Greenhouse Plant Production Journal 1(4) (2024) 1–10 gppj.araku.ac.ir

Greenhouse Plant Production Journal

Importance of rootstock and indole butyric acid in propagation of *Chaenomeles japonica* L. by stenting method under greenhouse condition

Mina Taghizadeh [a*], Milad Ghobadi Nasab [b], Mousa Solgi[c]

[a, b,c] *Department of Horticultural Sciences, Faculty of Agriculture and Environment Science, Arak University, 38156-8-8349 Arak, Iran*
**Corresponding author e-mail: m-taghizadeh@araku.ac.ir*

Original Article

Use your device to scan and read the article online

Citation: Taghizadeh, M., Ghobadi Nasab, M, and Solgi, M. 2024. Importance of rootstock and indole butyric acid in propagation of *Chaenomeles japonic*a L. by stenting method under greenhouse condition. Greenhouse Plant Production Journal, 1(4): 1–10.

https://10.61186/gppj.1.4.1

KEYWORDS

Chlorosis
Grafting
Indole butyric acid
Ornamental plant
Rooting

ABSTRACT

A challenge in cultivating *Chaenomeles japonica* L. is the occurrence of iron chlorosis. Employing rootstocks that are tolerant of calcareous soils represents the effective strategy for addressing the encounters posed by alkaline soils. This study examines the compatibility of *Chaenomeles japonica* L. grafting with rootstocks and evaluates the influence of IBA on the grafting process using the stenting method. The investigation focused on the influence of IBA (0, 1000, and 2000 mg l-1) and rootstocks (*Rosa alba*, *Pyracantha coccinea*, *Malus domestica* cv. Gami Almasi, *Pyracantha coccinea*, *Cydonia oblonga*, and the Malling M9) utilizing the budding grafting and splice grafting technique. The evaluation of traits, success of the grafting, rooting percentage, root volume, the number of activated scions, the callus formation, the length of shoot, the inter-node distance, and the leaves number, was conducted. The findings indicated that the application of IBA effectively promoted root development. The most significant root development was observed in *Chaenomeles japonica* L. when grafted onto Rosa alba rootstock and subjected to at 2000 mg of IBA. The *Pyracantha coccinea* exhibited the lowest number of activated grafts; however, it demonstrated the highest callus formation at the grafting site among the rootstocks, suggesting a superior grafting potential. It is considered a suitable candidate for the propagation of *Chaenomeles japonica* L. grafts through the cutting-grafting technique. Grafting *Chaenomeles japonica* L. on *Pyracantha coccinea* demonstrates superior compatibility and enhanced growth vigor. It is expected that this rootstock will exhibit improved tolerance to alkaline soil, potentially eliminating the leaf early chlorosis.

ARTICLE HISTORY

Received: 29 November 2024
Revised: 28 December 2024
Accepted: 31 December 2024

* Corresponding author: M. Taghizadeh
E-mail address: m-taghizadeh@araku.ac.ir

Publisher: Arak University

1. Introduction

Japanese quince (*Chaenomeles japonica* L.) is a deciduous species within the Rosaceae family, commonly utilized as an ornamental shrub in landscaping. A significant challenge in cultivating this plant is the occurrence of iron chlorosis. While *Chaenomeles japonica* L. can survive in clay soils, its growth is suboptimal in such conditions. The presence of alkaline soils leads to a gradual yellowing of the plant's leaves, a phenomenon attributed to the impaired absorption of iron. Consequently, the leaves, particularly the younger ones, exhibit yellowing throughout the growing season due to iron deficiency (Rumpunen, 2002). The manifestation of leaf chlorosis is indicative of reduced chlorophyll content, which adversely affects the plant's productivity and ultimately diminishes both its yield and aesthetic appeal. The application of iron chelates as a remedial measure is discouraged due to their high cost and potential environmental repercussions. Therefore, employing rootstocks that are tolerant of calcareous soils represents the most effective strategy for addressing the challenges posed by alkaline conditions. While some plants are propagated through grafting for asexual reproduction, this technique can also be employed to enhance resistance to abiotic stresses such as salinity, cold temperatures, or unfavorable soil conditions. Grafting practices in ornamental horticulture include the combination of hard-rooted Rhododendron cultivars with those that are easier to root. To date, there appears to be a lack of research focused on grafting studies addressing nutritional deficiencies in ornamental plants utilizing appropriate rootstocks. In the alkaline soils, grafting serves as an effective strategy to mitigate chlorosis in fruit trees. The "Pyrudwarf" rootstock, derived from *Pyrus communis* L., is characterized by its high yield, robust establishment, and reduced vulnerability to chlorosis associated with iron deficiency, making it suitable for cultivation in alkaline conditions (Campbell 2003). Rootstocks from *Pyrus communis* exhibit superior nutrient absorption capabilities compared to those from *P. ussuriensis* and *P. calleryana*, resulting in a lower incidence of iron deficiency in grafted plants (Jackson 2003). Quince rootstocks (*Cydonia oblonga* Mill.) are commonly employed in the cultivation of dwarf pear varieties due to their effective dwarfing characteristics (Jiang et al., 2018). Nonetheless, pear trees grafted onto quince rootstocks often experience significant iron-deficiency chlorosis, despite the resistance of certain quince clones to calcareous soils (Prado and Alcántara-Vara, 2011).

