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Characteristics of rooting in rose cuttings (*Rosa* spp.) depending on cultivar and morphometric parameters under greenhouse conditions

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Abstract. The relevance of this study stems from the need in ornamental horticulture for high-quality, uniform and cultivar-specific rose planting material, which can be produced under controlled microclimatic conditions. Rooting of cuttings is a crucial stage in vegetative propagation; however, its effectiveness depends on the biological characteristics of the cultivar and the parameters of the harvested shoot. The aim of this study was to determine the characteristics of rooting of semi-hardwood rose cuttings depending on cultivar and morphometric parameters under greenhouse conditions. The cultivars Jude the Obscure, The Pilgrim and Abraham Darby were studied. For each cultivar, cuttings 25, 40 and 60 cm in length were used; the number of internodes, shoot diameter, length of the lower cut, percentage of rooted cuttings, average root length and average root system mass were determined. The cuttings were planted in a sterile substrate of peat and perlite in a 1:1 ratio at an air temperature of 22-25°C, relative

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humidity of 85-95%, diffused light and regular fine-mist irrigation. It was found that as the length of the cuttings increased from 25 to 60 cm, the number of internodes, the diameter of the shoots and the area of the lower cut all increased; however, the maximum length did not always result in the highest survival rate. The best rooting rates for all cultivars were achieved using 40 cm-long cuttings: for Jude the Obscure the rooting rate was 82%, for The Pilgrim 76%, and for Abraham Darby 86%. Cuttings 60 cm in length formed a longer and more robust root system; in particular, for Abraham Darby, the average root length reached 7.4 cm and the root mass was 0.94 g, although the rooting percentage was lower than for the 40 cm cuttings. The lowest results were observed when using 25 cm-long cuttings. Based on a range of indicators, the Abraham Darby cultivar proved to be the most promising for propagation by cuttings. The practical value of this study lies in substantiating the feasibility of using 40 cm-long semi-hardwood cuttings to increase the yield of high-quality rose planting material under greenhouse conditions

Keywords: ornamental horticulture; English roses; semi-hardwood shoots; substrate; root formation; planting stock; cuttings

INTRODUCTION

Ornamental horticulture requires techniques that ensure a consistent supply of uniform planting stock with a high degree of preservation of cultivar characteristics. For roses, this issue is particularly important, as their ornamental value is determined not only by the colour and shape of the flower, but also by vigour, repeat flowering, resilience to growing conditions and the ability to retain typical cultivar characteristics during propagation. O.Yu. Bondarenko *et al.* (2024), analysing the range of cultivated plants in botanical collections, emphasised the importance of selecting adapted ornamental crops for landscaping, whilst H.V. Pantsyreva (2019) substantiated the prospects for using flowering ornamental plants in the design of park plantings. I.L. Denysko (2022) demonstrated the potential for introducing David Austin roses into the Right-Bank Forest-Steppe region of Ukraine and noted their high ornamental value and adaptive potential. H. Gill *et al.* (2025) demonstrated that certain ornamental traits of roses, in particular the characteristics of flower colour change, are genetically determined; thus, it is important to use propagation methods that ensure the preservation of cultivar identity. A. Kalisz *et al.* (2023) also drew attention to the varietal specificity of roses, identifying significant differences between cultivars in the content of bioactive compounds in the petals.

Vegetative propagation by cuttings is one of the most practical methods for obtaining uniform planting stock of roses. P.V. Bezikonnyi *et al.* (2023) found that the application of growth biostimulants affects the rooting of green cuttings of the wrinkled rose under protected ground conditions. E.K. Blythe *et al.* (2004) demonstrated that the method of applying auxin and the use of a surfactant can alter the rooting efficiency of rose cuttings. A. Muraleedharan *et al.* (2020) also noted that the rooting of rose cuttings depends on the hormonal preparation used, whilst N. Ghazijahani *et al.* (2017) demonstrated that rhizogenesis in soft rose cuttings can be regulated by treating the mother plants with organic acids. I. Mohammed *et al.* (2024) confirmed that the response of rose cuttings to indolebutyric acid

and an anti-transpirant depends on the rose cultivar, the method of application and the characteristics of the cutting. These results indicate that rooting is not only a technical process but also a cultivar-dependent one.

