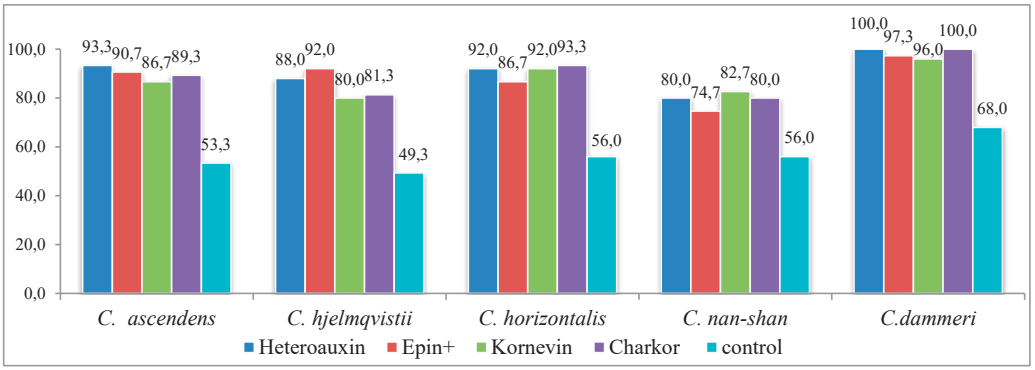

Figure 2. Effect of growth stimulant and substrate II on rooting of green cuttings (%)

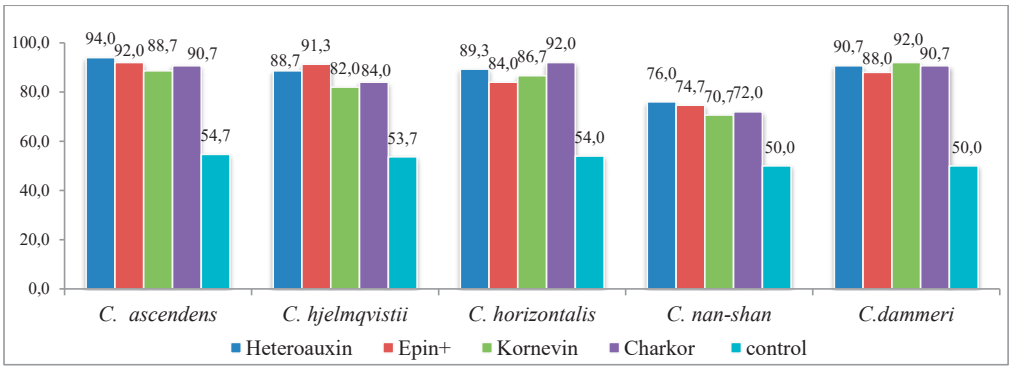

Figure 3. Effect of growth stimulant and substrate III on rooting of green cuttings (%)

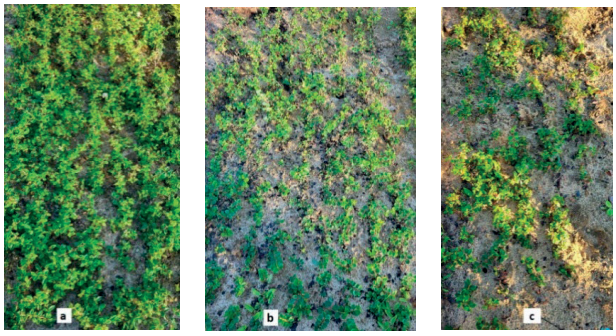

Figure 4. Rooted cuttings

a) *C. dammeri,* Heteroauxin, substrate I*;* b) *C. nan-shan,* control, substrate III*;* c) *C. hjelmqvistii,* control, substrate III

The highest rooting percentage of semi-woody cuttings of *C. ascendens, C. hjelmqvistii, C. nan-shan* and *C. dammeri* (Figure 8a) was obtained when was used Heteroauxin solution and substrate I (Figure 5). Kornevin stimulator also induced 100% rooting in both *C. hjelmqvistii* and *C. horizontalis* cuttings. Charkor stimulator and substrate I, obtained 100% rooting in *C. nan-shan* and *C. dammeri*.

The lowest rooting result (60%) was found in the control variant (*C. horizontalis, C. nan-shan*). Heteroauxin stimulator and substrate II obtained the highest percentage of rooting of *C. horizontalis* (100%) (Figure 6).

