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Vegetative propagation of peach tree rootstock genotypes associated with different concentrations of indole-3-butyric acid

Rafael Anzanello
Secretariat of Agriculture, Livestock, Sustainable Production and Irrigation - SEAPI, Brazil
E-mail: rafael-anzanello@agricultura.rs.gov.br, Orcid: https://orcid.org/0000-0002-2406-2789

Bruno Giombelli Moreschi
University of Caxias do Sul - UCS, Brazil
E-mail: moreschibruno@outlook.com, Orcid: https://orcid.org/0009-0005-1441-0128

Carine Cocco
Agricultural Research and Rural Extension Company of Santa Catarina - EPAGRI, Brazil
E-mail: carinecocco@epagri.sc.gov.br, Orcid: https://orcid.org/0000-0002-1850-2266

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Abstract

Traditionally, peach rootstock propagation occurs sexually, resulting in genetic variability, non-uniformity among seedlings produced, longer seedling formation times and a delay in the onset of production. Vegetative propagation is an alternative technique for obtaining uniform seedlings and, consequently, more homogeneous orchards after establishment. This work aimed to evaluate the rooting potential of six peach rootstock genotypes in association with different concentrations of indole-3-butyric acid (IBA). For this, herbaceous cuttings were collected from a rootstock orchard belonging to CEFRUTI/DDPA in Veranópolis, RS, Brazil. The genotypes Capdeboscq, Okinawa, Chorão, Cascata 534, Tsukuba 2 and I-67-55-9 submitted to IBA concentrations of 0, 2,000 and 4,000 mg L^{-1} were evaluated. The experimental design was completely randomized, in a 6×3 factorial arrangement, with four replications and 12 cuttings per experimental unit. After 50 days in an intermittent nebulization chamber, the variables of rooting rate, budburst rate, length and fresh mass of roots were evaluated. The use of IBA increased rooting percentage, budburst percentage, root length, and fresh root mass compared with the control treatment across all genotypes. The IBA concentration of 2,000 mg L^{-1} was efficient for Okinawa and Chorão, while the IBA concentration of 4,000 mg L^{-1} proved to be effective for all rootstocks and analyzed variables. Peach rootstock genotypes show the potential to be vegetatively propagated by cuttings using IBA, making it technically possible to clone all tested accessions.

Keywords: *Prunus persica*; seedlings; rooting; clonal propagation; growth regulators.

Resumen

Propagación vegetativa de genotipos de portainjerto de duraznero asociada a concentraciones de ácido indolbutírico

Tradicionalmente, la propagación de los portainjertos de duraznero se realiza de forma sexuada, lo que genera variabilidad genética, falta de uniformidad de las plantas, mayor tiempo de formación y retraso en el inicio de la producción. La propagación vegetativa se presenta como una alternativa para obtener plantas uniformes y, en consecuencia, huertos más homogéneos. El objetivo de este estudio fue evaluar el potencial de enraizamiento de seis genotipos de portainjertos de duraznero asociados al uso de ácido indolbutírico (AIB). Se recolectaron estacas herbáceas provenientes de un huerto de portainjertos perteneciente al CEFRUTI/DDPA, Veranópolis, RS, Brasil. Se evaluaron los genotipos Capdeboscq, Okinawa, Chorão, Cascata 534, Tsukuba 2 e I-67-55-9, sometidos a concentraciones de AIB de 0, 2.000 y 4.000 mg L^{-1}. El diseño experimental fue usando muestras aleatorias, en un esquema factorial 3x6, con cuatro réplicas y 12 estaciones por parcela. Después de 50 días en cámara de nebulización intermitente, fue evaluada el porcentaje de enraizamiento y brotación, así como la longitud y la masa fresca de las raíces. El uso de AIB incrementó todas las variables evaluadas en comparación con el testigo, independientemente del genotipo. La concentración de 2.000 mg L^{-1} fue eficiente para los genotipos Okinawa y Chorão, mientras que 4.000 mg L^{-1} fue eficaz para todos los portainjertos. Los genotipos evaluados presentan potencial para la propagación vegetativa por estaquillas con el uso de AIB, siendo técnicamente viable la clonación de todos los accesos analizados.

Palabras clave: *Prunus persica*; plântulas; enraizamento; propagación clonal; reguladores de crecimiento.

