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Standardization and Evaluation of Vegetative Propagation Techniques for Elite Rose Apple (*Syzygium jambos* L.) Genotypes

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A B S T R A C T

A survey was conducted to evaluate seedling-originated rose apple (*Syzygium jambos* L.) genotypes collected from 3 districts representing the Eastern Dry and Hilly agro-climatic zones of Karnataka. Based on growth, yield and fruit quality attributes, five elite genotypes BRDKRA-1, BNYRA-9, BRACRA-1, BRHSRA-1 and CMGRA-6 were identified and selected for vegetative multiplication. These genotypes were subsequently evaluated for their propagation potential through softwood grafting and patch budding. The present investigation was carried out during 2025-26 at the College of Horticulture, Bengaluru, Karnataka. Significant variation was observed among the genotypes for graft success, bud take, sprouting behaviour, survival and vegetative growth parameters. Among the grafted plants, BRDKRA-1 recorded the highest graft success (70.00%) at 60 days after grafting (DAG) and graft survival (62.50%) at 120 DAG. The genotype also exhibited the earliest graft sprouting (18.32 days), highest number of sprouts per graft (3.13 at 30 DAG), maximum number of leaves per sprout (14.25 at 120 DAG) and maximum graft height (19.71 cm). Under patch budding, BNYRA-9 recorded the highest bud take (52.50%) at 60 days after budding (DAB) and bud survival (37.50%) at 120 DAB. The same genotype also produced the highest number of shoots per plant (0.60), maximum sprout length (16.22 cm), maximum leaf length (13.53 cm) and highest graft girth (6.05 mm) during the later stages of growth. Softwood grafting consistently resulted in earlier sprouting, higher success and survival percentages and superior vegetative growth compared with patch budding.

Introduction

Rose apple (*Syzygium jambos* L.), a member of the family Myrtaceae, is an underutilized fruit crop with considerable potential for commercial cultivation due to its attractive fruits, pleasant rose-like aroma, nutritional value and adaptability to diverse agro-climatic conditions. Native to Southeast Asia, it is widely distributed in tropical and subtropical regions and grows well under warm, humid climates (Morton, 1987; Van Lingen, 1991). The crop produces bisexual flowers in terminal clusters and is mainly pollinated by insects, particularly honeybees (Saha, 1986; Kishore *et al.,* 2016).

Traditionally, rose apple is propagated through seeds, which are often polyembryonic. However, seed propagation may result in variability in growth, flowering, yield and fruit quality, besides a prolonged juvenile phase that delays fruit production (Morton, 1987; Van Lingen, 1991). Therefore, vegetative propagation is essential for producing true-to-type plants and rapidly multiplying superior genotypes. Vegetative propagation methods such as grafting and budding help maintain genetic fidelity, promote early bearing and ensure uniform growth and fruiting. Among these methods, softwood grafting and patch budding have shown promising results in Myrtaceous fruit crops such as jamun, wax apple and guava (Bharad and Mahorkar, 2011; Kaur and Kaur, 2018; Pavithra *et al.,* 2020; Ruchitha *et al.,* 2022; Kumar and Chander, 2024). These techniques improve stock-scion compatibility, encourage rapid callus formation and enhance plant establishment.

Despite the increasing interest in rose apple cultivation, scientific information regarding the standardization of grafting and budding techniques in elite genotypes remains limited. Identification of suitable propagation methods is essential for the rapid multiplication, conservation and commercial utilization of superior genotypes. Therefore, the present investigation was undertaken to evaluate and standardize softwood grafting and patch budding techniques in selected elite rose apple genotypes and to identify the most suitable genotype propagation method combination for efficient vegetative propagation and commercial cultivation.

Materials and Methods

The present investigation was conducted during May 2025 at the College of Horticulture, Bengaluru, Karnataka, India, to standardize and evaluate vegetative propagation techniques in elite rose apple (*Syzygium jambos* L.) genotypes. The elite genotypes used in the study were selected from a survey conducted in Bengaluru Rural, Bengaluru Urban and Chikkamagaluru districts of Karnataka. Based on their superior growth, yield and fruit quality attributes, five elite genotypes, namely BRDKRA-1, BNYRA-9, BRACRA-1, BRHSRA-1 and CMGRA-6, were identified and selected for vegetative propagation studies. The experiment was laid out in a Completely Randomized Design (CRD) comprising the five elite genotypes with four replications. A total of 200 grafts and 200 budded plants were raised using one-year-old healthy, vigorous and disease-free rootstocks of uniform size.

Collection and Preparation of Scion Material

Scion shoots were collected from selected elite mother plants and pre-cured by defoliation, retaining the petiole for 7-10 days prior to propagation to promote bud maturity and enhance sprouting. Healthy terminal shoots of pencil thickness were selected as scion material. The collected scions were wrapped in moist cloth and transported immediately to the propagation site to prevent moisture loss and desiccation.

Softwood Grafting Procedure

Softwood grafting was performed on one-year-old rootstocks by beheading the terminal portion of the stock and making a vertical cleft in the softwood region. The basal end of the scion was shaped into a wedge and inserted into the cleft after ensuring proper cambial alignment. The graft union was secured firmly with 200-gauge polyethylene strips and covered with transparent polycaps to maintain adequate humidity around the graft union.