We found the lowest rooting percentage (54%) in semi-woody cuttings of *C. horizontalis* (control variant) in substrate III (Figure 7).

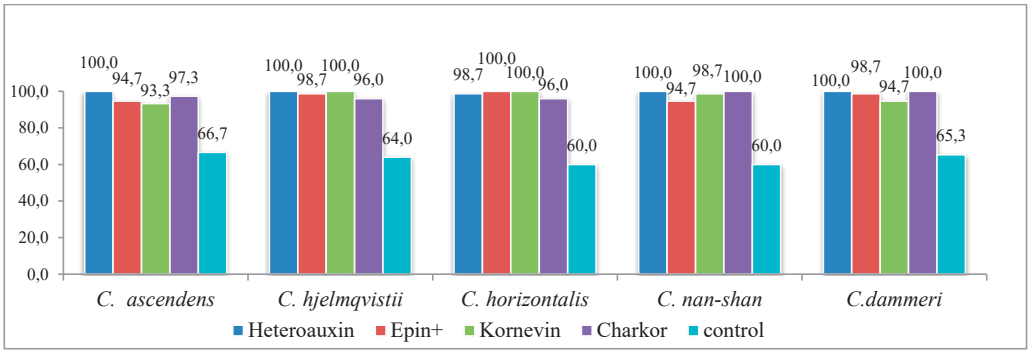

Figure 5. Effect of growth stimulant and substrate I on rooting of semi-woody cuttings (%)

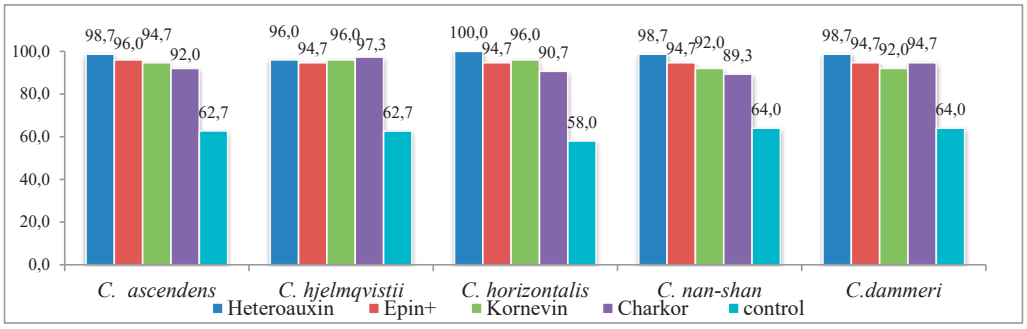

Figure 6. Effect of growth stimulant and substrate II on rooting of semi-woody cuttings (%)

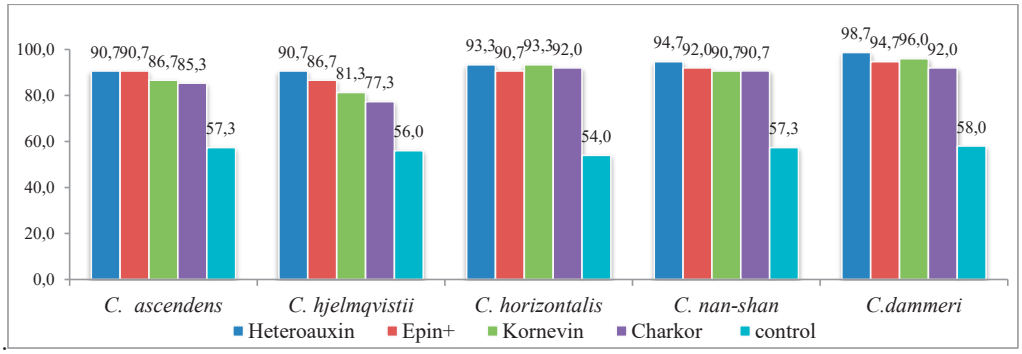

Figure 7. The effect of growth stimulant and substrate III on rooting of semi-woody cuttings (%)