A. Ait Hida *et al.* (2022), studying cuttings of *Rosa damascena* Mill., demonstrated that the origin of the cutting material and auxin treatment significantly affect the rooting percentage. Similar conclusions regarding the importance of auxin regulation of root formation are also presented in the studies by S. Erçişli *et al.* (2005), A. Kazankaya *et al.* (2005) and I. Mohammed *et al.* (2024), which emphasise the role of indolebutyric acid, the substrate, the physiological state of the cutting and the technical conditions of rooting. *In vitro* studies have also confirmed the importance of growth regulators for root formation and subsequent regeneration in roses (Chhargri *et al.*, 2020; Kosenko *et al.*, 2021; El Malahi *et al.*, 2025). Furthermore, R.J. Morales-Orellana *et al.* (2022) demonstrated that localised laser damage to tissues can stimulate the formation of adventitious roots in rose cuttings, highlighting the complexity of the physiological mechanisms of rhizogenesis. O.V. Kobets (2013), using green cuttings of berry crops as an example, also demonstrated the importance of growth regulators and the conditions under which mother plants are maintained for the rooting process. Thus, existing studies have confirmed the importance of growth regulators; however, the question of the optimal length of cuttings and their morphometric parameters for specific rose cultivars remains insufficiently detailed. The scientific problem lies in the fact that most existing studies examine the influence of substrates, auxins or the origin of cuttings in isolation, whilst a comprehensive assessment of cultivar characteristics and the morphometric parameters of cuttings under controlled greenhouse conditions remains limited. It is therefore important to identify those parameters of cuttings that ensure not only high survival rates but also the formation of a sufficiently developed root system in the cultivars Jude the Obscure, The Pilgrim and Abraham Darby.

The aim of the study was to investigate the effect of cultivar and the morphometric parameters of cuttings on their rooting under greenhouse conditions and to determine the optimal cutting parameters for producing high-quality rose planting stock. To achieve this aim, the study involved analysing the biological characteristics of the cultivars under investigation, determining the morphometric parameters of the cuttings, assessing their impact on the rooting percentage, investigating root system development, and establishing the optimal cutting parameters for the effective vegetative propagation of roses under greenhouse conditions. The scientific novelty of this work lies in the comparative assessment of the rooting of cuttings from three rose cultivars with different morphometric parameters under controlled greenhouse conditions.

MATERIALS AND METHODS

The study was conducted in June-July 2025 in the greenhouse of the “Amity” Horticultural and Landscape Centre. The study focused on semi-hardwood cuttings of roses (*Rosa spp.*) of the cultivars Jude the Obscure, The Pilgrim and Abraham Darby, rooted under greenhouse conditions. The study was conducted

in accordance with the principles of the Convention on Biological Diversity (1992). The experimental design involved the study of two factors: rose cultivar and cutting length. Factor A comprised three cultivars: Jude the Obscure, The Pilgrim and Abraham Darby; factor B comprised three cutting lengths: 25, 40 and 60 cm. The experiment was set up in triplicate. The treatments were arranged randomly within each replicate in the greenhouse, which minimised the impact of variations in light, humidity and temperature.

Cuttings were taken from well-developed, healthy semi-hardwood shoots in 2025. In each treatment, the length of the cutting, the number of internodes, the shoot diameter and the length of the lower cut were determined. The lower cut was made at a 45° angle immediately below a bud, whilst the upper cut was made straight, 1-2 cm above the top bud. The lower leaves were removed, and the upper leaves were partially shortened to reduce moisture evaporation, in line with general methodological approaches to the propagation of ornamental crops by cuttings (Bezvikonnyi *et al.*, 2023; Mohammed *et al.*, 2024). The morphometric parameters of the cuttings are presented in Table 1.

Table 1. Morphometric characteristics of rose cuttings depending on cultivar

Cultivar	Variant No.	Cutting length, cm	Number of internodes, no.	Shoot diameter, mm	Length of basal cut, cm
Jude the Obscure	1	25	2	3.4	2.0
	2	40	5	4.5	3.5
	3	60	7	5.6	5.0
The Pilgrim	1	25	2	3.2	2.0
	2	40	4	4.3	3.4
	3	60	6	5.3	4.8
Abraham Darby	1	25	3	3.7	2.2
	2	40	5	4.8	3.7
	3	60	7	5.9	5.1

Source: compiled by the authors

Before planting, the base of the cuttings was treated with “Kornevin”, the active ingredient of which is indolebutyric acid (IBA). The working solution was prepared immediately before use at a rate of 1 g of the product per 1 litre of water. The lower part of the cuttings was immersed in the solution to a depth of 2-3 cm and left for 12 hours, after which the cuttings were planted in a sterile substrate of peat and perlite in a 1:1 ratio. The planting depth was 2-3 cm. In the greenhouse, the air temperature was maintained at 22-25°C, relative humidity at 85-95%, with diffused lighting and regular moistening of the substrate. Fine-mist irrigation was used to maintain high humidity, and ventilation was carried out to prevent the development of fungal diseases and rotting of the cuttings.