Patch Budding Procedure

Patch budding was carried out using pre-cured scion buds by removing a rectangular bark patch (2.5-3.0 cm × 1.0-1.5 cm) from the rootstock at 15-20 cm above ground level and replacing it with a corresponding patch containing a healthy dormant bud from the scion. The bud union was wrapped tightly with polyethylene strips to prevent desiccation and ensure successful union formation. Regular irrigation was provided and sprouts arising below the graft or bud union were removed periodically.

Observations Recorded in Grafted Plants

Observations on grafted plants were recorded at 30, 60, 90 and 120 days after grafting (DAG). The number of days taken for sprouting was recorded from the date of grafting to the appearance of the first visible sprout. The number of sprouts per graft and number of leaves per sprout were counted manually at each observation interval. Graft height was measured from 1 cm above the graft union to the terminal growing point using a centimeter scale, while graft girth was measured at the graft union using a digital vernier caliper. Graft success percentage was determined at 60 DAG as the proportion of successful graft unions to the total number of grafts performed, whereas graft survival percentage was recorded at 120 DAG as the proportion of grafts remaining alive relative to the total number of successful grafts.

Observations Recorded in Budded Plants

In budded plants, observations were recorded at 60, 90 and 120 days after budding (DAB). The number of days taken for bud sprouting was recorded from the date of budding to the emergence of the first visible sprout. The number of sprouts per bud, number of shoots per plant and number of leaves per plant were counted manually at each observation stage. Sprout length was measured from the bud union to the tip of the developing shoot using a centimeter scale, while leaf length was measured on fully expanded leaves and expressed in centimeters. Bud survival percentage was calculated at 120 DAB as the proportion of successfully sprouted and surviving buds relative to the total number of buds propagated.

Statistical Analysis

The experimental data were subjected to statistical analysis using R statistical software (Version 4.5.3) under a Completely Randomized Design (CRD). Analysis of Variance (ANOVA) was performed to determine the significance of treatment effects. Percentage data were subjected to arc-sine transformation before analysis to stabilize variance. Whenever treatment effects were significant, means were compared using the Critical Difference (CD) test at the 5 per cent level of significance ($P \leq 0.05$). Interpretation of the results was carried out according to the procedures described by Panse and Sukhatme (1967).

Results and Discussion

Comparative performance of soft wood graft success, graft survival, patch budding take and bud survival percentage in selected rose apple genotypes

Significant differences were observed among the selected rose apple genotypes with respect to softwood graft success, graft survival, patch budding take and bud survival percentage (Fig. 1 & Plate 1), indicating a strong genotypic influence on the success of vegetative propagation. Among the genotypes evaluated, BRDKRA-1 recorded the highest graft success percentage (70.00%) at 60 days after grafting (DAG), which was significantly superior to the remaining genotypes. It was followed by BNYRA-9 (55.00%) and BRACRA-1 (52.50%), whereas the lowest graft success was recorded in CMGRA-6 (45.00%). Similarly, graft survival at 120 DAG was highest in BRDKRA-1 (62.50%), followed by BNYRA-9 and BRACRA-1 (50.00% each), while CMGRA-6 recorded the lowest survival percentage (37.50%).

The superior graft success and survival observed in BRDKRA-1 may be attributed to better stock-scion compatibility, rapid callus proliferation and efficient cambial union formation, resulting in early establishment of vascular continuity between stock and scion. The favourable environmental conditions prevailing during May, particularly optimum temperature and relative humidity, might have promoted cambial activity and callus development at the graft interface. High humidity prevents desiccation of newly formed callus tissues and facilitates rapid healing of the graft union, thereby enhancing graft establishment and subsequent survival. Furthermore, rapid swelling of axillary and terminal buds could have contributed to early sprouting and vigorous growth of grafts. Similar findings were reported by Bharad and Mohorkar (2011) and Kaur and Kaur (2018) in jamun. Similarly, Mulla *et al.,* (2011) reported maximum graft success and survival during May owing to favourable climatic conditions that enhanced graft union formation and growth.

In contrast, patch budding exhibited comparatively lower success and survival percentages across genotypes. Among the genotypes, BNYRA-9 (Plate 2) recorded the highest bud take percentage (52.50%) at 60 days after budding (DAB), followed by BRDKRA-1 and BRHSRA-1 (45.00% each), whereas BRACRA-1 recorded the lowest bud take (40.00%). Similarly, bud survival at 120 DAB was highest in BNYRA-9 (37.50%), followed by BRDKRA-1 (27.50%) and BRACRA-1 (22.50%), while the lowest survival was observed in CMGRA-6 (10.00%).

The comparatively lower bud take and bud survival percentages may be attributed to slower bud union formation, partial incompatibility between stock and bud patch, or fluctuations in environmental conditions during the healing period. Successful patch budding depends largely on active sap flow, proper cambial contact and maintenance of favourable moisture conditions around the bud union. Any interruption in these factors may adversely affect bud establishment and subsequent survival. Similar genotype-dependent variation in budding performance has been reported in jamun by Ruchitha *et al.,* (2022). Earlier, Singh and Singh (2006) observed that propagation success in jamun varied considerably with propagation method and season. Bharad and Mohorkar (2011) also reported superior performance of softwood grafting over budding, while Baloda *et al.,* (2016) emphasized the importance of favourable temperature, humidity and active sap flow for successful budding.