Resumo

Propagação vegetativa de genótipos de porta-enxerto de pessegueiro associado a concentrações de ácido indolbutírico

Tradicionalmente a propagação de porta-enxertos do pessegueiro ocorre de forma sexuada, acarretando em variabilidade genética, desuniformidade de mudas produzidas, maior tempo para formação da muda e retardo no início da produção. A propagação vegetativa mostra-se como uma técnica capaz de promover uniformidade nas mudas e, consequentemente, do pomar após a implantação. Este trabalho objetivou avaliar o potencial de enraizamento de seis genótipos de porta-enxertos de pessegueiro associado ao uso de ácido indolbutírico (AIB). Para isso, foram coletadas estacas herbáceas oriundas de pomar de porta-enxertos, pertencente ao CEFRUTI/DDPA - Veranópolis - RS. Foram avaliados os genótipos Capdeboscq, Okinawa, Chorão, Cascata 534, Tsukuba 2 e I-67-55-9 submetidos às concentrações de AIB de 0, 2.000 e 4.000 mg L^{-1}. O delineamento foi inteiramente casualizado, em esquema fatorial 3x6, dispondo-se de quatro repetições com 12 estacas por parcela. Após 50 dias em câmara de nebulização intermitente foi avaliada a porcentagem de enraizamento, porcentagem de brotação, e comprimento e massa fresca de raízes. O uso de AIB aumentou a porcentagem de enraizamento, porcentagem de brotação, comprimento e massa fresca de raiz, comparado a testemunha para todos os genótipos. A concentração de AIB de 2.000 mg L^{-1} foi eficiente para o Okinawa e Chorão, já a concentração de AIB de 4.000 mg L^{-1} mostrou-se eficaz para todos os porta-enxertos e variáveis analisadas. Os genótipos de porta-enxertos de pessegueiro demostram potencial para serem propagados vegetativamente por estaquia mediante o uso de AIB, sendo tecnicamente possível clonar todos os acessos testados.

Palavras-chave: *Prunus persica*; mudas; enraizamento; propagação clonal; reguladores de crescimento.

Introduction

According to the FAO, global peach production in 2024 reached 27,891,645 t, with predominance of the Asian continent, which accounted for 75.4% of total production, followed by Europe (13.4%) and the Americas (7.2%). China, Spain, Italy and Turkey stand out as the main global producers of peaches and nectarines (FAO, 2024). In Brazil, due to the climatic requirements of the crop, especially the need for winter chilling during the dormancy period, which varies among cultivars - Southern and Southeastern regions provide the most favorable conditions for adaptation and expansion of peach cultivation (Madall; Raseira, 2008). The main producing states are Rio Grande do Sul (RS), São Paulo, Santa Catarina, Minas Gerais and Paraná, with shares of 64.9%, 16.4%, 7.7%, 5.9% and 4.8%, respectively (IBGE, 2024). In RS, peach cultivation has significant socioeconomic importance, particularly for smallholders, with a production of 123,633 t, harvested area of 11,337 ha and an average yield of 10.9 t ha^{-1}, predominantly involving dual-purpose and processing cultivars (IBGE, 2024).

In fruit growing, the establishment of new orchards requires the use of planting material with proven genetic and sanitary quality. Fruit production, yield and quality are directly related to the quality of the seedlings used (Mayer *et al.*, 2014). Although lower-cost seedlings may reduce initial investment, their use may result in sanitary, productive and orchard longevity problems (Hoffmann; Nachtigal; Bernardi, 2003).

Peach seedling production is mainly based on grafting, with the rootstock playing a fundamental role in providing productive and phytosanitary advantages and enabling cultivation under different edaphoclimatic conditions (Rosa, 2014). In Brazil, rootstocks are predominantly obtained from seeds, while vegetative propagation by cuttings is rarely used (Mayer; Rickes; Ueno, 2018). In the southern region of the country, pits from late-maturing cultivars, especially Aldrighi and Capdeboscq, are predominantly used for rootstock formation.

However, the reduced availability of these cultivars has led to the use of other varieties, often derived from varietal mixtures originating from the processing industry, which increases genetic variability and uncertainty regarding the rootstock used in seedling production (Hoffmann; Nachtigal; Bernardi, 2003; Mayer *et al.*, 2013).

The main drawbacks of using seeds to produce peach rootstocks are related to the high rate of cross-pollination among mother plants, which may reach up to 33% (Miller; Parfitt; Weinbaum, 1989). Consequently, sexual propagation may promote genetic variability and interfere with vigor and plant behavior in future orchards (Rosa *et al.,* 2017). Furthermore, seed propagation, due to genetic segregation, may result in plant non-uniformity, longer juvenile periods and increased time required for seedling formation (Fachinello; Hoffmann; Nachtigal, 2005).