Records were taken on days 14, 21, 28 and 35 after planting. The rooting period lasted 35 days. A cutting was considered rooted if it had at least three adventitious roots longer than 1.0 cm and the above-ground

part remained viable. The rooting percentage was determined as the proportion of rooted cuttings out of the total number of cuttings planted in each treatment. The average root length was determined by measuring the developed roots on the rooted cuttings. Statistical analysis of the results was carried out using standard methods of variance analysis. For each experimental treatment, the arithmetic mean of the studied parameters was calculated.

RESULTS AND DISCUSSION

Analysis of the morphometric parameters of rose cuttings showed that, in all the cultivars studied, as the cutting length increased from 25 to 60 cm, the number of internodes, shoot diameter and length of the lower cut increased in a regular pattern. This trend indicates an increase in the reserve of plastic substances in longer cuttings and a potentially larger area for root formation, which is consistent with data on internode

lengths and shoot growth parameters in roses reported by S. Demotes-Mainard *et al.* (2013). In Jude the Obscure, the number of internodes ranged from 2 to 7, and the shoot diameter from 3.4 to 5.6 mm. This indicates a gradual increase in the physiological potential of the cuttings as their length increased. The The Pilgrim cultivar had slightly lower morphometric parameters compared with other cultivars: the number of internodes was 2-6, and the shoot diameter was 3.2-5.3 mm. Such cuttings remained suitable for rooting but required stable temperature and humidity conditions (Rubtsova *et al.*, 2020; Denysko, 2025).

The highest morphometric parameters were observed in the Abraham Darby cultivar: shoot diameter

ranged from 3.7 to 5.9 mm, and the number of internodes ranged from 3 to 7. This indicates better-developed shoots and a greater reserve of nutrients, which may have a positive effect on root system development. In terms of morphometric characteristics, the cuttings of the Abraham Darby cultivar were the most robust; Jude the Obscure had slightly lower values, whilst The Pilgrim had the lowest. Cuttings of an average length of 40 cm were the most balanced for subsequent rooting, as they combined a sufficient number of internodes and shoot diameter without an excessive risk of moisture loss (Ouyang *et al.*, 2019; Mohammed *et al.*, 2024). The results of cutting rooting, depending on cultivar and morphometric parameters, are presented in Table 2.

Table 2. Rooting performance of rose cuttings depending on cultivar and morphometric parameters under greenhouse conditions

Cultivar	Variant No.	Cutting length, cm	Rooted cuttings, %	Mean root length, cm	Mean root system mass, g
Jude the Obscure	1	25	65	4.2	0.48
	2	40	82	6.5	0.75
	3	60	78	7.1	0.88
The Pilgrim	1	25	61	3.9	0.43
	2	40	76	6.1	0.68
	3	60	72	6.6	0.79
Abraham Darby	1	25	69	4.6	0.54
	2	40	86	6.9	0.82
	3	60	81	7.4	0.94

Source: compiled by the authors

Root formation efficiency depended on both the cultivar and the length of the cuttings. For all the cultivars studied, the lowest rooting rates were observed for cuttings 25 cm in length. This can be explained by the smaller number of internodes, limited reserves of plastic substances and weaker physiological potential for root system formation, which is consistent with data on the influence of the origin and physiological state of cuttings on rhizogenesis (Ait Hida *et al.*, 2022; Mohammed *et al.*, 2024). The highest percentage of rooted cuttings across all cultivars was observed when using 40 cm-long cuttings. For the Jude the Obscure cultivar, this figure was 82%, for The Pilgrim 76%, and for Abraham Darby 86%. Thus, cuttings of medium length exhibited the most favourable balance between nutrient reserves, the number of internodes and the level of transpiration losses. It was precisely this length that ensured better survival rates and more stable root formation, confirming the importance of considering cutting length and methods to reduce water loss during rooting (Mohammed *et al.*, 2024).

Cuttings 60 cm in length were characterised by a greater average root length and a higher root system mass compared with shorter variants. In the Abraham Darby cultivar, the average root length was 7.4 cm and the root system mass was 0.94 g, which was the highest value among all variants. At the same time, the rooting percentage for 60 cm-long cuttings was lower than

that for the 40 cm variant. This may be due to greater water loss and increased stress on the cutting during the period prior to the formation of a fully developed root system, as previously noted by S. Demotes-Mainard *et al.* (2013) and P.V. Bezvikonnyi *et al.* (2023).