Number of days taken for softwood graft sprouting, patch bud sprouting and sprouting percentage in selected rose apple genotypes

The data presented in a Fig. 2 revealed significant differences among the elite rose apple genotypes with respect to the number of days taken for softwood graft sprouting, number of days taken for patch bud sprouting and sprouting percentage at 60 days after budding (DAB). Among the genotypes, BRDKRA-1 recorded the earliest graft sprouting (18.32 days), which was significantly superior to the remaining genotypes, followed by BNYRA-9 (20.17 days) and BRHSRA-1 (21.53 days). The maximum number of days taken for graft sprouting was observed in BRACRA-1 (23.15 days). In patch budding, CMGRA-6 recorded the earliest bud sprouting (30.25 days), which was on par with BNYRA-9 (30.67 days), whereas BRACRA-1 exhibited the longest duration for bud sprouting (37.40 days). With respect to sprouting percentage at 60 DAB, BRDKRA-1 and BRHSRA-1 recorded the highest sprouting percentage (37.50%), followed by BNYRA-9 (35.00%) and BRACRA-1 (27.50%), while CMGRA-6 recorded the lowest sprouting percentage (10.00%).

The results clearly demonstrated that softwood grafting promoted earlier sprouting compared to patch budding in all the genotypes studied. The faster sprouting observed in grafted plants may be attributed to rapid callus formation, early establishment of vascular connections and efficient translocation of water, nutrients and growth-promoting substances across the graft union. The use of pre-cured scion shoots might have further enhanced bud break by facilitating quicker activation of dormant buds. The higher sprouting percentage recorded in BRDKRA-1 and BRHSRA-1 indicates better stock–scion compatibility and successful union formation, resulting in improved establishment and growth. Conversely, the lower sprouting percentage observed in CMGRA-6 may be attributed to slower callus development, delayed vascular differentiation and comparatively poor compatibility between stock and scion tissues. Genotypic differences in carbohydrate reserves, endogenous hormone levels and physiological status of the propagules may also have contributed to the observed variation in sprouting behaviour.

The present findings are in agreement with those of Mulla *et al.,* (2011), who reported early sprouting and better establishment in softwood-grafted jamun. Similar results were reported by Bharad and Mohorkar (2011), who attributed higher sprouting and success in softwood grafting to rapid graft union formation and active cambial growth. Singh and Singh (2006) also observed that sprouting behaviour and propagation success in jamun varied with propagation method and season. Further, Baloda *et al.,* (2016) reported that budding performance in Myrtaceous fruit crops is greatly influenced by environmental conditions, active sap flow and physiological status of the propagules.

Number of sprouts per graft and number of sprouts per bud in selected rose apple genotypes

Significant differences were observed among the selected rose apple genotypes with respect to the number of sprouts per graft and number of sprouts per bud at different stages of observation (Fig. 3). Under softwood grafting, BRDKRA-1 consistently recorded the highest number of sprouts per graft throughout the study, registering 3.13, 2.04, 1.17 and 1.06 sprouts at 30, 60, 90 and 120 DAG, respectively. This was followed by BNYRA-9 and BRACRA-1, whereas CMGRA-6 recorded the lowest number of sprouts per graft at all observation stages. A gradual decline in the number of sprouts per graft was observed across genotypes with advancement of growth, which may be attributed to the dominance of vigorous sprouts and natural shedding or suppression of weaker sprouts.

In patch budding, BRDKRA-1 and BRHSRA-1 recorded the highest number of sprouts per bud (0.35) at 60 DAB and were on par with BNYRA-9 (0.33). At 90 DAB, BRDKRA-1 maintained superiority with 0.48 sprouts per bud, while at 120 DAB the highest value was recorded in BNYRA-9 (0.50), which was statistically on par with BRDKRA-1 and BRHSRA-1 (0.48 each). The lowest sprouting performance was generally observed in CMGRA-6 and BRACRA-1.

The superior sprouting performance exhibited by BRDKRA-1, BNYRA-9 and BRHSRA-1 may be attributed to better stock–scion compatibility, rapid callus formation, efficient vascular connection and higher physiological vigour of the propagules, which favoured early bud break and greater sprout production. In contrast, the lower sprouting response observed in CMGRA-6 may be due to comparatively weaker graft or bud union formation and reduced physiological activity. The results further indicated that softwood grafting was more effective than patch budding in promoting sprout production under the prevailing environmental conditions.

Similar genotype-dependent variations in sprouting and graft performance have been reported in jamun by Bharad and Mohorkar (2011), Ghojage *et al.,* (2011), Ruchitha *et al.,* (2022), Rawa *et al.,* (2023) and Kumar and Chander (2024), who attributed the differences to variations in compatibility, callusing ability and physiological status of the propagules.