As a means of ensuring greater genetic and sanitary identity of rootstocks, as well as minimizing genetic variability, propagation by cuttings has become a promising practice, offering low cost, rapid production and maintenance/preservation of agronomic traits of interest (Rosa, 2014). However, according to Tofanelli, Ono and Rodrigues (2003), the main limitation of cutting propagation in peaches is the low rooting rate of cuttings.

Raseira, Pereira and Carvalho (2022) emphasize that numerous factors influence the success of rooting by cuttings. Wendling (2003) identifies species/clone, season of the year, physiological condition of the plant material, climatic conditions, position of the propagule on the mother plant, cutting size, type and time of collection, rooting medium and growth regulators as the main determinants of rooting success.

Different chemical compounds can be applied exogenously to promote rooting of cuttings through vegetative propagation. According to Oliveira *et al.* (2001), auxins play a crucial role in achieving adequate rooting rates. The most commonly used auxins for rooting are indole-3-butyric acid (IBA) and naphthaleneacetic acid (NAA) (Miranda *et al.*, 2003). These growth regulators promote cell elongation, stimulate root primordium formation, and promote the development of adventitious roots (Rosa, 2014; Taiz *et al*., 2024). According to Mayer *et al.* (2013), cutting propagation under Southern Brazilian conditions can be carried out in late spring/early summer (herbaceous cuttings with leaves), late summer (semi-hardwood cuttings with leaves), or autumn (hardwood cuttings without leaves), with the most promising results obtained using herbaceous cuttings.

The adoption of cutting propagation in peaches remains limited in nurseries in Southern Brazil, mainly due to the need for greater technical knowledge regarding this propagation method. Therefore, the objective of the present study was to evaluate the rooting potential of herbaceous cuttings from different peach rootstock genotypes in association with different concentrations of indole-3-butyric acid.

Material and Methods

The experiment was conducted at the State Center for Diagnosis and Research in Fruticulture (CEFRUTI), part of the Department of Agricultural Diagnosis and Research (DDPA) of the Secretariat of Agriculture, Livestock, Sustainable Production and Irrigation (SEAPI), located in the municipality of Veranópolis, Rio Grande do Sul, Brazil. CEFRUTI is situated in the Upper Slope of the Northeastern Highlands region (Serra Gaúcha), at the geographical coordinates 28°53′20.67″ S and 51°32′44.39″ W, at an altitude of 705 m. According to the Köppen climate classification, the regional climate is Cfb - humid temperate, with no defined dry season and an average temperature of the warmest month below 22 °C (Junges; Tonietto, 2022).

The study was carried out in an agricultural greenhouse equipped with an automated intermittent misting system. The greenhouse covered an area of 128 m^2, measuring 8.0 m in width and 16.0 m in length, with a ceiling height of 3.5 m. The roof and sidewalls were covered with transparent polyethylene film (150 μm thickness) treated for ultraviolet (UV) radiation. The structure included a lateral antechamber with arched frames covered with milky polyethylene film and enclosed with anti-aphid mesh.

The plant material consisted of shoots derived from *Prunus spp.* rootstock mother plants maintained in the CEFRUTI/DDPA germplasm bank, which comprises more than 30 rootstock accessions grown under field conditions (without irrigation). The orchard consisted of 15-year-old trees planted at a spacing of 3 m between plants and 5 m between rows. The rootstock collection orchard was managed according to the technical recommendations established for peach cultivation, including fertilization and other cultural practices (Raseira; Pereira; Carvalho, 2022). The plants were regularly monitored to ensure adequate phytosanitary conditions, vigor, and uniformity.

Six rootstock genotypes were used in the study: ‘Capdeboscq’, ‘Okinawa’, ‘Chorão’, ‘Cascata’, ‘Tsukuba

2' and I-67-55-9. Three mother plants of each genotype were selected for the collection of plant material. The selection of these genotypes was based on their superior productive performance under the edaphoclimatic conditions of the Serra Gaúcha region, according to results from a previous experiment conducted at CEFRUTI/DDPA (Moreschi *et al.*, 2023), in which agronomic traits conferred by 30 rootstocks grafted onto the same scion cultivar (Chimarrita variety) were evaluated.