Varietal differences were also clearly evident. Overall, the Abraham Darby showed the best results, with a rooting percentage of 69-86%, an average root length of 4.6-7.4 cm, and a root system mass of 0.54-0.94 g. This indicates its superior ability for vegetative propagation and the formation of a well-developed root system. The Jude the Obscure also showed high rooting rates, particularly with 40 cm-long cuttings. The The Pilgrim showed slightly lower results, but followed the general pattern: the best rooting was observed in cuttings of medium length, a finding also reported by O.L. Rubtsova *et al.* (2020), I.L. Denysko (2022) and A. Ait Hida *et al.* (2022).

The results obtained confirm that the rooting process of rose cuttings under greenhouse conditions is cultivar-specific and depends to a large extent on the morphometric parameters of the cuttings. The most consistent rooting rates were observed when using cuttings of an average length of 40 cm, which provided the optimal combination of the number of internodes, shoot diameter and physiological potential for root formation. Shorter cuttings were characterised by a lower rooting percentage due to a smaller reserve of

nutrients, whilst longer cuttings formed a more robust root system but had a slightly lower survival rate due to higher moisture loss (Ercişli *et al.*, 2005; Bezzvikonnyi *et al.*, 2023; Mohammed *et al.*, 2024).

Thus, the success of rose cuttings in greenhouse conditions depends not only on maintaining an optimal microclimate, but also on the correct selection of the cultivar and the characteristics of the cuttings. For practical purposes, it is most advisable to use semi-hardwood cuttings 40 cm in length, as these ensure the highest rooting rate and the development of a sufficiently well-developed root system. This makes it possible to increase the yield of high-quality rose planting stock for ornamental horticulture, landscaping and flower production.

The results obtained are consistent with the findings of P.V. Bezzvikonnyi *et al.* (2023), who established the positive effect of growth biostimulants on the rooting of green cuttings of *Rosa rugosa* Thunb. in protected soil. A common finding is the confirmation that controlled growing conditions and the stimulation of root formation enhance the efficiency of cuttings. At the same time, the present study focuses not only on the application of the stimulant but also on the comparison of cultivars and cutting lengths.

I. Mohammed *et al.* (2024) investigated the response of rose cuttings to indolebutyric acid and an anti-transpirant and demonstrated that reducing water loss is a key factor in successful rooting. This explains the results obtained in the treatment with 60 cm-long cuttings: they formed a larger root mass but had a lower rooting percentage compared with 40 cm-long cuttings, presumably due to an increased transpiration load. A. Ait Hida *et al.* (2022) demonstrated that the origin of *Rosa damascena* Mill. cuttings and the exogenous application of auxin significantly influence the rooting percentage. A similar pattern was observed in the present study: the cultivars Jude the Obscure, The Pilgrim and Abraham Darby responded differently to identical cuttings conditions, indicating cultivar-specific characteristics in the root formation process. S. Ercişli *et al.* (2005) determined the importance of the substrate and IBA concentration for the formation of adventitious roots in *Rosa dumalis* cuttings. The results obtained in this study confirm the advisability of using a light, aerated substrate of peat and perlite, whilst supplementing previous findings with information on the role of the cuttings' morphometric parameters.

A. Kazankaya *et al.* (2005) demonstrated that the rooting efficiency of *Rosa canina* L. cuttings depends on the time of collection and the concentration of IBA. In this study, the time of collection was standardised, which allowed to focus on varietal differences and cutting length. This allows to consider cutting length as an independent technological factor in the vegetative propagation of roses. I. Skoroplyas (2016) investigated the rooting of rose cuttings on different substrates at

the Kremenets Botanical Garden and emphasised the importance of the substrate's physical properties for rhizogenesis. In this study, the substrate was the same for all treatments; thus, differences between cultivars and cutting lengths can be attributed primarily to the morphophysiological characteristics of the shoots. S. Demotes-Mainard *et al.* (2013) developed a model of leaf and internode growth in roses that accounts for inter-plant variability. Their results explain why, even within a single crop, different cultivars may have varying morphometric potential. In this study, the Abraham Darby exhibited the highest values for shoot diameter and number of internodes, accompanied by the best overall rooting performance. I.L. Denysko (2022) noted the potential of David Austin's rose cultivars for the conditions of the Right-Bank Forest-Steppe of Ukraine. These findings are complemented by a practical aspect: for cultivars of this group under greenhouse conditions, 40 cm long semi-hardwood cuttings were the most effective. Consequently, the patterns identified can be used to improve the technology for producing planting material for English roses. Thus, the research results confirm that the effectiveness of rose cuttings is determined by a combination of three factors: cultivar-specific characteristics, the morphometric parameters of the cuttings, and controlled microclimatic conditions.

