DOI : 10.58993/ijh/2026.83.1.10

Indian J. Hortic. 83(1), March 2026: 71-78

Standardization of time and method of grafting in custard apple cv. Balanagar in Bundelkhand region

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ABSTRACT

The present study aimed to standardize the time and method of grafting in custard apple cv. Balanagar under Bundelkhand conditions. The experiment was conducted at Rani Lakshmi Bai Central Agricultural University, Jhansi, during 2022, using a Factorial Completely Randomized Design (FCRD) with twelve treatment combinations and three replications. The study evaluated the effect of grafting time and method on graft success, vegetative growth, and biomass accumulation. Grafting performed in the 3rd week of February consistently resulted in superior performance, recording the highest graft sprouting (18.50), graft success (92.50%), and survival (81.67%), along with maximum shoot number, shoot length, leaf production, and leaf area (25.62 cm²) at 30, 60, and 90 days after grafting. Wedge grafting outperformed side grafting, showing faster sprouting (15.61 days), higher success (80.56%), and improved vegetative growth. The combination of wedge grafting during the 3rd week of February produced the best overall results with maximum graft success (93.33%) and vigorous shoot and leaf development. These findings suggest that wedge grafting in the 3rd week of February is the most effective strategy for achieving high graft success, survival, and growth of custard apple cv. Balanagar in the semi-arid Bundelkhand region.

Key words: Custard apple, wedge grafting, grafting success, shoot number, biomass.

INTRODUCTION

Custard apple (*Annona squamosa* L.), commonly known as Sitaphal, Sugar apple, or Sweet sop, is a highly valued dryland fruit crop of India, renowned for its sweetness, delicate flavor, and custard-like pulp Kudmulwar *et al*. (9). Its remarkable adaptability, drought tolerance, and ability to thrive in marginal soils make it an important fruit crop for arid and semi-arid regions where other fruit crops perform poorly Shinde *et al*. (21). Belonging to the family Annonaceae, *A. squamosa* is a deciduous or semi-deciduous shrub reaching 5–6 m in height with irregularly spreading branches Hazra *et al*. (7). The fruit, greenish-brown with a quilted surface, encloses sweet, creamy-white pulp containing numerous black seeds Panchal, (16). Cultivation is widespread in tropical and subtropical regions including the West Indies, Mexico, Brazil, and India, with major production in Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, and Uttar Pradesh, covering about 46,000 ha and producing approximately 4,01,000 metric tonnes annually Anonymous, (1). The crop flourishes under sub-tropical climates with moderate humidity and temperatures between 15°C and 25°C; extremes above 40°C or prolonged cold adversely affect flowering and fruiting. In addition to its taste and aroma, custard apple has significant nutritional and medicinal value, and its pulp is used in ice creams, beverages, and confectionery products Lanzes *et al*. (11). Its hardy nature and low input requirements make it particularly suitable for drought-prone areas such as Bundelkhand Kudmulwar *et al*. (9). Among cultivars, Balanagar has shown superior adaptability, yield, and fruit quality under semi-arid conditions with reduced irrigation needs.

Seed propagation in custard apple results in high genetic variability, long juvenile periods, and inconsistent fruit quality Nandre *et al*. (14). To address these limitations, vegetative propagation techniques including budding, inarching, layering, and grafting have been explored, with grafting being the most practical and economical method for producing uniform, true-to-type, and early-bearing plants (Panchal, 16). Graft success, however, is influenced by environmental conditions, physiological state of rootstock and scion, and timing of the operation Chander *et al*. (3). Despite its importance, detailed information on the standardization of grafting time and method for custard apple under the semi-arid conditions of Bundelkhand is limited, representing a critical research gap. Therefore, the present study, was undertaken to identify the optimal grafting

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technique and period for achieving higher graft success, better establishment, and uniform plant growth under local agro-climatic conditions.