The cuttings of the different genotypes were collected during the second half of October 2022, taking into account the vegetative development of the rootstock accessions and preserving the herbaceous nature of the cuttings. Collection was performed from shoots or shoot portions whose vegetative buds had not yet sprouted (unbranched shoots). The plant material was collected in the morning from shoots arising on the scaffold branches of the mother plants, using pruning shears. The plants from which the cuttings were collected were not subjected to drastic pruning, as has been done in other studies (Mayer *et al.*, 2013), to stimulate shoot induction.

After field collection, the shoots were immediately transported to the intermittent mist chamber for processing. Cuttings were standardized to 15 cm in length and 8.0 to 10.0 mm in diameter, with a straight basal cut and a beveled apical cut. On average, three to six leaves per cutting were retained and cut in half in order to reduce leaf area, allow better tray packing and minimize transpiration.

After cutting preparation, two opposite wounds (approximately 3 cm in length) were made in the basal region of each cutting using a scalpel to expose the vascular cambium. For treatments that use indole-3-butyric acid (IBA; purity > 98%), an IBA solution was prepared in a hydroalcoholic medium (92.8% INPM). Amounts of 0.2 g and 0.4 g of IBA were weighed using a semi-analytical balance, dissolved in 50 mL of alcohol in a beaker using a magnetic stirrer and then brought to a final volume of 100 mL with distilled water, resulting in IBA concentrations of 2,000 and 4,000 mg L^{-1}, respectively. The cuttings were immersed in the IBA solutions for 10 seconds and then planted in the substrate. A control treatment was also included, in which cuttings were prepared in the same manner but without IBA application.

The cuttings were placed in 72-cell expanded polystyrene trays (67.0 cm × 34.0 cm × 11.5 cm) filled with fine-grade expanded vermiculite and arranged on wooden benches (3.5 m × 80.0 cm × 90.0 cm) inside the greenhouse. The intermittent misting system was programmed to operate for 20 seconds with 3 minutes off intervals, according to a pre-established automatic control panel setting. The mean temperature and relative humidity maintained in the greenhouse during the experimental period were 25 °C and 80%, respectively.

After 50 days, the cuttings were manually removed from the trays for evaluation of the following variables: rooting percentage, budburst percentage, root length and fresh root mass.

Rooting percentage was visually assessed by determining whether or not each cutting had formed roots. Budburst percentage was similarly evaluated based on the presence or absence of shoots. Root length was measured using a 30 cm millimeter ruler, considering the longest root produced by each cutting and expressed in centimeters (cm). For fresh root mass determination, the root system produced by each cutting was detached and weighed on a digital analytical balance, with results expressed in grams (g).

The experimental design was completely randomized in a 6 (genotypes) × 3 (IBA concentrations) factorial arrangement. Four replicates were used for each genotype × IBA concentration combination, with 12 cuttings per experimental unit, which were considered subsamples, totaling 48 cuttings per treatment.

Data on rooting and budburst percentages, root length and fresh root mass were subjected to analysis of variance (ANOVA). Prior to the analysis, the assumptions of normality of residuals and homogeneity of variances were verified. Percentage data were analyzed without transformation, as they met the assumptions required for ANOVA. When significant differences were detected by the F test, means were compared using Tukey's test at a 5% probability level. Statistical analyses were performed using SPSS (Statistical Package for the Social Sciences), version 22.0.

Results and Discussion

Rooting percentages of the rootstocks are presented in Table 1A. Rooting of the cuttings was directly influenced by IBA concentrations, regardless of the rootstock evaluated. While rooting rates at 2,000 and 4,000 mg L^{-1} IBA were close to or higher than 70% for all genotypes, in rootstocks grown without IBA application rooting percentages ranged from 12.5% to 54.1%, depending on the rootstock. The 4,000 mg L^{-1} IBA concentration was superior to 2,000 mg L^{-1} for the rootstocks 'Capdeboscq', 'Cascata 534' and I-67-55-9, whereas no difference between concentrations was observed for the remaining genotypes.

The effectiveness of IBA in promoting rooting of peach cuttings has also been reported by Timm *et al.* (2015), who highlighted that IBA application results in higher rooting rates in vegetative propagation of peach, demonstrating the necessity of using plant growth regulators for seedling production from cuttings. The importance of IBA application was similarly demonstrated by Mayer *et al.* (2013), who achieved rooting percentages above 80% in herbaceous cuttings of 'Tsukuba 2' and 'Okinawa' using a dose of 3,000 mg L^{-1} IBA. Taiz *et al.* (2024) describe how IBA promotes adventitious rhizogenesis by stimulating cell division and differentiation in competent cells, particularly parenchymatic cells associated with the vascular cambium and secondary phloem in the basal region of cuttings, favoring the formation and development of root primordia that subsequently originate adventitious roots.