The majority of rose cultivars found in the market are derived from grafting onto *Rosa canina* or other wild rose species, primarily due to the superior resistance of certain rootstocks to environmental stresses such as drought, cold temperatures, and biological threats. In Iran, *Rosa canina* is extensively cultivated, with approximately 95% of rose plants being grafted onto this particular rootstock (Khaligi, 2018). This species is recognized for its advantageous traits, including vigorous growth, compatibility with a variety of cultivars for grafting, an extensive root system, adaptability to diverse soil types, healthy growth potential, ease of grafting and propagation, making it one of the best rose rootstocks generally (Buck, 1978). In temperate and colder regions, *Chaenomeles japonica* L. often exhibits significant leaf chlorosis due to the calcareous soil conditions and insufficient iron absorption, which detracts from its visual beauty. This issue can be mitigated through the grafting of this ornamental shrub onto appropriate rootstocks. Furthermore, *Chaenomeles japonica* L. cultivation could be improved by using cultivars grafted on tolerant rootstocks. Thus, evaluation of *Chaenomeles japonica* L. propagation through bud grafting techniques seems necessary. The present study aimed to evaluate the vegetative propagation of *Chaenomeles japonica* L. by the stenting method (simultaneous cutting and grafting). Consequently, the initial step involves identifying the most effective grafting technique and selecting the suitable rootstock. This study examines the compatibility of *Chaenomeles japonica* L. grafting with appropriate rootstocks and evaluates the influence of indole butyric acid (IBA) on the grafting process using the cutting-graft (stenting) method.

2. Materials and methods

The study was conducted in the research greenhouse of Agricultural and Environmental Science at Arak University (49° 40' 40" N, 34° 4' 50" E, Arak, Iran). This study was carried out through two distinct experiments within a controlled research greenhouse, maintaining temperature conditions of approximately 25°C, 70% humidity, and 10,000 lux of light. The investigation focused on the influence of varying concentrations of indole butyric acid (IBA) and different rootstocks utilizing the budding grafting and splice grafting technique. Plant materials were collected from the nursery of the Parks and Landscape Organization of Arak Municipality. The plants of pyracantha (*Pyracantha coccinea*), seedling apple (*Malus domestica* cv. Gami Almasi, dog rose (*Rosa alba*), and Japanese quince (*Chaenomeles japonica*) were used as the rootstock, and Japanese quince (*Chaenomeles japonica* L.) was used as the scion. Rooted softwood cuttings were cultivated in pots filled with agricultural soil (25% sand+ 38% silt+ 37% clay).

2.1. The effect of different IBA concentration and rootstocks by budding grafting method

In order to implement stenting, cuttings measuring 15 cm in length and approximately 1 cm in diameter were sourced from one-year-old branches. The budding grafting method employed scions obtained from the current year's growth of *Chaenomeles japonica* L. This experiment was designed as a completely randomized design with three replications conducted in September. The treatments examined included various rootstock types [Japanese quince (*Chaenomeles japonica* L.), dog rose (*Rosa alba*), and pyracantha (*Pyracantha coccinea*)] combined with IBA concentrations of 0, 1000, and 2000 ppm applied at both the grafting site and the distal end of the cutting. A control group was established using *Chaenomeles japonica* L. without grafting or IBA treatment. To ensure moisture retention, the grafts were wrapped with a grafting strip for a duration of two weeks. All grafted cuttings were planted in individual pots filled with sandy substrate. The success of the grafting procedure was assessed four weeks post-grafting (Figure 1). Additionally, four months into the experiment, measurements of rooting percentage and root volume were conducted. The assessment of the root's volume, following its immersion in a specified volume of water in accordance with Archimedes' principle, was conducted by determining the difference in volume produced (Davarynejad et al., 2015).