MATERIALS AND METHODS

The experiment was carried out in Horticulture Nursery, Department of Fruit Science, COH&F, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh during January to June 2022. The experiment was laid out in Completely Randomized Design with factorial concept (FCRD) with twelve treatment combinations and replicated thrice. Twelve treatment combination comprising of six different grafting times (S) *viz.*, S_1- 1st week of January, S_2- 3rd week of January, S_3- 1st week of February, S_4- 3rd week of February, S_5- 1st week of March, S_6- 3rd week of March with two different grafting methods (M) *viz.*, M_1- wedge grafting, M_2- side grafting (Table 1). The climate of Bundelkhand region is semi-arid and sub-tropical, characterized by hot and dry winds during summer months, warm humid in monsoon and cold dry weather in winter. An average annual temperature of this region ranges from 7.4 to 42.2 °C and April and May are the hottest month of this region. An average annual rainfall of this region is about 714.2 mm. The average maximum and minimum relative humidity ranges from 80-95 % and 48-68 % as shown in figure 1. Monsoon of this region is often erratic and uncertain, both in respect of total rainfall and its distribution. One year old rootstocks and scions of cv. Balanagar of similar thickness were used. In wedge grafting, the rootstock was cut 15-20 cm above ground with a "V"-shaped slit; the scion was shaped to fit and tied with 300-gauge polythene. In side grafting, a 2-2.5 cm downward cut was made on the rootstock, and a matching scion was inserted and wrapped similarly. Twenty grafts per treatment were prepared. Observations were recorded on various growth and grafting parameters, including the number of graft sprouts, days taken for first graft sprouting,

Table 1: Effect of grafting time and method on days taken for first graft sprouting.

Treatment	Days take for first graft sprout
Grafting time (S)	
S_1 (1st week of January)	27.67
S_2 (3rd week of January)	24.17
S_3 (1st week of February)	16.50
S_4 (3rd week of February)	9.50
S_5 (1st week of March)	7.67
S_6 (3rd week of March)	10.67
S.E(m)±	0.30
CD ≤ 5%	0.89
Method of grafting (M)	
M_1 (Wedge grafting)	15.61
M_2 (Side grafting)	16.44
S.E(m)±	0.17
CD ≤ 5%	0.50
Interaction (S X M)	
S_1M_1	27.33
S_2M_1	23.67
S_3M_1	15.33
S_4M_1	9.00
S_5M_1	7.33
S_6M_1	11.00
S_1M_2	28.00
S_2M_2	24.67
S_3M_2	17.67
S_4M_2	10.00
S_5M_2	8.00
S_6M_2	10.33
S.E(m)±	0.42
CD ≤ 5%	1.24

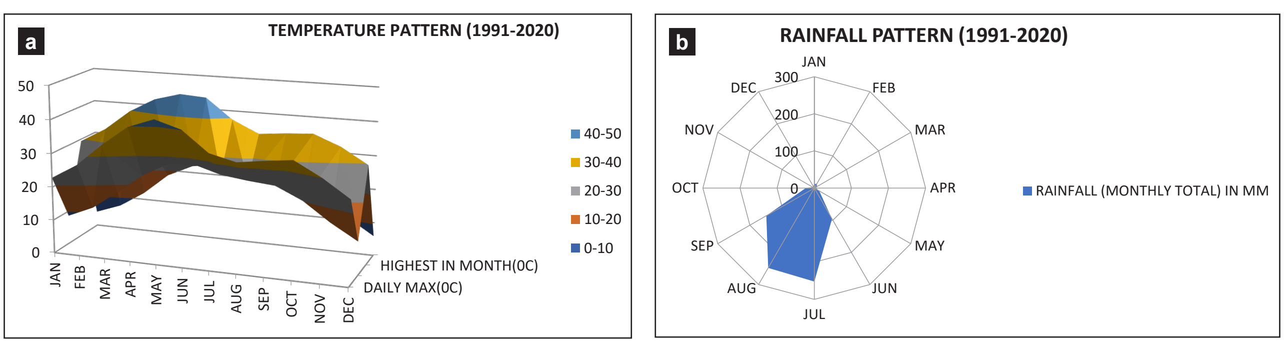

Fig. 1. The average temperature (a) and rainfall (b) pattern in the Jhansi district of Bundelkhand region, Central India (1991-2020).