In herbaceous cutting propagation, leaves play a major role in rooting, as they are sources of auxins, rooting cofactors and carbohydrates (Oliveira; Nienow; Calvete, 2003). These compounds are essential for the formation of adventitious roots (Gaspar; Hoffinger, 1988). Rosa *et al.* (2017), in studies on vegetative propagation of *Prunus* spp., reported that during the herbaceous period, when the plant is more actively growing, there is greater availability of free auxin and its transport to the basal portion of the cutting is facilitated, thereby stimulating root formation. Conversely, in semi-hardwood cuttings, higher levels of IBA tend to occur in conjugated forms, which restrict its transport and utilization by plants. This may explain the satisfactory rooting rates observed in the present study, in which herbaceous cuttings were propagated under an intermittent mist system with IBA application.

In the control treatment without IBA, among the evaluated genotypes, the rootstock 'Tsukuba 2' showed a natural rooting percentage of 54.1% at 50 days after evaluation (Table 1A). This result indicates that this genotype has genetic potential for root system formation by cuttings without exogenous IBA application. It is noteworthy that in other studies on vegetative propagation of peaches, the rooting percentage of cuttings has been evaluated at 90 days (Mayer *et al.* (2013). Thus, longer evaluation periods could be considered in future studies to determine whether maintaining cuttings for periods exceeding 50 days may further increase rooting percentages, particularly in rootstocks with intrinsic rooting capacity, such as 'Tsukuba 2'.

The use of natural rooting in rootstocks with intrinsic rooting capacity may reduce the need for exogenous application of rooting hormones, potentially reducing propagation costs. However, extending the rooting period beyond 50 days may increase greenhouse maintenance costs and prolong the seedling production cycle. According to Leite *et al.* (2005), successful plant propagation should consider the production of high-quality seedlings, with satisfactory growth and reducing costs, leading to maximum raw material utilization and waste reduction.

Table 1 - Rooting percentage (A); budburst percentage (B); root length (cm) (C); fresh root mass (g) (D) of peach rootstock cuttings treated with different IBA concentrations. Veranópolis, 2023

			A – Rooting (%)			
IBA concentration (mg L^{-1})	**Rootstocks**					
	Okinawa	Capdeboscq	Chorão	Tsukuba 2	Cascata 534	I-67-55-9
0	12.5 Bb	14.5 Cb	14.5 Bb	54.1 Ba	35.3 Cab	37.4 Cab
2,000	93.7 Aa	68.7 Bb	83.3 Aab	85.3 Aab	70.7 Bb	70.8 Bb
4,000	100.0 Aa	95.8 Aa	91.6 Aa	93.7 Aa	91.6 Aa	100.0 Aa
CV (%)	12.38					

			B – Budburst (%)			
IBA concentration (mg L^{-1})	**Rootstocks**					
	Okinawa	Capdeboscq	Chorão	Tsukuba 2	Cascata 534	I-67-55-9
0	24.9 Bc	58.3 Bb	81.2 Ba	45.8 Bb	39.5 Bbc	31.2 Bbc
2,000	24.9 Bc	70.8 Aa	87.4 ABa	45.8 Bb	54.1 ABb	46.8 Bb
4,000	39.5 Ac	77.5 Aab	91.6 Aa	56.2 Abc	64.5 Ab	74.9 Ab
CV (%)	14,52					

C – Root length (cm)						
IBA concentration (mg L^{-1})	**Rootstocks**					
	Okinawa	Capdeboscq	Chorão	Tsukuba 2	Cascata 534	I-67-55-9
0	0.72 Bc	0.50 Cc	0.92 Bb	2.92 Ba	1.88 Cab	1.93 Bab
2,000	8.80 Aa	6.94 Bb	9.35 Aa	7.05 Ab	5.21 Bc	3.86 Bc
4,000	8.90 Aab	9.27 Aa	10.50 Aa	8.06 Aab	9.86 Aa	7.79 Ab
CV (%)	17.74					

D – Fresh root mass (g)						
IBA concentration (mg L^{-1})	**Rootstocks**					
	Okinawa	Capdeboscq	Chorão	Tsukuba 2	Cascata 534	I-67-55-9
0	0.14 Bb	0.21 Cb	0.15 Bb	0.36 Ca	0.27 Ca	0.30 Ca
2,000	4.00 Aa	2.16 Bb	2.59 Ab	2.41 Bb	2.56 Bb	5.25 Ba
4,000	5.71 Ab	5.76 Ab	3.78 Ac	6.99 Ab	6.17 Ab	13.59 Aa
CV (%)	15,63					

Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ significantly by Tukey's test at the 5% probability level.