Number of leaves per sprout in grafted plants, number of shoots per plant and number of leaves per budded plant in selected rose apple genotypes

Significant differences were observed among the selected rose apple genotypes with respect to the number of leaves per sprout in grafted plants, number of shoots per plant and number of leaves per budded plant at different stages of observation (Fig. 4). In grafted plants, BRACRA-1 recorded the highest number of leaves per sprout at 30 DAG (6.50), followed by BRDKRA-1 (6.25). However, from 60 DAG onwards, BRDKRA-1 consistently recorded the highest number of leaves per sprout, with 8.75, 12.25 and 14.25 leaves at 60, 90 and 120 DAG, respectively.

In contrast, BNYRA-9 recorded the lowest number of leaves at the initial stages, while CMGRA-6 exhibited the lowest values at the later stages of growth. In budded plants, BNYRA-9 recorded the highest number of shoots per plant at 60 DAB (0.50) and 120 DAB (0.60), whereas BRDKRA-1 and BNYRA-9 were on par at 90 DAB (0.50 each). Regarding the number of leaves per budded plant, BRACRA-1 recorded the highest values at 60 DAB (1.80) and 90 DAB (2.60), while BNYRA-9 registered the highest number of leaves at 120 DAB (3.10). The lowest values for both number of shoots and leaves were generally observed in CMGRA-6.

The superior vegetative growth exhibited by BRDKRA-1 under grafting and BNYRA-9 under budding may be attributed to better stock-scion compatibility, rapid callus formation and efficient vascular connection, which facilitated greater translocation of water, nutrients and photosynthates, thereby promoting leaf production and shoot development.

Enhanced physiological activity and higher carbohydrate reserves in these genotypes might have further contributed to vigorous vegetative growth. Conversely, the comparatively poor performance of CMGRA-6 may be due to weaker graft or bud union formation, slower establishment of vascular tissues and lower physiological vigour, which restricted nutrient movement and subsequent growth.

Overall, softwood grafting resulted in better vegetative growth than patch budding, particularly in BRDKRA-1, as evidenced by the higher number of leaves per sprout throughout the observation period. Similar genotype- and propagation method-dependent variations in vegetative growth have been reported in jamun by Bharad and Mohorkar (2011), Muniyappan *et al.,* (2019), Ruchitha *et al.,* (2022), Kumar and Chander (2024) and Sumit *et al.,* (2024), who attributed improved leaf and shoot production in grafted plants to stronger stock-scion compatibility and better establishment of the graft union.

Length of new sprout after budding and length of leaves per bud after budding in selected rose apple genotypes

Significant differences were observed among the elite rose apple genotypes with respect to sprout length and leaf length of budded plants at different stages after budding (Fig. 5).

At 60 DAB, the maximum sprout length was recorded in BRHSRA-1 (4.24 cm), which was statistically on par with BNYRA-9 (4.14 cm), whereas the lowest sprout length was observed in CMGRA-6 (3.23 cm). At 90 and 120 DAB, BNYRA-9 recorded significantly higher sprout lengths of 9.50 cm and 16.22 cm, respectively, followed by BRHSRA-1 (9.10 cm and 15.60 cm). The lowest sprout length at later stages was recorded in BRACRA-1 (6.21 cm and 11.50 cm).

Fig.1 Frequency distribution of elite rose apple genotype for soft wood graft success, survivability, patch wood bud take percentage and survivability