graft success percentage, number of shoots, shoot length (cm), and number of leaves at 30, 60, and 90 days after grafting (DAG). Leaf area (cm²), scion girth (mm), and internodal length (cm) were measured at 60 and 90 DAG, while fresh shoot biomass (g), fresh root biomass (g), dry shoot biomass (g), and dry root biomass (g) were recorded at 90 DAG. Survival percentage of grafted plants was also determined at 90 DAG.

$$\text{Graft success per cent} = \frac{\text{No. of sprouted grafts}}{\text{Total no.of grafts prepared}} \times 100$$

$$\text{Survival per cent} = \frac{\text{Number of survived grafts}}{\text{Total number of grafts}} \times 100$$

The data recorded was statistically analysed by adopting randomized block design with factorial concept as suggested by Panse and Sukhatme (1978). The significance of the treatments was tested through 'F' test at 5 per cent level of significance. The critical difference CD was calculated to assess the significance of difference among the different treatments.

RESULTS AND DISCUSSION

Grafting time and method significantly affected sprouting as shown in Figure 2. The highest sprouts (18.50) occurred in the 3rd week of February (S4), while the lowest (11.17) was in the 1st week of January (S1). Wedge grafting (M1) outperformed side grafting (M2) with 16.11 sprouts. The combination S4M1 gave the maximum sprouts (18.67), comparable to S4M2 and S5M1. The higher number of grafts sprouted during February and March may be attributed to favorable climatic conditions that promote scion physiological activity and greater accumulation of food reserves in the mother plant, thereby enhancing sprouting Chouksey *et al*. (4). The superiority of wedge grafting might be due to the better alignment and greater contact area between scion and rootstock, facilitating rapid callus formation and early graft union Kumar *et al*. (10). Similar findings were also reported by Kudmulwar *et al*. (9) in custard apple and Padmapriya *et al*. (15) in guava. The results showed that grafting in late February to early March (S4-S5) led to the fastest sprouting, while January grafting (S1) was slowest. Early sprouting during February-March is likely due to higher temperatures and humidity, which increase sap flow and metabolic activity, and scions may have more carbohydrate reserves to support callus formation Mehta *et al*. (2018). Wedge grafting (M1) performed better than side grafting (M2) because it provides closer cambial contact, promoting faster union and sprout emergence Kudmulwar *et al*. (9). The combination of S5M1 showed the shortest time to sprouting (7.33 days), highlighting the importance of both timing and method. Delayed sprouting in January can be attributed to low temperature, reduced growth activity, and slower callus development. These findings align with earlier studies in custard apple and other fruit crops Patil *et al*. (17), confirming that environmental conditions and graft technique jointly determine the speed and success of graft establishment. The data indicated that grafting in the 3rd week of February (S4) with wedge grafting (M1) gave the highest graft success (93.33%) (Fig. 3). This may be due to favorable environmental conditions during late February, such as moderate temperature and humidity, which enhance sap flow and metabolic activity in both scion and rootstock (Panchal, 16). Additionally, wedge grafting provides better cambial contact and a larger surface area for callus formation, leading to faster union and higher survival. These results are in agreement with Kudmulwar *et al*. (9), Kumar *et al*. (10), and, who reported that grafting success is

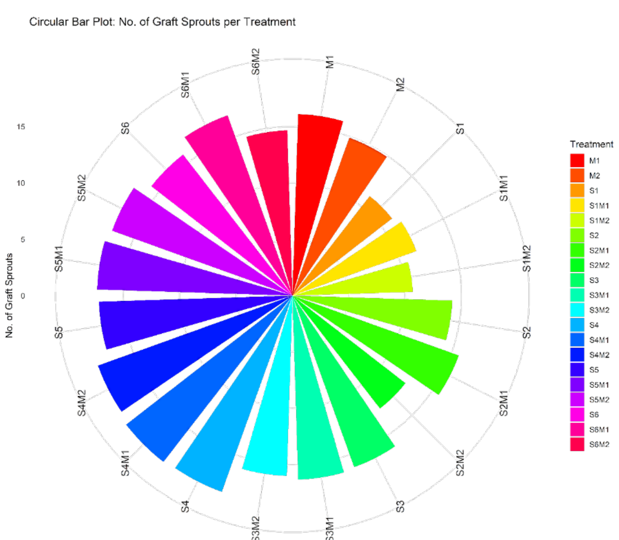

Fig. 2. Effect of grafting time and method on number of graft sprouts.