Regarding budburst percentage, cuttings treated with IBA at a concentration of 4,000 mg L^{-1} showed higher budburst rates compared with the control treatment for all genotypes. The concentration of 2,000 mg L^{-1} was particularly effective for the rootstocks 'Capdeboscq', 'Chorão' and 'Cascata 534', achieving budburst rates above 50% (Table 1B). In addition, the rootstocks 'Capdeboscq' and 'Chorão' showed a greater tendency for shoot emergence from cuttings, regardless of IBA application. Different results were reported by Cardoso *et al.* (2011), who observed no interaction between IBA concentrations and substrates for the budburst variable in cuttings of the peach rootstock 'Okinawa'. These differences among genotypes may be associated with their differential sensitivity to exogenous auxin and with variations in endogenous hormonal balance and reserve mobilization, which can influence bud activation and shoot emergence during the rooting process of the cuttings (Mayer *et al.*, 2014).

To produce fruit tree rootstocks through vegetative propagation, both budburst and rooting capacity of cuttings must be considered (Mayer *et al.*, 2013). This is because grafting of the scion cultivar onto rooted peach rootstocks is predominantly performed by T-budding, using a shoot originating from the rootstock (Raseira; Pereira; Carvalho, 2022). According to Tecchio *et al.* (2007), a good rootstock should be adapted to adverse soil conditions, exhibit ease of rooting and budburst, show compatibility with the scion cultivar, present good vegetative performance, longevity and resistance to the main pests and diseases.

In fruit crops, the adult stage of plants is important due to their fruit-bearing capacity. However, at this stage, plant clonability is reduced. This limitation can be minimized through plant rejuvenation (Wendling; Xavier, 2005). Pereira and Mayer (2005) reported that one of the basic premises for successful vegetative propagation by herbaceous cuttings is the adoption of drastic pruning of mother plants in order to stimulate the emergence of new, vigorous and uniform shoots. Similar approaches have been adopted in previous studies with peach rootstocks, in which severe pruning or rejuvenation strategies were used to increase rooting capacity and improve the uniformity of propagules (Mayer *et al.*, 2013; Mayer *et al.*, 2014). Nevertheless, in the present study, high rooting percentages (≥ 70% with IBA application) were obtained even without the adoption of drastic pruning of mother plants. These results indicate that the use of herbaceous cuttings collected from non-rejuvenated stock plants can also represent a technically viable alternative for rootstock propagation. The effectiveness observed may be associated with the juvenile condition of the newly formed herbaceous shoots and the adequate management of donor plants, suggesting that drastic pruning, although beneficial in some propagation systems, may not be an essential requirement when other factors, such as cutting type, physiological stage of shoots, and auxin application, are properly managed.

According to Cardoso *et al.* (2011), in commercial seedling production, the aim should be to use plants with a well-formed and well-established root system, since this is responsible for the absorption of water and nutrients, providing better development of the seedling after transplanting to the field. Regarding root length and fresh root mass (Tables 1C and 1D), rootstocks treated with IBA showed higher values for both variables than those observed in the control treatment across all genotypes. The effectiveness of IBA application was also demonstrated by Mayer *et al.* (2014), whose reported variation in root length of peach rootstocks exposed to different IBA concentrations, with treatments involving synthetic auxin application promoting greater root development.

The rootstocks 'Okinawa' and 'Chorão' did not differ between the concentrations of 2,000 and 4,000 mg L^{-1} IBA for root length and fresh root mass (Tables 1C and 1D). In contrast, the rootstocks 'Capdeboscq', 'Cascata 534' and I-67-55-9 showed greater root length and fresh root mass at a concentration of 4,000 mg L^{-1}. The rootstock 'Tsukuba 2', in turn, exhibited higher fresh root mass at 4,000 mg L^{-1} IBA, while root length did not differ between the IBA concentrations of 2,000 and 4,000 mg L^{-1}. The greater root development observed in response to the different IBA concentrations, which varied among rootstocks, highlights the genotype-specific response to auxin, an important aspect to consider when defining strategies for vegetative propagation and seedling production (Mayer *et al.*, 2014).