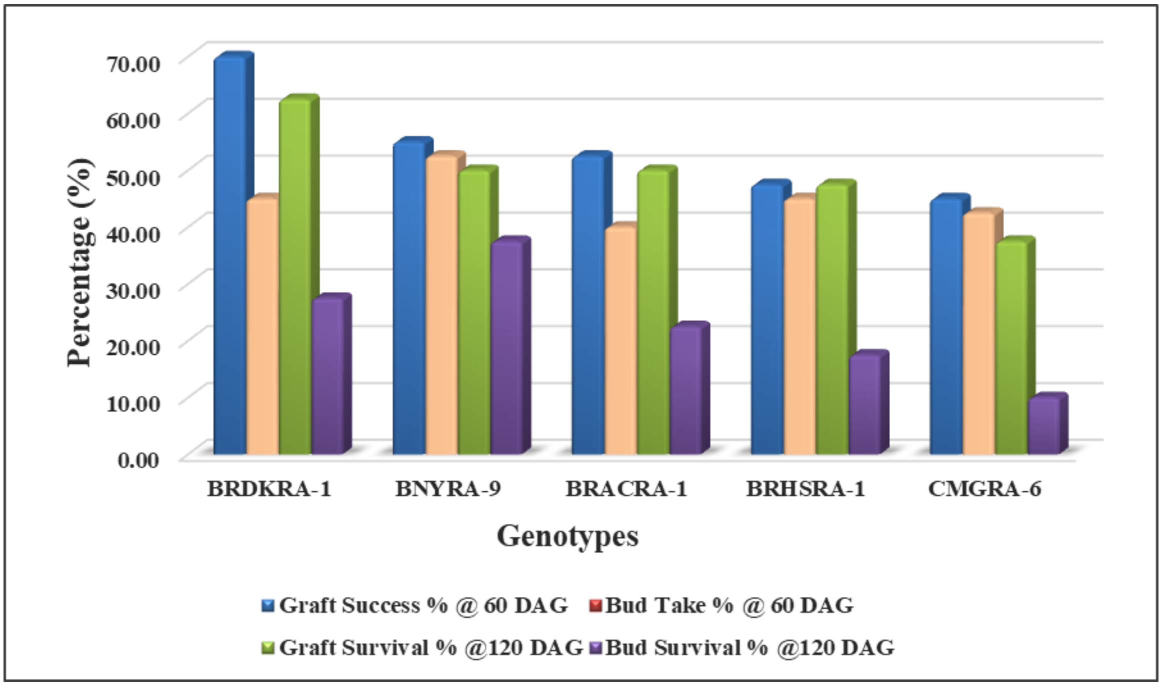

Fig.2 Frequency distribution for number days taken for soft wood grafted bud, patch wood bud sprouting and sprouting percent at 60 days after budding of elite rose apple genotypes

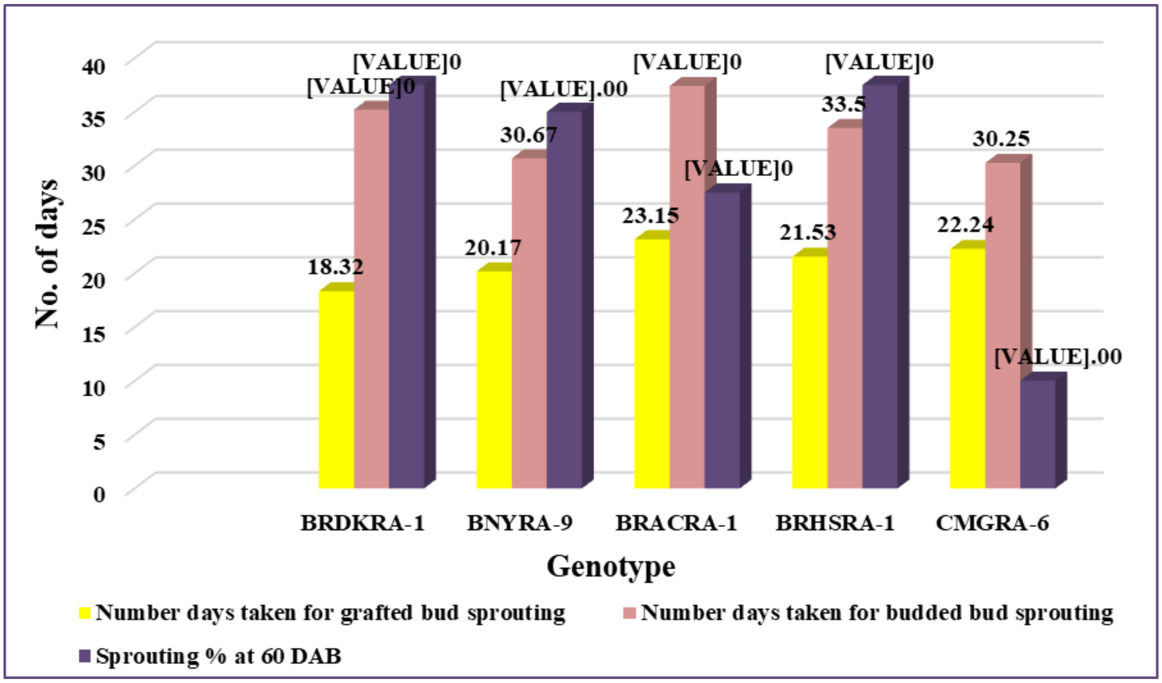

Fig.3 Frequency distribution for number of sprouts per graft at 30, 60, 90, 120 days after grafting and number of sprouts per bud at 60, 990 120 days after budding of selected rose apple genotypes