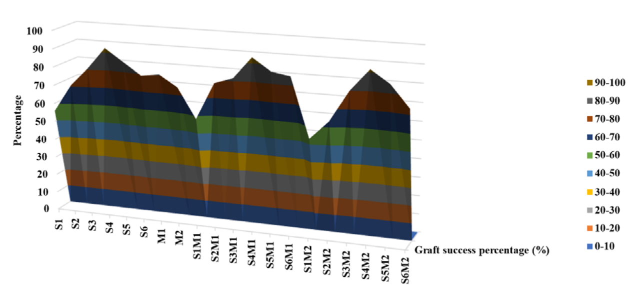

Fig. 3. Effect of grafting time and method on graft success percentage.

influenced by both environmental conditions and the grafting technique in custard apple. The data in Table 2 showed that grafting in the 3rd week of February (S4) produced the highest number of shoots per plant at 30, 60, and 90 DAG, while wedge grafting (M1) was superior among methods. The combination S4M1 recorded the maximum shoots at 60 and 90 DAG. The higher shoot production in February may be due to favorable temperature promoting cell division and callus formation Bhandari, (2). Wedge grafting likely enhanced shoot growth through better scion-rootstock compatibility and improved physiological activity Rani *et al*. (18). The data in table 2 showed that grafting in the 3rd week of February (S4) resulted in the highest shoot length at 30, 60, and 90 DAG, while wedge grafting (M1) produced longer shoots than side grafting. The combination S4M1 recorded the maximum shoot length at all stages. Superior shoot growth in February may be due to favorable temperatures and climatic conditions that promote callus formation and cellular activity, enhancing graft union (Bhandari, 2). Wedge grafting likely improved shoot elongation through better cambial contact and nutrient translocation Chouksey *et al*. (4); Rani *et al*. (18). The data in table 2 indicated that grafting in the 3rd week of

Table 2: Effect of grafting time and method on number of shoots (cm), shoot length and number of leaves.