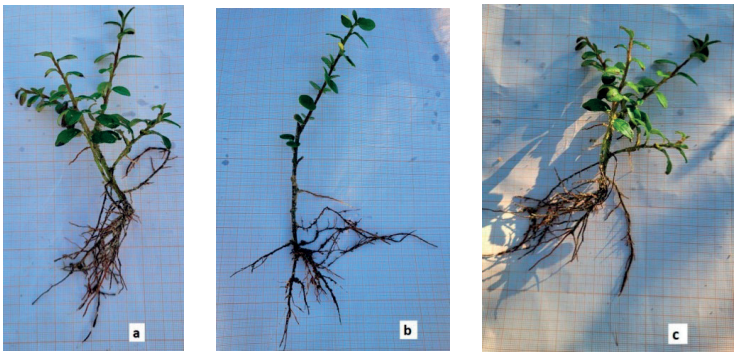

Figure 8. Rooting of green cuttings of plants of the genus *Cotoneaster* 45 days after planting in substrate I
a) *C. dammeri,* Heteroauxin; b) *C. ascendens,* Epin+; c) *C. nan-shan,* Charkor

The use of stimulants and various substrates has a positive effect on the percentage of rooting of cuttings, as well as on the growth and development of the root system and the above-ground part of the cuttings (Tables 2, 3, Figure 8).

Shoot growth, number of roots, and length of the root system were not significantly different when using the stimulants Heteroauxin, Epin+, Kornevin and Charkor in green cuttings of *Cotoneaster* species (Table 2). With the use of stimulants, the height of the above-ground part of rooted green cuttings exceeded the control variant by 1 cm. The number of roots per plant in the control variant was on average 2 fewer, and their length was 1.9 cm less. It was found that the use of substrate I was more effective (Table 2, Figure 8, Figure 9).

Biometric indicators such as shoot growth, number of roots, and length of the root system of rooted semi-woody cuttings almost did not differ (Table 3). The growth of the above-ground part of the cuttings using stimulants exceeded the control by 0.6 cm, the number of roots exceeded by 1.4 pcs and the length of the root system was 1.6 cm longer. The best result was obtained when using substrate I (Table 3, Figure 9a).

Table 2. Characteristics of green cuttings of plants of the genus *Cotoneaster* 45 days after planting (n=15, X̄±SE)

Species	Shoot height, cm			Number of roots, pcs.			Root system length, cm		
	Substrate, №			Substrate, №			Substrate, №		
	I	II	III	I	II	III	I	II	III
With stimulants									
C. ascendens	2.3±0.10^{a}	1.8 ±0.11^{a}	1.1±0.08^{a}	4.0±0.28^{a}	4.8 ± 0.26^{a}	2.8±0.24^{a}	7.4±0.42^{a}	5.9 ± 0.35^{a}	4.6±0.21^{a}
C. hjelmqvistii	2.8±0.11^{b}	2.4±0.12^{b}	1.1±0.09^{ac}	3.1±0.31^{b}	2.9±0.24^{b}	2.1±0.18^{b}	5.4±0.28^{b}	4.9±0.38^{b}	4.5±0.37^{ac}
C. horizontalis	3.0±0.10^{c}	2.8±0.12^{c}	1.2±0.08^{ad}	4.8±0.28^{c}	4.7±0.25^{a}	3.0±0.26^{a}	5.5±0.40^{b}	5.1±0.33^{b}	4.9±0.28^{ad}
C. nan-shan	2.2±0.13^{a}	1.8±0.17^{a}	1.8±0.14^{b}	3.9±0.25^{a}	3.3±0.25^{c}	2.2±0.24^{b}	5.6±0.26^{b}	5.0±0.32^{b}	4.6±0.34^{ac}
C.dammeri	3.2±0.18^{d}	2.7±0.13^{c}	1.2±0.10^{cd}	5.8±0.30^{d}	4.0±0.31^{d}	3.1±0.27^{a}	7.3±0.37^{a}	6.1±0.33^{a}	5.2±0.30^{bd}
X̄	2.7	2.3	1.3	4.3	3.9	2.6	6.4	5.5	4.7
Control									
C. ascendens	1.7±0.13^{a}	1.5 ± 0.14^{a}	1.0±0.07^{ac}	3.3±0.23^{a}	3.8 ± 0.33^{a}	2.3±0.18^{a}	5.4±0.28^{a}	4.6 ± 0.30^{a}	3.7±0.20^{a}
C. hjelmqvistii	1.6±0.13^{ab}	1.7±0.18^{bc}	1.0±0.08^{a}	2.7±0.23^{b}	2.3±0.23^{b}	1.9±0.18^{b}	4.1±0.23^{b}	3.8±0.19^{b}	3.7±0.24^{a}
C. horizontalis	1.5±0.13^{bc}	1.6±0.14^{ac}	1.0±0.07^{ac}	3.5±0.31^{a}	3.5±0.27^{ac}	2.3±0.25^{a}	4.0±0.22^{b}	3.0±0.20^{c}	3.1±0.20^{b}
C. nan-shan	1.4±0.14^{cc}	1.2±0.09^{c}	1.2±0.12^{b}	3.1±0.29^{a}	2.5±0.27^{b}	1.9±0.24^{b}	3.8±0.21^{b}	3.8±0.20^{b}	3.5±0.23^{a}
C.dammeri	2.2±0.19^{d}	2.0±0.17^{d}	1.1±0.10^{c}	4.1±0.35^{c}	3.3±0.28^{c}	2.4±0.27^{a}	5.0±0.26^{c}	4.5±0.32^{a}	4.3±0.20^{c}
X̄	1.7	1.6	1.1	3.3	3.1	2.2	4.5	3.9	3.7