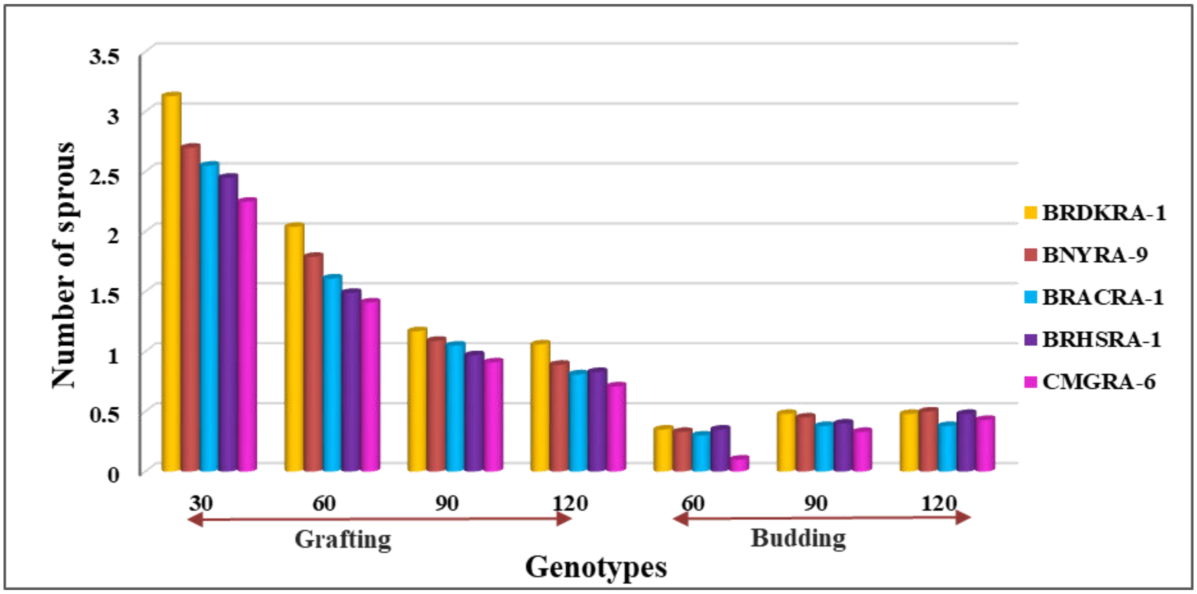

Fig.4 Frequency distribution number of leaves per sprout of grafted plant at 30, 60, 90, 120 days after grafting, number of shoots and number of leaves per budded plant at 60, 90, 120 DAB of selected rose apple genotypes

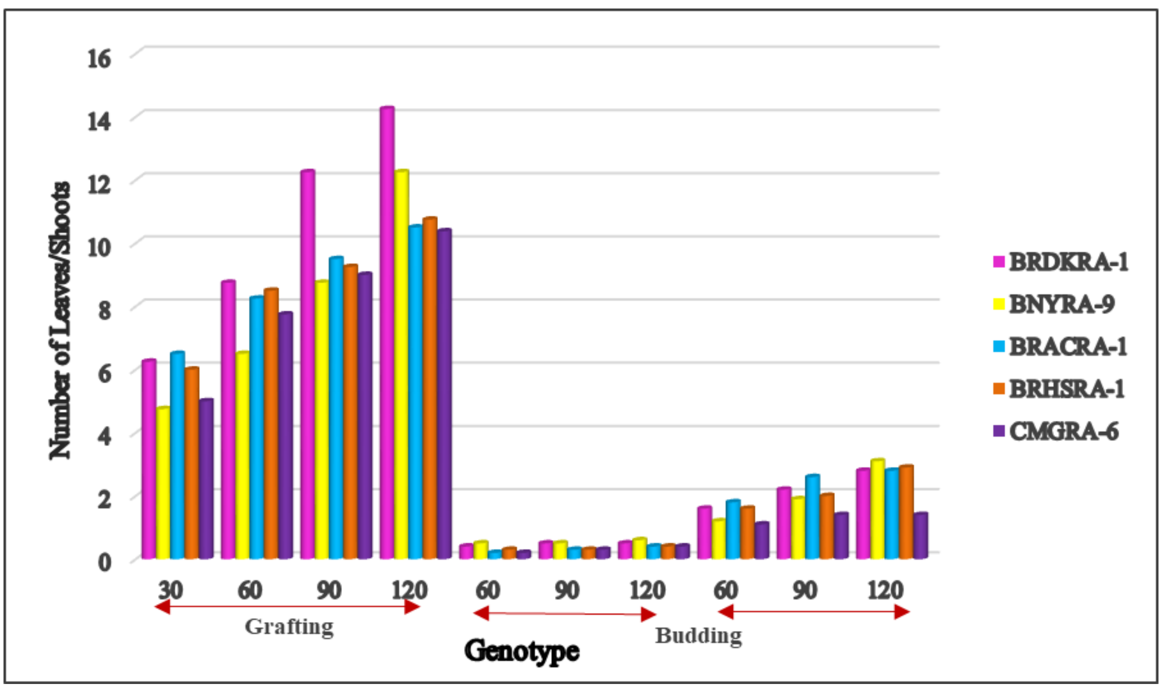

Fig.5 Frequency distribution for length of new sprout at 60, 90, 120 days after budding and length of leaves per bud at 60, 90, 120 days after budding of selected rose apple genotypes