Figure 1 Success grafting with activated bud overlap of scions and rootstocks using budding grafting (left) and unsuccessful grafting (right) *Chaenomeles japonica* L.

2.2. The effect of different rootstocks by Splice grafting method:

The influence of various rootstocks utilizing the splice grafting technique was investigated in this study. Cuttings measuring 15 cm in length and approximately 0.5-1 cm in diameter were prepared from seedling apple (*Malus domestica* cv. Gami Almasi), *Pyracantha coccinea*, *Rosa alba*, seedling quince (*Cydonia oblonga*), and the Malling M9 apple rootstock. Additionally, one-year branches from *Chaenomeles japonica* L. were selected, ensuring that the diameters of both the rootstock and scion were similar. Each scion consisted of three buds. The experiment was designed as a completely randomized design with three replications (12 cutting in each replication), and conducted in March. A diagonal cut was made at the end of each cutting, which was then aligned with the rootstock to ensure contact between the cambial layers of both components. The grafts were secured with a grafting strip to maintain moisture levels (Figure 2). Following the grafting process, the cuttings were planted in a sandy medium (based on experimental pretreatments). Control samples comprised *Chaenomeles japonica* L. cuttings that were not subjected to grafting. The evaluation of various traits, including the number of activated scions on the rootstock, the count of grafting sites exhibiting callus formation, the length of the tallest shoot, the inter-node distance of the tallest shoot, and the number of leaves on the tallest shoot manually, was conducted 30 days post-grafting. After a period of 14 days post-grafting, buds exhibiting brown, black, and shriveled characteristics were classified as unsuccessful grafts, whereas those that remained green were deemed successful. The percentage of activated buds was calculated by taking the ratio of the number of sprouted grafts to the total number of grafted plants following the bud opening.

2.3. Statistical analysis

These experiments were conducted in a completely randomized design (CRD) included 4 treatments (pyracantha, seedling apple, dog rose, and Japanese quince rootstocks) with four replications and 3 observations for each replication (4 plant in each replication). Data were subjected to one-way ANOVA using the "JMP© 9.0" software (SAS Institute, Inc.). Duncan's multiple range test (DMRT) was conducted to determine significant differences at $P \leq 0.01$ between the average treatments.

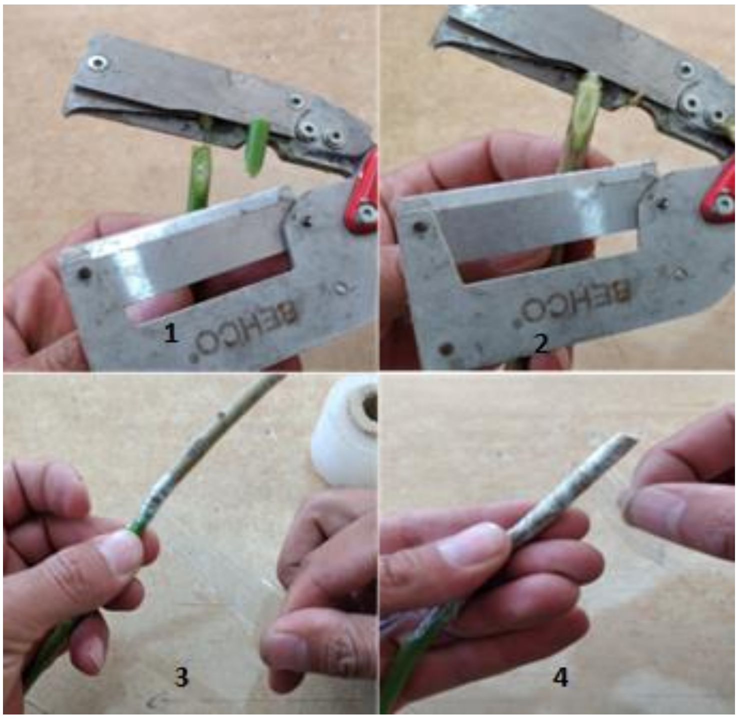

Figure 2. Preparing the rootstock and scions in splice graft leading of *Chaenomeles japonica*