Treatment	No. of shoots/ grafted plant			Shoot length (cm)			No. of leaves/ grafted plant		
	30 DAG	60 DAG	90 DAG	30 DAG	60 DAG	90 DAG	30 DAG	60 DAG	90 DAG
Grafting time (S)									
S_1 (1st week of January)	2.73	3.33	4.43	3.06	5.46	6.40	2.87	6.63	7.93
S_2 (3rd week of January)	3.47	4.10	4.70	3.15	5.77	7.29	3.47	6.97	8.97
S_3 (1st week of February)	3.73	4.30	4.90	3.43	5.71	8.78	3.73	7.63	10.93
S_4 (3rd week of February)	4.23	4.83	6.10	3.87	6.08	11.97	4.63	8.33	12.57
S_5 (1st week of March)	3.83	4.53	5.37	3.53	5.89	11.02	3.97	8.00	11.73
S_6 (3rd week of March)	2.83	3.97	4.90	3.23	5.56	8.50	3.17	7.13	9.13
S.E(m)±	0.10	0.07	0.06	0.05	0.07	0.07	0.09	0.10	0.08
CD ≤ 5%	0.29	0.20	0.18	0.15	0.20	0.21	0.27	0.29	0.23
Method of grafting (M)									
M_1 (Wedge grafting)	3.66	4.34	5.21	3.46	5.93	9.16	3.84	7.79	10.53
M_2 (Side grafting)	3.29	4.01	4.92	3.29	5.56	8.83	3.43	7.11	9.89
S.E(m)±	0.06	0.04	0.04	0.03	0.04	0.04	0.05	0.06	0.05
CD ≤ 5%	0.17	0.11	0.11	0.09	0.11	0.12	0.16	0.17	0.14
Interaction (S X M)									
S_1M_1	2.80	3.33	4.67	3.12	5.55	6.47	3.00	6.73	8.07
S_2M_1	3.73	4.13	4.73	3.19	5.87	7.31	3.73	7.27	9.27
S_3M_1	3.80	4.40	4.93	3.49	6.02	9.01	3.87	8.00	11.20
S_4M_1	4.67	5.13	6.20	4.05	6.21	12.11	4.93	8.67	12.67
S_5M_1	4.07	4.87	5.67	3.72	6.05	11.23	4.00	8.33	12.40
S_6M_1	2.87	4.20	5.07	3.21	5.89	8.82	3.53	7.73	9.60
S_1M_2	2.67	3.33	4.20	3.00	5.37	6.34	2.73	6.53	7.80
S_2M_2	3.20	4.07	4.67	3.10	5.67	7.26	3.20	6.67	8.67
S_3M_2	3.67	4.20	4.87	3.36	5.40	8.54	3.60	7.27	10.67
S_4M_2	3.80	4.53	6.00	3.69	5.95	11.84	4.33	8.00	12.47
S_5M_2	3.60	4.20	5.07	3.33	5.73	10.81	3.93	7.67	11.07
S_6M_2	2.80	3.73	4.73	3.25	5.22	8.17	2.80	6.53	8.67
S.E(m)±	0.14	0.09	0.09	0.07	0.09	0.10	0.13	0.14	0.11
CD ≤ 5%	NS	0.27	0.26	0.21	0.28	0.30	NS	NS	0.33