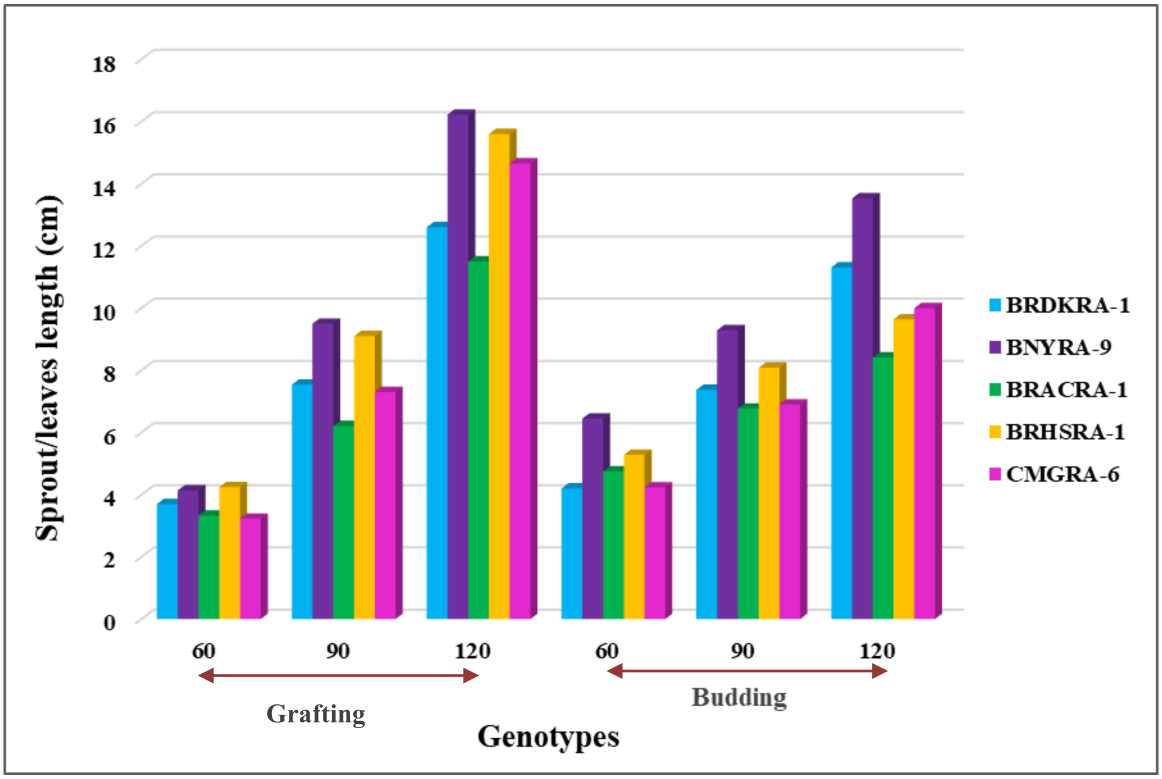

Fig.6 Frequency distribution graft height and graft girth at 30, 60, 90, 120 days after grafting of selected rose apple genotypes

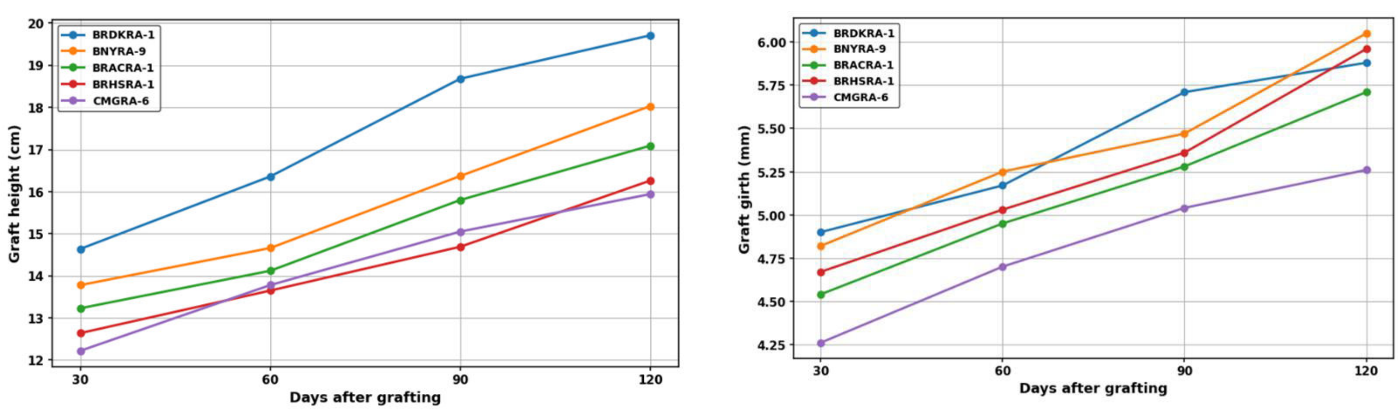

Plate.1 Successful grafts of rose apple genotypes

BRDKRA-1

BNYRA-9

BRACRA-1

Plate.2 Successful budding of rose apple genotype

BNYRA-9

Similarly, leaf length varied significantly among the genotypes. BNYRA-9 consistently recorded the maximum leaf length at all stages, measuring 6.45 cm, 9.29 cm and 13.53 cm at 60, 90 and 120 DAB, respectively. In contrast, BRACRA-1 recorded the lowest leaf length at 90 DAB (6.77 cm) and 120 DAB (8.41 cm), while BRDKRA-1 exhibited the lowest value at 60 DAB (4.20 cm).

The superior performance of BNYRA-9 with respect to sprout elongation and leaf development may be attributed to better bud union formation, efficient vascular connectivity between stock and scion, and greater physiological vigour, which enhanced the translocation of water, nutrients and growth-promoting substances. The higher initial sprout growth observed in BRHSRA-1 at 60 DAB may be due to rapid bud break and early establishment following budding. Conversely, the relatively poor performance of BRACRA-1 and CMGRA-6 could be associated with slower callus formation, weaker stock–scion compatibility and reduced metabolic activity, resulting in restricted vegetative growth. Similar genotypic variations in post-budding shoot growth and leaf development have been reported in jamun by Singh and Singh (2006), Baloda *et al.,* (2016) and Ruchitha *et al.,* (2022), who attributed differences in vegetative growth to variations in compatibility and vigour among propagated genotypes.