3. Results

3.1. The effect of different IBA concentration and rootstocks by budding grafting method

The findings indicated that the effects of rootstock type and indole butyric acid (IBA) concentration were significant for grafting traits, root length, and root volume ($p \leq 1\%$), while no significant effect was observed on the rooting of cuttings. Notably, the highest graft success was achieved using dog rose rootstock with an IBA concentration of 0 mg l^{-1}. Conversely, the maximum root length and root volume were recorded for dog rose at an IBA concentration of 2000 mg l^{-1}; however, due to unsuccessful grafting, this treatment is considered inappropriate. Therefore, the optimal rootstock for grafting *Chaenomeles japonica* L. is one that does not apply IBA treatment (Table 1). The findings of this experiment indicated that the rootstocks of *Pyracantha coccinea* and *Rosa alba* exhibit superior growth capabilities, as evidenced by their ability to generate longer and extensive roots compared to *Chaenomeles japonica* L. Specifically, successful grafting with *Pyracantha coccinea* resulted in roots that were approximately 16% longer and had a root volume that was 59% greater than those of *Chaenomeles japonica* L. at a concentration of 2000 mg l^{-1} IBA. Additionally, *Rosa alba* 100 demonstrated longer and wider roots in comparison to apple rootstocks at an IBA concentration of 0 mg l^{-1}.

Table 1. The effect of rootstock and concentration of indole butyric acid on morphological traits of budding grafting

Treatment	Grafting success (%)	Root length (cm)	Root volume (cm^3)
Pyracantha coccinea + 0mg l^{-1} IBA	$0±0^{c}$	$6±1^{c}$	$1±0.7^{d}$
Pyracantha coccinea+ 1000mg l^{-1} IBA	$0±0^{c}$	$12.3±3^{b}$	$3.3±1.1^{b}$
Pyracantha coccinea+ 2000mg l^{-1} IBA	$66±0.5^{ab}$	$4.8±0.3^{bc}$	$1.6±1.4^{c}$
Rosa alba + 0mg l^{-1} IBA	$100±0^{a}$	$12.2±3^{b}$	$3.2±1.1^{b}$
Rosa alba + 1000mg l^{-1} IBA	$0±0^{c}$	$0±0^{c}$	$0±0^{d}$
Rosa alba+ 2000mg l^{-1} IBA	$0±0^{c}$	$20±8^{a}$	$7±^{a}$
Chaenomeles japonica +0 mg l^{-1} IBA	$33±0.5^{bc}$	$0±0^{c}$	$0±0^{d}$
Chaenomeles japonica + 1000 mg l^{-1} IBA	$33±0.5^{bc}$	$3±1^{c}$	$0.33±0.1^{cd}$
Chaenomeles japonica + 2000mg l^{-1} IBA	$66±0.5^{ab}$	$4±2^{bc}$	$0.66±0.1^{cd}$
Chaenomeles japonica without grafting + 0mg l^{-1} IBA	-	$2.6±2^{c}$	$0.5±0.1^{cd}$
Chaenomeles japonica without grafting + 1000mg l^{-1} IBA	-	$7±3^{bc}$	$1.33±0.2^{cd}$
Chaenomeles japonica without grafting + 2000mg l^{-1} IBA	-	$2.1±2^{c}$	$0.33±0.2^{cd}$

In each column, means with the same letters are not significantly different (Duncan, $p \leq 0.01$).

3.2. The effect of different rootstocks by Splice grafting method

The analysis of variance revealed that the influence of rootstock on various traits, including the number of activated scions, callus formation at grafting sites, the length of the tallest bud, inter-node distance in the tallest bud, and the number of leaves on the tallest bud, was statistically significant ($p \leq 1\%$). The *Pyracantha coccinea* rootstock exhibited the lowest number of activated buds, whereas the *Cydonia oblonga*, *Malus domestica* cv. Gami Almasi, *Rosa alba*, and Maling M9 rootstocks demonstrated the highest counts of activated buds. Notably, *Pyracantha coccinea* rootstock also had the greatest number of graft sites with callus formation, followed by *Cydonia oblonga*, *Rosa alba*, and Maling M9, while the *Malus domestica* cv. Gami Almasi exhibited the least callus at graft sites. The longest shoot was associated with the *Cydonia oblonga* rootstock, with *Pyracantha coccinea*, *Malus domestica* cv. Gami Almasi, ungrafted Japanese, *Rosa alba*, and Maling M9 following in that order. The *Cydonia oblonga* rootstock also had the greatest inter-node distance in the tallest bud, ungrafted *Chaenomeles japonica* L., *Pyracantha coccinea*, *Rosa alba*, *Malus domestica* cv. Gami Almasi, and Maling M9. The highest leaf count in the tallest shoot was associated to the