Tofanelli, Ono and Rodrigues (2003) observed rooting of herbaceous cuttings in three peach genotypes ('Delicioso Precoce', 'Jóia 1' and 'Okinawa'), with average root length values ranging from 2.5 to 7.0 cm at IBA concentrations of 1,250, 2,500 and 3,750 mg L^{-1}, using the quick-dip method (5 seconds immersion) and retaining two leaves per cutting. These values are lower than those obtained in the present study, in which mean root length ranged from 3.8 to 10.5 cm for the six evaluated rootstocks at IBA concentrations of 2,000 and 4,000 mg L^{-1}.

Fresh root mass is an indicator of root volume and/or adventitious root formation. The rootstock I-67-55-9 showed significantly higher fresh root mass compared with the other rootstocks, particularly at concentration of 4,000 mg L^{-1} IBA, which is an important trait for the production of high-quality fruit tree seedlings. According to Raseira, Pereira and Carvalho (2022), peach trees develop a fibrous root system, especially when propagated vegetatively, resulting in a greater volume of adventitious roots responsible for water and nutrient uptake. Mayer *et al.* (2013) reported that root mass is a more relevant variable for evaluating the peach root system than root length, being an effective measure for assessing final seedling quality.

In the evaluation of fresh root mass, the rootstock 'Chorão' showed the lowest root mass (Table 1D). This response may be associated with the higher budburst percentage observed for this rootstock (Table 1B), although this relationship was not directly evaluated in the study. It is possible that the higher development of shoots may have increased the demand for stored reserves in the cuttings, potentially reducing the resources available for root formation and affecting root development. Similar results were reported by Antunes *et al.* (1996), who demonstrated that when budburst occurs before rooting during vegetative propagation by cuttings, root formation can be negatively affected due to reserve consumption. Thus, an adequate balance between auxins and carbohydrates is essential for optimal root production, since during the rooting process there is continuous mobilization of starch and soluble sugars toward the basal portion of the cutting (Neto, 2005). When carbohydrates are preferentially allocated to shoot development, reduced carbon and nitrogen availability may limit rooting capacity. Additional studies on carbohydrate dynamics and biomass allocation between shoots and roots in peach rootstocks during the rooting process are needed to clarify this relationship.

Considering all variables jointly in the present study, across all evaluated genotypes and IBA concentrations, the results indicate that IBA application significantly increased rooting percentage, budburst rate, root length and fresh root mass, supporting the feasibility of vegetative propagation by cuttings for all evaluated peach rootstocks compared with treatments without IBA. These findings demonstrate the technical feasibility, at the commercial nursery level, of using herbaceous cuttings for peach rootstock propagation. Thus, it is possible to obtain high rooting percentages and other parameters of interest for formation of peach rootstock genotype seedlings by the technique of cuttings, as also reported by Fischer *et al.* (2013).

Aguiar *et al.* (2005) affirmed that the optimal IBA concentration varies according to species, genotype and type of cutting. Based on the data presented, the IBA concentration of 2,000 mg L^{-1} can be considered sufficiently effective for seedling production of the genotypes 'Okinawa' and 'Chorão', as these rootstocks showed higher rooting percentage, root length and root mass for 'Okinawa' and higher rooting percentage, budburst rate and root length for 'Chorão'. In contrast, the IBA concentration of 4,000 mg L^{-1} was effective for all evaluated rootstocks and variables and can therefore be considered the most suitable concentration for peach rootstock propagation by cuttings.

Conclusion

Peach rootstocks 'Capdeboscq', 'Okinawa', 'Chorão', 'Cascata 534', 'Tsukuba 2' and I-67-55-9 showed potential for vegetative propagation by cuttings under the evaluated conditions when treated with IBA. The concentration of 2,000 mg L^{-1} was particularly effective for 'Okinawa' and 'Chorão', whereas the concentration of 4,000 mg L^{-1} improved rooting responses in 'Capdeboscq', 'Cascata 534', I-67-55-9, 'Okinawa', 'Chorão' and 'Tsukuba 2'. Further evaluations across different environments and propagation periods are recommended to confirm the consistency of these responses.

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