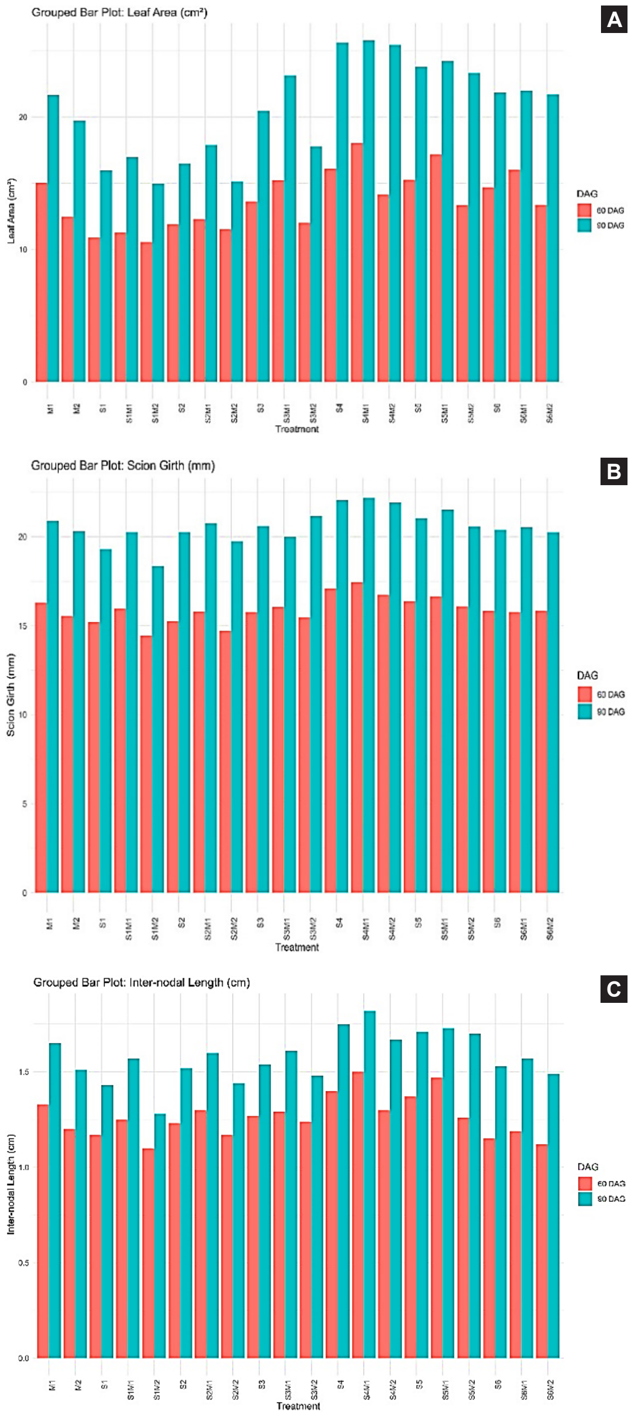

Fig. 4. Effect of grafting time and method on leaf area (cm^2) (A), scion girth (mm) (B) and inter nodal length (cm) (C).

February (S4) produced the highest number of leaves at 30, 60, and 90 DAG, while wedge grafting (M1) performed better than side grafting. The combination S4M1 recorded the maximum leaves (12.67) at 90 DAG. The higher leaf production in February grafts may be due to increased meristematic activity and faster differentiation of shoot tissues at the graft site, promoting more leaf primordia formation Patil *et al*. (17). Additionally, scions collected during this period may have higher endogenous growth hormones like cytokinins, which stimulate leaf initiation and expansion Kudmulwar *et al*. (9). Wedge grafting likely favored more uniform leaf emergence by providing stable mechanical support and better alignment of vascular tissues for nutrient distribution. These observations are in agreement with findings in custard apple and other fruit crops Chouksey *et al*. (4). The data in Figure 4a showed that grafting in the 3rd week of February (S4) produced the largest leaf area at 60 and 90 DAG, while wedge grafting (M1) resulted in greater leaf expansion than side grafting. The combination S4M1 recorded the maximum leaf area (25.79 cm² at 90 DAG). Larger leaf area may be attributed to earlier graft union formation, which ensures efficient water and nutrient transport, promoting cell expansion in developing leaves. Additionally, favorable temperatures during late February may enhance photosynthetic activity and assimilate accumulation, supporting leaf growth (Panchal, 16). Wedge grafting likely contributed by providing better cambial alignment and faster callus proliferation, enabling more vigorous vegetative development. These findings align with reports in custard apple and jamun Dhutraj *et al*. (5). The data in Figure 4a showed that grafting in the 3rd week of February (S4) produced the largest leaf area at 60 and 90 DAG, while wedge grafting (M1) resulted in greater leaf expansion than side grafting. The combination S4M1 recorded the maximum leaf area (25.79 cm² at 90 DAG). Larger leaf area may be due to early establishment of the graft union, which ensures efficient transport of water, minerals, and photosynthates to developing leaves Dhutraj *et al*. (5). Additionally, favorable temperatures and gradually increasing light intensity in late February may enhance cell expansion and leaf growth Panchal, (16). Wedge grafting likely contributed by providing better cambial contact and callus formation, supporting vigorous vegetative development. These findings are consistent with earlier reports in custard apple and jamun Ghojage *et al*. (6). The data in figure 4c showed that grafting in the 3rd week of February (S4) produced the longest inter-nodal length at 60 and 90 DAG, with wedge grafting (M1) outperforming side grafting. The combination S4M1 recorded the maximum inter-nodal length (1.82 cm at 90 DAG). Increased inter-nodal length may be due to early cambial connection and rapid healing of graft cuts, which enable quick formation of new shoots. This allows active photosynthesis and efficient nutrient transport, supporting elongation between nodes. Wedge grafting likely enhanced shoot elongation by ensuring faster graft union and better vascular alignment compared to side grafting. These findings