Cydonia oblonga, followed by *Pyracantha coccinea*, *Rosa alba*, ungrafted *Chaenomeles japonica* L., and Maling M9 (Table 2 and Figure 3). In this experiment, the greatest number of grafting sites with callus was noted in the *Pyracantha coccinea* rootstock, while the *Malus domestica* cv. Gami Almasi showed the least. Additionally, the longest shoot length was attributed to the *Cydonia oblonga*, with Maling M9 having the shortest. The *Cydonia oblonga* rootstock also exhibited the highest inter-node distance and leaf count in the tallest shoot, with Maling M9 recording the lowest values. Grafted *Chaenomeles japonica* L. exhibited superior growth compared to ungrafted specimens when cultivated on *Cydonia oblonga* and *Pyracantha coccinea* rootstocks. Specifically, plants grafted onto *Cydonia oblonga* demonstrated an increase of 58% in branch length, 25% in internode length, and 37% in leaf production relative to their ungrafted counterparts. Furthermore, those grafted onto *Pyracantha coccinea* showed a 28% enhancement in branch length and a 34% increase in leaf count compared to ungrafted *Chaenomeles japonica* L.

Table 2. The effect of rootstock on morphological traits in splice grafting

Rootstock	Activated buds(%)	Callus(%)	Longest branch length (cm)	Internode (cm)	Leaf (no.)
Cydonia oblonga	100±0^{a}	50±0^{b}	12±2^{a}	3±0^{a}	8±1^{a}
Malus domestica	100±0^{a}	0±0^{d}	2.5±1^{d}	0.5±0.1^{d}	3±1^{d}
Pyracantha coccinea	50±0^{b}	66.6±14^{a}	7±1^{b}	1.5±0.5^{c}	7.6±0.5^{ab}
Rosa alba	100±0^{a}	41.6±14^{b}	4±1^{cd}	1.4±0.3^{c}	6±1^{bc}
Malling M9	100±0^{a}	25±0^{c}	2±1^{d}	0.46±0.1^{d}	2.6±1.5^{d}
Chaenomeles japonica without grafting	-	-	5±1^{bc}	2.23±0.2^{b}	5±1^{c}

In each column, means with the same letters are not significantly different (Duncan, $p < 0.05$).

Figure 3. *Chaenomeles japonica* L. grafted on different rootstocks (*Cydonia oblonga*, Malling M9, *Malus domestica*, *Pyracantha coccinea*, *Chaenomeles japonica* without grafting, *Rosa alba*, respectively from the left) after 30 days.