Note: the different letters indicate statistically significant differences in the means of the compared pair according to the Tukey criterion

Table 3. Characteristics of semi-woody cuttings of plants of the genus *Cotoneaster* 45 days after planting (n=15, X̄±SE)

Species	Shoot height, cm			Number of roots, pcs.			Root system length, cm		
	Substrate, №			Substrate, №			Substrate, №		
	I	II	III	I	II	III	I	II	III
With stimulants									
C. ascendens	2.0±0.14^{a}	1.7 ± 0.11^{a}	0.9±0.07^{a}	4.9±0.34^{a}	4.6 ± 0.27^{a}	2.6±0.19^{a}	6.3±0.44^{a}	5.2 ± 0.35^{a}	4.7±0.40^{a}
C. hjelmqvistii	2.2±0.18^{b}	2.3±0.15^{b}	1.2±0.16^{b}	4.3±0.40^{b}	3.2±0.28^{b}	2.4±0.19^{a}	4.8±0.38^{b}	4.0±0.28^{b}	5.5±0.44^{b}
C. horizontalis	2.9±0.10^{c}	2.2±0.21^{b}	0.9±0.07^{ac}	4.3±0.34^{b}	3.7±0.35^{c}	2.9±0.21^{b}	5.5±0.44^{b}	5.1±0.32^{ab}	4.6±0.35^{a}
C. nan-shan	1.7±0.19^{d}	1.4±0.15^{c}	1.0±0.11^{c}	4.1±0.27^{b}	3.2±0.26^{b}	2.4±0.21^{a}	5.6±0.39^{b}	4.9±0.34^{b}	4.7±0.30^{a}
C.dammeri	2.6±0.18^{c}	2.1±0.18^{b}	1.1±0.09^{bc}	5.3±0.33^{c}	4.0±0.32^{c}	2.5±0.24^{a}	6.8±0.41^{a}	5.3±0.31^{a}	4.6±0.26^{a}
X̄	2.3	1.9	1.0	4.6	3.7	2.6	5.9	5.1	4.5
Control									
C. ascendens	1.4±0.14^{a}	1.3 ±0.12^{a}	0.7±0.09^{a}	3.0±0.31^{ac}	2.7 ± 0.30^{a}	2.1±0.23^{a}	4.7±0.22^{a}	4.1 ± 0.20^{a}	3.8±0.23^{a}
C. hjelmqvistii	1.4±0.13^{a}	1.4±0.13^{b}	1.0±0.10^{b}	2.9±0.26^{a}	2.3±0.27^{b}	1.9±0.21^{a}	4.0±0.24^{b}	4.0±0.32^{ad}	3.2±0.17^{b}
C. horizontalis	2.1±0.13^{b}	1.8±0.19^{c}	0.7±0.07^{ad}	2.7±0.25^{ad}	2.7±0.30^{a}	2.3±0.21^{b}	3.8±0.23^{b}	3.8±0.18^{bd}	3.±0.22^{b}
C. nan-shan	1.4±0.17^{a}	1.2±0.09^{a}	0.8±0.12^{cd}	3.1±0.25^{ac}	2.4±0.19^{b}	1.9±0.18^{a}	3.8±0.22^{b}	3.7±0.16^{b}	3.2±0.16^{b}
C.dammeri	1.8±0.09^{c}	1.6±0.14^{c}	0.9±0.08^{c}	3.6±0.27^{b}	2.9±0.27^{a}	1.7±0.15^{c}	5.1±0.20^{c}	4.2±0.13^{a}	3.5±0.16^{c}
X̄	1.6	1.5	0.8	3.1	2.6	2.0	4.3	4.0	3.4