align with reports in custard apple Patil *et al*. (17). The data in figure 5 showed that grafting in the 3rd week of February (S4) produced the highest fresh shoot biomass at 90 DAG, with wedge grafting (M1) performing better than side grafting. The combination S4M1 recorded the maximum biomass (11.07 g). Higher biomass may be due to favorable temperatures and optimal physiological activity in the scion and rootstock, which promote vegetative growth Pawar *et al*. (18). Increased leaf number likely enhanced photosynthate production, supporting shoot development. Wedge grafting contributed by ensuring better cambial contact and faster union formation, allowing efficient nutrient and water transport. These results are in agreement with findings in mango and custard apple Kaur & Kaur, (8). The data in figure 5 showed that grafting in the 3rd week of February (S4) produced the highest fresh root biomass at 90 DAG, with wedge grafting (M1) outperforming side grafting. The combination S4M1 recorded the maximum root biomass (6.05 g). Enhanced root growth may be attributed to early establishment of graft union, which stimulates hormonal signaling (particularly auxins) that promotes root initiation and elongation. Additionally, favorable late-February conditions likely improved overall plant vigor, supporting better root system development Roshan *et al*. (20). Wedge grafting facilitates stronger cambial contact, ensuring efficient nutrient and water transport to roots. These observations are consistent with findings in custard apple, mango, and aonla Kaur & Kaur, (8). The data in figure 5 showed that grafting in the 3rd week of February (S4) produced the highest dried shoot biomass at 90 DAG, with wedge grafting (M1) performing best. The combination S4M1 recorded 4.73 g. Higher dried biomass may result from greater shoot and leaf production, which increases carbohydrate accumulation and structural growth Kaur & Kaur, (8). Wedge grafting likely enhanced callus formation and cambial connectivity, improving nutrient and water translocation and supporting accumulation of dry matter. These results are consistent with observations in mango and custard apple Pawar *et al*. (18). The data in Figure 5 showed that grafting in the 3rd week of February (S4) produced the highest dried root biomass at 90 DAG, while wedge grafting (M1) outperformed side grafting. Higher dried root biomass may be due to enhanced deposition of structural carbohydrates and lignin in the roots, which reflects better root maturation and secondary growth. Favorable late-February conditions likely stimulated root differentiation and thickening Pawar *et al*. (18). Wedge grafting may have supported faster vascular integration at the graft union, enabling improved translocation of assimilates to the root system. These findings are consistent with previous reports in custard apple, mango, and aonla Kaur & Kaur, (8). The data in Figure 6 showed that grafting in the 3rd week of February (S4) recorded the highest survival percentage at 90 DAG, with wedge grafting (M1) performing better than side grafting. Higher survival may be attributed to sufficient carbohydrate reserves in the scion during February, which support meristematic activity and rapid callus formation at the graft union Panchal, (16). Favorable climatic conditions during this period also accelerate healing and reduce stress on young grafts. The