4. Discussion

These findings suggest that a high concentration of IBA (2000 mg l^{-1}) may enhance root development but negatively impacts grafting success. Raised levels of auxin impede the elongation of roots; however, they promote cell differentiation, cell division, and the development of lateral roots (Teale et al., 2005). Auxin may have facilitated the hydrolysis and translocation of carbohydrates and nitrogenous compounds at the base of cuttings, leading to enhanced cell elongation and division under appropriate environmental conditions (Singh et al., 2003). Consequently, the cells within the grafting zone experience restricted access to nutrients, resulting in inadequate cell division and insufficient vascular connections in that region. Izadi et al. (2014) examined the influence of IBA on the grafting success of *Rosa hybrida* onto wild dog rose rootstock, reporting that rootstocks treated with IBA at the grafting site exhibited a greater number of roots, branches, and a higher rooting percentage compared to the control. However, IBA treatment did not affect the number of leaves produced. The increase in carbohydrates is crucial for providing the necessary nutrients for rooting in cuttings-grafts. In budding grafting, where the scion lacks leave, the best root length and volume were associated with dog rose rootstock treated with 2000 mg l^{-1} IBA, followed by the treatment with 0 mg l^{-1} IBA. This suggests that both grafting success and leaf production may influence root quantity and quality. The findings of Khalili et al. (2009) regarding the propagation of *Rosa* sp. Olivia through the stenting method and the application of IBA indicate that the highest grafting success rate was observed in the rootstock of *Rosa indica* var. major. They determined that treating the terminal portion of the root cutting with different hormone concentrations did not significantly influence grafting outcomes. This observation aligns with the current experiment, which found that the optimal grafting success occurred at a concentration of 0 mg l^{-1} of IBA in the dog rose rootstock. Furthermore, grafting in the control group (*Chaenomeles japonica* L. grafted onto *Chaenomeles japonica* L. rootstock) across all IBA concentrations (0, 1000, and 2000 mg l^{-1}) highlighted the importance of species, genetic traits, and varying compatibility levels between the rootstock and scion, supporting the conclusions of Khalili et al. (2009). The consistently response of non-grafted *Chaenomeles japonica* L. to varying concentrations of IBA suggests that the influence of wound stimulation during the grafting process may play a more critical role in promoting root growth in this species than the application of IBA itself. Furthermore, if the analysis were limited to only those *Chaenomeles japonica* L. treated with different IBA concentrations, a significant variation among the treatments would likely be observed. Additional research supports the findings of this study, emphasizing the varying impacts of rootstocks on grafting success (Hazar and Ibrahim, 2005). The inadequate connection between the scion and rootstock in grafted plants may stem from genetic disparities among species and the physiological states of both the rootstock and scion at the time of grafting (Babaei et al., 2013). Genetic variations among different cultivars can influence grafting success by affecting tissue water content, soluble sugars, starch levels, C/N ratios, and the concentration of endogenous hormones in both the rootstock and scion (Soleymani et al., 2009). The highest percentage of rooting and the greatest number of roots were recorded at elevated concentrations of IBA. The application of this exogenous auxin enhances the activity of IAA, leading to an increase in its internal synthesis, and can also promote rooting by enhancing tissue sensitivity to IAA (Hartman et al., 2002; Ingle and Venugopal, 2009). Additionally, auxin facilitates the movement and allocation of mobile rhizocalins and carbohydrates to the rooting zone, activating these compounds at the targeted sites, thereby playing a crucial role in root initiation and differentiation (Reezi et al., 2006; Zarrinball et al., 2005). Consequently, the maximum root length and volume observed in the treatment with 2000 mg l^{-1} of rootstock dog rose can be attributed to these mechanisms. IBA is recognized as a primary rooting agent (Hartman et al., 2002; Izadi and Zarei, 2014). Solgi et al. (2022) noted that the highest rooting percentage in black mulberry tree propagation was achieved through stenting. The splice grafting method yielded the longest leaf, longest shoot, and longest root at a concentration of 1000 mg l^{-1} IBA. Conversely, the amount of carbohydrate storage in the scion is another critical factor influencing the success of cuttings and grafting. The stored carbohydrates undergo hydrolysis into simpler forms and are subsequently transferred to the tissues. Treatment with IBA enhanced the success rates of both cuttings and grafts, improving the percentage of root characteristics compared to the control group. This improvement may be linked to auxin-induced cell division at the grafting and root formation sites (Solgi et al., 2012). Based on the current findings, it can be concluded that the concentration of IBA significantly influences root length and volume traits; however, it does not consistently correlate with grafting success. This inconsistency may be due to insufficient food storage in the scion, which, in the budding method, contains only a bud and the surrounding bark.

The activation of the cambium layer, along with callus formation and vascular connection, is influenced by various factors, including environmental conditions such as temperature and humidity, plant growth regulators, and species (Hartman et al., 2002; Izadi et al., 2013; Solgi et al., 2012). A significant role of rootstock is its ability to regulate tree size by altering the growth rate of the grafted scion (Rahmati et al., 2015). Alizadeh et al. (2022) conducted a study revealing that the grafting of OH×F69 onto the pyrodwarf rootstock resulted in reduced growth cultivars. The rootstock plays a crucial role in the distribution and transfer of carbohydrates, nutrients, and growth regulators throughout various plant parts, thereby influencing the vegetative growth of grafted trees (Rufato et al., 2014). The observed limited bud growth in the Maling M9 rootstock aligns with the findings of Alizadeh et al. (2022). Additionally, the presence of short roots in grafted trees can adversely affect tree growth by altering physiological processes, ultimately leading to a reduction in tree size (Ikinci et al., 2014). The anatomical characteristics of the grafting site are critical determinants of root strength. Alizadeh et al. (2022) findings indicate that the trunk diameter at various locations of the grafting site in the pyrodwarf rootstock exceeds that of the OH×F69 rootstock. This discrepancy is attributed to the effects of the shorter pyrodwarf rootstock, where increased cell division, stimulated by auxin hormone accumulation from the terminal bud at the grafting site, leads to localized swelling (Karbasi and Arzani, 2018). Furthermore, the tissue at the grafting site in shorter stems may restrict the polar movement of auxin, thereby limiting water transport from the roots to the shoots and affecting the transfer of minerals and growth regulators, particularly cytokinins, within the stem's vascular system, which in turn diminishes vegetative growth (Atkinson and Else, 2003). Zamorskyi (2011) noted that auxin transport rates in shorter apple rootstocks were lower than those in taller rootstocks, attributing this difference to the larger vascular elements present in the wood vessels of shorter rootstocks near the grafting site. Esmaili et al. (2020) further asserted that varying rootstocks influence the height of grafted plants by altering the distance between nodes, which is in agreement with the results of the present study in relation to The short distance between the nodes is consistent with the rootstock of Maling M9. It can also be said that the low number of leaves in this rootstock is due to low growth and the shortening properties of Maling M9 rootstock.