CONCLUSIONS

Research has shown that the rooting of rose cuttings (*Rosa* spp.) under greenhouse conditions depended on cultivar characteristics and the morphometric parameters of the cuttings. The most significant factors were cutting length, the number of internodes and shoot diameter, which determined the reserve of plastic substances, the intensity of root formation and the cuttings' ability to take root. For all the cultivar studied – Jude the Obscure, The Pilgrim and Abraham Darby – the highest rooting percentage was observed when using semi-hardwood cuttings 40 cm in length. It was precisely these cuttings that provided the most balanced ratio between the number of internodes, the physiological potential of the shoots and the level of transpiration losses.

Cuttings 25 cm in length were characterised by lower rooting rates, which is attributed to a smaller number of internodes, a smaller shoot diameter and a limited supply of nutrients. In contrast, 60 cm-long cuttings formed a longer and more robust root system; however, their survival rate was slightly lower compared with cuttings of medium length. This suggests that an excessive increase in cutting length does not always ensure higher propagation efficiency, as it may be accompanied by increased water loss and a greater physiological stress on the plant material. Among the cultivars studied, Abraham Darby exhibited the best overall rooting performance, which can be explained by better shoot development, a larger cutting diameter and a higher potential for root system formation. The

Jude the Obscure cultivar also demonstrated a high capacity for rooting, particularly when using 40 cm-long cuttings. The The Pilgrim cultivar showed slightly lower performance, but still followed the general trend favouring cuttings of medium length.

Thus, for effective vegetative propagation of roses under greenhouse conditions, it is advisable to use semi-hardwood cuttings 40 cm in length, which ensure the highest survival rate and sufficient root system development. Maintaining optimal temperature and humidity conditions, using a light, well-aerated growing medium, and applying root-forming stimulants also help to improve the efficiency of cuttings. Future

research should focus on clarifying the effects of different concentrations of auxin preparations, substrate composition and the timing of cutting collection for the rose cultivars under study.

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Особливості укорінення живців троянд (*Rosa* spp.) залежно від сорту та морфометричних параметрів у тепличних умовах

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Анотація. Актуальність дослідження зумовлена потребою декоративного садівництва у якісному, однорідному та сортово-типовому садивному матеріалі троянд, який можна отримувати в умовах контрольованого мікроклімату. Укорінення живців є важливим етапом вегетативного розмноження, однак його ефективність залежить від біологічних особливостей сорту та параметрів заготовленого пагона. Метою роботи було встановити особливості укорінення напівдерев'янистих живців троянд залежно від сорту та морфометричних показників у тепличних умовах. Досліджували сорти Jude the Obscure, The Pilgrim та Abraham Darby. Для кожного сорту використовували живці довжиною 25, 40 і 60 см, визначали кількість міжвузлів, діаметр пагона, довжину нижнього зрізу, відсоток укорінених живців, середню довжину коренів і середню масу кореневої системи. Живці висаджували у стерильний субстрат із торфу та перліту у співвідношенні 1:1 за температури повітря 22-25°C, відносної вологості 85-95 %, розсіяного освітлення та регулярного дрібнодисперсного зрошення. Встановлено, що зі збільшенням довжини живців від 25 до 60 см зростали кількість міжвузлів, діаметр пагонів і площа нижнього зрізу, однак максимальна довжина не завжди забезпечувала найвищу приживлюваність. Найкращі показники укорінення у всіх сортів одержано за використання живців довжиною 40 см: у Jude the Obscure укорінення становило 82 %, у The Pilgrim 76 %, у Abraham Darby 86 %. Живці довжиною 60 см формували довшу і масивнішу кореневу систему, зокрема у Abraham Darby середня довжина коренів досягала 7,4 см, а маса кореневої системи – 0,94 г, проте відсоток укорінення був нижчим, ніж у варіанті 40 см. Найнижчі результати спостерігали за використання живців довжиною 25 см. За комплексом показників найбільш перспективним для живцювання був сорт Abraham Darby. Практична цінність роботи полягає в обґрунтуванні доцільності використання напівдерев'янистих живців довжиною 40 см для підвищення виходу якісного садивного матеріалу троянд у тепличних умовах

Ключові слова: декоративне садівництво; англійські троянди; напівдерев'янілі пагони; субстрат; коренеутворення; садивний матеріал; живці