Performance of rose apple genotypes for graft height and graft girth at different days after grafting

Significant variation was observed among the selected rose apple genotypes with respect to graft height and graft girth at different stages after grafting (Fig 6).

Among the genotypes, BRDKRA-1 recorded the maximum graft height throughout the study period, registering 14.64, 16.36, 18.68 and 19.71 cm at 30, 60, 90 and 120 DAG, respectively. In contrast, the lowest graft height was generally observed in CMGRA-6, which recorded 12.22 cm at 30 DAG and 15.94 cm at 120 DAG. The superior height growth in BRDKRA-1 indicates better graft establishment and vegetative vigour following graft union formation. With respect to graft girth, BNYRA-9 recorded the highest values at 60 DAG (5.25 mm) and 120 DAG (6.05 mm), while BRDKRA-1 exhibited the maximum girth at 30 DAG (4.90 mm) and 90 DAG (5.71 mm). The lowest graft girth throughout the observation period was recorded in CMGRA-6, ranging from 4.26 mm at 30 DAG to 5.26 mm at 120 DAG.

The superior performance of BRDKRA-1 and BNYRA-9 may be attributed to better stock-scion compatibility, rapid callus formation, enhanced cambial activity and efficient vascular connection at the graft union. These factors facilitate greater translocation of water, nutrients and photosynthates, resulting in improved shoot elongation and stem thickening. Conversely, the lower graft height and girth observed in CMGRA-6 may be associated with slower graft union formation, reduced cambial activity and comparatively weaker physiological compatibility between stock and scion. Similar genotype-dependent variation in graft growth has been reported in jamun by *Ruchitha et al.,* (2022), Kumar and Chander (2024) and Sumit *et al.,* (2024), who observed that successful graft union formation and favourable environmental conditions significantly influence graft height and girth development. The present findings indicate that BRDKRA-1 and BNYRA-9 are promising genotypes for softwood grafting owing to their superior post-grafting growth performance.

In conclusion, the propagation studies conducted on selected elite genotypes revealed that softwood grafting was superior to patch budding in rose apple. The highest graft success was recorded in BRDKRA-1 (70.00%), followed by the highest graft survival in BRDKRA-1 (62.50%). Under patch budding, the highest bud take and bud survival were recorded in BNYRA-9 (52.50% and 37.50%, respectively). The earliest graft sprouting was observed in BRDKRA-1 (18.32 days), whereas the earliest bud sprouting under budding was observed in CMGRA-6 (30.25 days). The highest sprouting percentage at 60 DAB was recorded in BRDKRA-1 and BRHSRA-1 (37.50%). Under grafting, BRDKRA-1 recorded the highest number of sprouts per graft at all stages, with 3.13, 2.04, 1.17 and 1.06 sprouts at 30, 60, 90 and 120 DAG, respectively. Under budding, the highest number of sprouts per bud was recorded in BRDKRA-1 and BRHSRA-1 (0.35 each) at 60 DAB, BRDKRA-1 (0.48) at 90 DAB, and BNYRA-9 (0.50) at 120 DAB. BNYRA-9 also recorded the highest post-budding vegetative growth, with sprout length of 9.50 cm at 90 DAB and 16.22 cm at 120 DAB, and leaf length per bud of 6.45 cm at 60 DAB, 9.29 cm at 90 DAB and 13.53 cm at 120 DAB; however, at 60 DAB, the highest sprout length was recorded in BRHSRA-1 (4.24 cm). The highest graft height was recorded in BRDKRA-1, whereas the maximum graft girth at 60 and 120 DAG was recorded in BNYRA-9. These results indicated that BRDKRA-1 was superior for grafting performance, while BNYRA-9 was superior for budding performance, post-budding vegetative growth and graft girth under the present conditions.

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Author Contributions

P. Amrutha: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Validation, Visualization, Writing - Original Draft Preparation, manuscript preparation and correspondence with the journal. Dr. G. S. K. Swamy: Conceptualization, Methodology, Supervision, Project Administration, Resources, Validation, Formal Analysis, Writing - Review & Editing, overall planning of the research, execution, data compilation, analysis and thesis guidance. Dr. Anuradha Sane: Methodology, Validation, Resources, Investigation, Supervision, scientific guidance on underutilized fruit crops and rose apple research, Writing - Review & Editing. Dr. K. V. Ravishankar: Methodology, Validation, Formal Analysis, Resources, Supervision, guidance on genomics, molecular analysis and marker-assisted breeding, Writing - Review & Editing. Dr. Ashok Sangappa Alur: Validation, Formal Analysis, Resources, Supervision, guidance on quality parameter analysis, interpretation of results, Writing - Review & Editing. Dr. R. Rajeshwari: Investigation, Validation, Formal Analysis, Resources, technical support in research execution, data interpretation, Writing - Review & Editing. Dharmpal Singh: Investigation, Data Curation, Resources, field experimentation, maintenance of experimental materials, data recording and technical assistance. Kamala Devappa Gaddennavar: Investigation, Data Curation, Resources, field observations, compilation of experimental data and technical assistance.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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