Conclusion

The findings from the experiment indicated that the application of IBA hormone effectively promoted root development, with the greatest root length and volume observed in the *Rosa alba* root at a concentration of 2000 mg l^{-1}. In the subsequent experiment, the *Pyracantha coccinea* rootstock exhibited the lowest number of activated grafts; however, it demonstrated the highest callus formation at the grafting site among the rootstocks, suggesting a superior grafting potential. Additionally, following the *Cydonia oblonga* rootstock, *Pyracantha coccinea* displayed strong growth and an increased leaf count. Given the favorable conditions for callus formation and grafting observed in this rootstock, it is considered a suitable candidate for the propagation of *Chaenomeles japonica* L. grafts through the cutting-grafting technique utilizing the splice method. Furthermore, *Chaenomeles japonica* L. cultivation could be improved by using cultivars grafted on tolerant rootstocks. Thus, evaluation of *Chaenomeles japonica* L. propagation through bud grafting techniques seems necessary. Further research is recommended to determine if grafting *Chaenomeles japonica* L. on *Pyracantha coccinea* rootstock enhances the ornamental shrub's resistance to environmental stress, including leaf early chlorosis symptoms.

Conflict of interest

The authors declare no conflicts of interest.

Acknowledgments

The authors are grateful to Arak University for their support.

References

Alizadeh, M., Yadegari, M., Davarynejad, G., and Nemati, S.H. 2022. The Rootstock and Scion Interaction Effects on Growth and Bearing Characteristics of Young Pear Trees. Journal of Horticultural Science, 36(2): 519-531. https://doi.org/10.22067/jhs.2022.73938.1112

Atkinson, C.J., and Else, M.A. 2003. Enhancing harvest index in temperate fruit tree crops through the use of dwarfing rootstocks. In: International Workshop on Cocoa Breeding for Improved Production Systems. Accra, Ghana. 118-131. DOI: 10.1093/jxb/erg132

Babaei, H., Zarei, H., Hemmati, K. 2015. The Effect of Different Concentrations of IBA, Type of Plant Rootstock and Timeing of Cuttings on Propagation of Ficus benjamina CV. Variegata by Cutting - Graft. Journal of Crop Production and Processing, 5(17): 253-261. http://jcpp.iut.ac.ir/article-1-2424-fa.html

Buck, G.J. 1978. Rose rootstocks. Hortscience. 13: 601- 602.

Campbell, J. 2003. Pear rootstocks. NSW. Ext. Pub. Agfact. New South Wales Agriculture, Australia.

Davarynejad, G., Shokouhian, A. A., and Tehranifar, A. 2015. 'Effect of IBA and Medium on Rooting of Two New Selected Peach × Almond Hybrids Cuttings'. Journal of Horticultural Science, 29(2): 176-184. doi: 10.22067/jhorts4.v0i0.27561

Esmaili, A., Abdollahi, H., Bazgir, M., and Abdossi, V. 2020. Growth and nutrients uptake in commercial pear cultivars on seedling, Pyrodwarf and OH × F69 rootstocks. Seed and Plant Journal, 036(4): 403-420. 10.22092/SPPI.2021.123892

Hartman, H.T., Kester, D.E., Davies, F.T, and Geneve R.L. 2002. Plant Propagation: Principles and Practice. Englewood Cliffs: Prentice Hall, 880.

Hazar, D., and Ibrahim, B. 2005. Graft compatibility between two cut rose cultivers and a dog rose rootstock. Acta Horticulturae 690: 143-148. https://doi.org/10.17660/ActaHortic.2005.690.21

Ikinci, A., Bolat, I., Ercisli, I., and Kodad, O. 2014. Influence of rootstocks on growth, yield, and fruit quality and leaf mineral element contents of pear cv. Santa Maria in semi-arid conditions. Biology Research, 47: 1-8. https://doi.org/10.1186/0717-6287-47-71

Ingle, M.R., and Venugopal, C.K. 2009. Effect of Different Growth Regulators on Rooting of Stevia (Stevia rebaudiana Bertoni) Cuttings. Karnataka Journal of Agricultural Sciences, 22,455-456.