Note: the different letters indicate statistically significant differences in the means of the compared pair according to the Tukey criterion

Figure 9. Rooted semi-woody cuttings of plants of the genus *Cotoneaster* (45 days)
a) *C. horizontalis* Heteroauxin, substrate I; b) *C. hjelmqvistii* control, substrate II; c) *C. ascendens* control, substrate III

A comparative analysis of the results obtained in our studies with the conclusions of other authors showed that the use of stimulants had a positive effect on the rooting of cuttings. Kovalchuk et al. (2021) using the Heteroauxin stimulator and substrate II, reported high rooting rates of 94% of green cuttings of *Buxus sempervirens* L., which exceeded the control by 18%.

In our experiments, all green cuttings on Substrate II + Heteroauxin, have rooted in the species *C. dammeri*. Quite high rooting results were also obtained for *C. ascendens* - 93.3%, *C. horizontalis* - 92%, *C. hjelmqvistii* - 88%, but this combination was less effective in promoting rooting of *C. nan-shan* - 80%.

Rooting green cuttings of *Buxus sempervirens* L. according to the scheme Substrate II + Kornevin, Kovalchuk et al., (2021) achieved an efficiency level of 93%, which exceeded the control by 16%. In our studies, the same scheme (Substrate II + Kornevin) was most effective for green cuttings of *C. dammeri* (96%). When rooting *C. horizontalis*, the use of stimulants such as Kornevin or Heteroauxin leads to the same rooting result (92%). However, scheme Substrate II + Kornevin recorded slightly lower results at *C. ascendens* - 86.7%, *C. nan-shan* - 82.7% and *C. hjelmqvistii* - 80%.

Green cuttings of *Buxus sempervirens* on Epin+ and Substrate II, formed roots in 93% of the cuttings, as in the variant with the Kornevin stimulator, which exceeded the control by 16% (Kovalchuk et al., 2021). Using the same scheme, we obtained a fairly high result for *C. dammeri* - 97.3%, *C. hjelmqvistii* - 92%, *C. ascendens* - 90.7%, and for *C. horizontalis* and *C. nan-shan*, was less effective - 86.7 and 74.7%, respectively.

In the scheme Substrate II and control the rooting results were quite low: *C. ascendens* - 53.3%, *C. hjelmqvistii* - 49.3%, *C. horizontalis* - 56.7%, *C. nan-shan* - 56%, *C. dammeri* - 68%. In general, when using stimulants, the percentage of rooting of green cuttings of species of the genus *Cotoneaster* was higher by 18.7-42.7%.

Comparing the rooting rate of green cuttings of the species *C. ascendens, C. horizontalis, C. nan-shan* with the results of the experiments of Grevtsova & Kazanskaya (1997), it was found that in our studies the rooting rate is higher. For example, the maximum yield of rooted green cuttings of *C. nan-shan* was 90% when using indoleacetic acid and leafy soil as a substrate. In our study, the maximum yield of rooted green cuttings of *C. nan-shan* was 90.7%, using Kornevin and Charkor and substrate I (peat Mixkar MKS-1 0-6) (Figure 1). The maximum yield of rooted green cuttings of *C. ascendens* was 85% when using indolylbutyric acid and the substrate leaf soil, and in our studies 94.7% when using Heteroauxin and the substrate I. The maximum yield of rooted green cuttings of *C. horizontalis* was 83% when using indolylbutyric acid and the substrate leaf soil, and in our studies 93.3% when using Heteroauxin and the substrate I. The maximum yield of rooted green cuttings of *C. nan-shan, C. ascendens, C. horizontalis* in the control variant (talc + sand) was 48, 44, 41%, respectively, and in our studies 58, 56, 60%, respectively, when using substrate I.