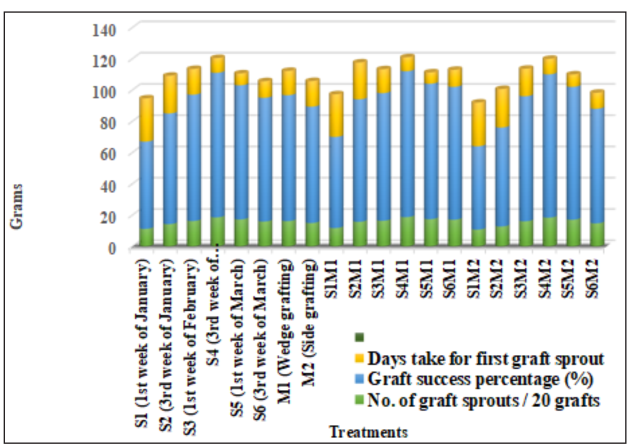

Fig. 5. Effect of grafting time and method on fresh shoot biomass (g), fresh root biomass (g), dried shoot biomass (g) and dried root biomass (g).

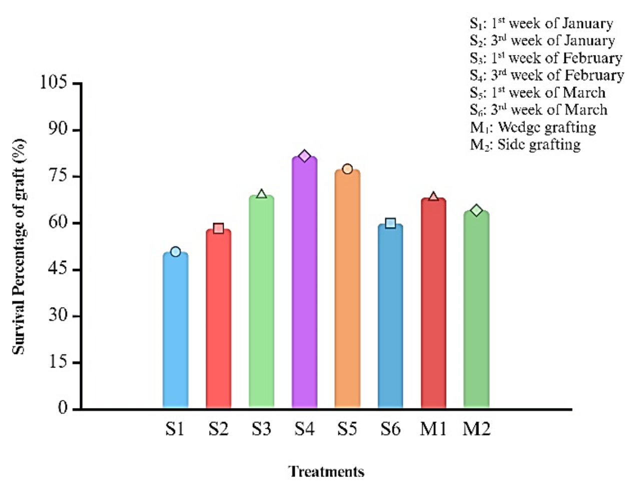

Fig. 6. Effect of grafting time and method on survival percentage (%).

wedge graft provides greater contact area and mechanical stability between scion and rootstock, improving vascular connectivity and nutrient translocation, thereby enhancing graft establishment Kaur & Kaur, (8). These findings are consistent with previous studies in custard apple, guava, mango, jamun, and sapota Muniyappan *et al*. (13). Pearson correlation analysis revealed that all grafting parameters were positively and significantly associated with each other as shown in figure 7. Number of shoots, shoot length, number of leaves, leaf area, scion girth, inter-nodal length, fresh and dried shoot biomass, and fresh and dried root biomass showed strong mutual correlations (r = 0.722-0.962**), indicating that improvement in one trait is likely to enhance others. For instance, number of shoots per grafted plant was highly correlated with dried root biomass (0.954**), shoot length (0.931**), and dried shoot biomass (0.927**), while shoot length was closely associated with number of leaves (0.949**) and leaf area (0.915**). Similarly, fresh shoot and root biomass, dried shoot and root biomass, scion girth, and inter-nodal length exhibited strong interdependence. These findings suggest that vegetative growth and biomass traits in grafted plants are closely linked, and optimizing grafting practices can simultaneously improve multiple growth parameters.

The overall conclusion of the study grafting time and method significantly influenced growth, graft success, biomass, and survival of custard apple. The 3rd week of February (S4) combined with wedge grafting (M1) consistently gave the best results across all parameters, highlighting the importance of optimal climatic conditions and effective grafting technique.

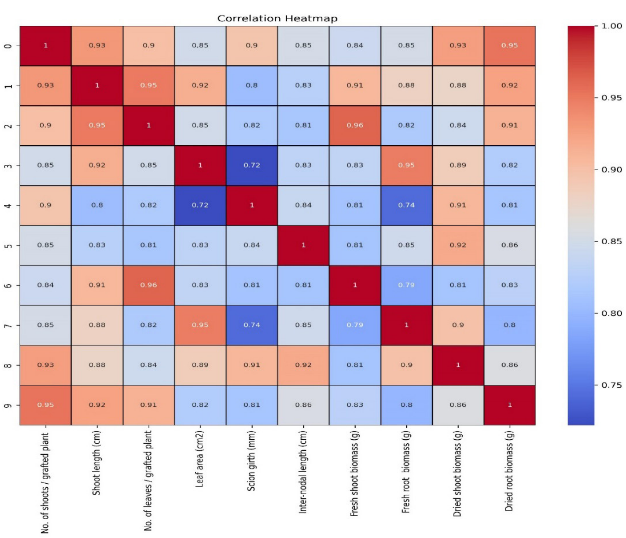

Fig. 7. Correlation between grafting parameters.

This combination ensures higher graft success, vigorous growth, and better survival, providing a practical guideline for efficient nursery propagation and early orchard establishment of custard apple.

AUTHOR'S CONTRIBUTION

Shreenidhi M.B. designed and conducted the experiment. Gaurav Sharma supervised the study. Shivali Sharma analyzed data and edited the manuscript. Ranjit Pal assisted in fieldwork. Ghan Shyam Abrol guided the research and approved the final manuscript.

DECLARATION

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

ACKNOWLEDGMENTS

The authors are grateful to the administration and staff of Rani Lakshmi Bai Central Agricultural University (RLBCAU), Jhansi, Uttar Pradesh, India for providing the necessary facilities, guidance, and support to carry out this research.

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(Received : October, 2025; Revised : March, 2026; Accepted : March, 2026)