Izadi, Z., Zarei, H., and Alizadeh, M. 2013. Role of grafting technique on the success of stenting propagation of two rose (*Rosa sp*.) varieties. American Journal of Plant Sciences, 4.5A: 41-44. DOI: 10.4236/ajps.2013.45A006

Jiang, S., Ou, Q., Wang, F., Zhang, Y., Ma, L., and Zhao, Y. 2018. Development and application of pear dwarf stock in China. North Fruits, 2: 1–3. https://doi.org/10.16376/j.cnki.bfgs.2018.02.001

Karbasi, M., and Arzani, K. 2018. Scion/rootstock interaction in some European (*Pyrus communis* L.) and Asian (*Pyrus serotina* Rehd.) pear cultivars on vegetatively propagated Pyrodwarf rootstock. Seed and Plant Production Journal, 34(2): 191-205. 10.22092/SPPJ.2018.118944

Khalighi, A. 1991. Floriculture and Ornamental Plants of Iran. Rozbahan Press, Tehran, 392 p.

Khalili, R., Nekonam, F., Khsosi, M., Naderi, R., and Jabarzadeh, J. 2011. The Effect of indole butyric acid hormone concentration and rootstock on propagation of rose Cv. "Olivia" through stenting technique Agroecology Journal, 6(4): 15

Khosh-Khui, M., and M. Zargarian. 2009. Effects of four rootstocks on growth and development of three rose scion cultivars. In V International Symposium on Rose Research and Cultivation 870: 207-212. https://doi.org/10.17660/ActaHortic.2010.870.27

Prado, R.M., and Alcántara-Vara, E. 2011. Tolerance to iron chlorosis in non-grafted quince seedlings and in pear grafted onto quince plants. Journal of Plant Nutrition and Soil Science, 11: 119–128. http://dx.doi.org/10.4067/S0718-95162011000400009

Rahmati, M., Arzani, K., Yadollahi, A., and Abdollahi, H. 2015. Influence of rootstock on vegetative growth and graft incompatibility in some pear (*Pyrus* spp.) cultivars. Indo-American Journal of Agricultural and Veterinary Sciences, 3: 225-232. doi: 10.1186/0717-6287-47-71

Reezi, S., Naderi, R., Khalighi, A., Zamani, Z., and Etemad, V. 2006. Asexual propagation of (*Picea pungens Koster)* through cuttings and grafting under various hormonal treatments. Iranian Journal of Natural Resources, 59(3): 589-601.

Rufato, L., Machado, B.D., Kretzschmar, A.A., Bogo, A., Luz, A.R. and Marcon Filho, J.L. 2014. Effect of high plant density on growth and production variables of European pear cultivars and quince rootstock combinations in southern Brazil. Acta Horticulture, 1058: 71-76. https://doi.org/10.17660/ActaHortic.2014.1058.6

Rumpunen, K. 2002. Chaenomeles: potential new fruit crop for northern Europe. Trends in new crops and new uses. Asha press, alexandria, va. 385–392.

Singh, A.K., Singh, R., Mittal, A.K., Singh, Y. P. and Jauhari, S. 2003. Effect of plant growth regulators on survival rooting and growth characters in long pepper (Piper longum L.). Progressive Horticulture. 35: 208-211.

Soleymani, A., Rabiei, V., Hasani, D., and Amiri, M. 2009. Effects of rootstock and cultivar on propagation of rabido Walnut (*Juglans regia* L.) using hypocotyle grafting. Seed and Plant Production Journal, 25(1): 93-101. doi: 10.22092/sppj.2017.110366

Solgi, M., Shahrjerdi, I., and Ebadi, A. 2012. Effects of scion genotype, rootstock age and time of grafting on success of soft grafting method in walnut. Acta Horticulturae. 940:119-123. https://doi.org/10.17660/ActaHortic.2012.940.14

Solgi, M., Taghizadeh, M., and Bagheri, H. 2022. Response of black mulberry onto white mulberry rootstock to stenting (cutting-grafting) techniques and IBA concentrations. Ornam*ental* Hortic*ulturae*. 28.1:78–84. https://doi.org/10.1590/2447-536X.v28i1.2413

Teale, W.D., Paponov, I.A., Ditengou, F. and Palme, K. 2005. Auxin and the developing root of Arabidopsis thaliana. Journal of Plant Physiology. 123:130-138.

Zamorskyi, V. 2011. Features of anatomic structure of the grafted young apple trees as the factor which forms potential efficiency. Acta Horticulturae. 903: 897-902. DOI:10.17660/ActaHortic.2011.903.125