Comparing the rooting efficiency of semi-woody cuttings of the species *C. ascendens, C. horizontalis, C. nan-shan* with the results of experiments in our studies, it was found that in our studies, rooting efficiency is also higher. The maximum yield of rooted semi-woody cuttings of *C. ascendens* was 92% when using indolylbutyric acid and the substrate leaf soil, and in our studies 100% when using Heteroauxin and substrate I (Figure 3). The maximum yield of rooted semi-woody cuttings of *C. nan-shan* was 79% when using indoleacetic acid and leaf soil substrate, and in our studies 100% when using Heteroauxin and Charkor and substrate I. acid and the substrate leaf soil, and in our studies 100% when using Heteroauxin and Charkor and the substrate I. The maximum yield of rooted semi-woody cuttings of *C. ascendens, C. nan-shan,* and *C. horizontalis* in the control variant (talc + sand) was 63, 40, and 25%, respectively, and in our studies it was 66.7% when using (substrate I), 64% (substrate II peat + sand 2:1), and 60% (substrate I), respectively.

A study of the effect of stimulants on the rooting of green and semi-woody cuttings was conducted by Kopylova (2021) on the species *Pyracantha coccinea, P. crenatoserrata*, and *P.* x 'Orange Charmer'. Growth stimulants accelerated and improved the rooting of *Pyracantha* cuttings. The best results (100%) in rooting green pyracantha cuttings were obtained when using Heteroauxin and in KTS substrate (2:1:1) and peat tablets. The onset and mass rooting occurred 6-8 days earlier than in the control, the difference in the average root length was from 6.2±1.24 to 9.64±4.5 cm, the number of roots from 4.4±1.88 to 6.2±1.36 pcs., the average shoot growth from 1.8±0.49 to 2.16±0.77 cm three months after cutting.

In our studies on rooting with green cuttings, the greatest shoot growth of 3.2±0.18 cm was found in plants of the species *C. dammeri*, and in plants of the species *C. ascendens* the greatest root system length was 7.4±0.42 cm in the variant using growth stimulants and in substrate I. When rooting with semi-woody cuttings, the greatest shoot growth of 2.9±0.10 cm was found in plants of the species *C. horizontalis*, and in plants of the species *C. dammeri* the greatest root system length was 6.8±0.41 cm in the variant using substrate I. We obtained the best biometric indicators when rooting green and semi-woody cuttings of plants of the genus *Cotoneaster* using stimulants and peat in the substrate.

CONCLUSIONS

It has been proven that in order to root a certain species of the *Cotoneaster* genus, it is necessary to use a specific type of growth stimulant and substrate. For semi-woody cuttings the best stimulator was Heteroauxin for *C. ascendens*, Heteroauxin and Kornevin for *C. hjelmqvistii* Kornevin and Epin+ for *C. horizontalis*, Heteroauxin and Charkor for *C. nan-shan*, Heteroauxin and Charkor for *C. dammeri*.

For green cuttings of *C. dammeri* Kornevin stimulator, promoted rooting at a level of 92.0 to 100%, Heteroauxin and Charkor - from 90.7 to 100%; and the Epin+ stimulator - from 88.0 to 100%.

An important factor in the technology of production of standard planting material is the substrate. The best substrates for rooting the studied species of the genus *Cotoneaster* were Mixkar MKS-1 0-6 pH 5.2-6 and peat + sand 2:1, pH (4.8).

When rooted using stimulants, cuttings formed greater shoot growth and a deeper root system. Also, shoots growth, of green cuttings was better. The number of roots under the influence of stimulants increased to a level of 2.6 to 4.3 pcs., and the length of the root system from 4.7 to 6.4 cm.

When stimulants were used on semi-woody cuttings, the growth of shoots ranged from 1 to 2.3 cm, and without the stimulant from 0.8 to 1.6 cm. The number of roots increased to a level of 2.6 to 4.6 pieces, and the length of the root system of 4.5 to 5.9 cm.

Therefore, we recommend these stimulants and substrates for mass propagation.

The practical significance of the research results for industrial plant nurseries lies in the possibility of improving the technology of propagation of *Cotoneaster* species through cost-effective growth regulators. Establishing sustainable agronomic practices is an important step in introducing plants of the *Cotoneaster* genus into ornamental gardening, which create long-lasting and decorative plantings

throughout the growing season, while requiring minimal care.

Our research may be useful for future studies on how growth promoters affect root or shoot formation. These data are important for basic research in plant physiology and may also form the basis for further research in plant breeding.

The results of our work can be used to improve laboratory methods for studying the effects of growth stimulants on other plant species, and will also help to evaluate the effectiveness of different stimulants and substrates in comparison.

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