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Standardizing propagation methods and timing in bael (*Aegle marmelos* L.) under semi-arid conditions of Uttar Pradesh

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ABSTRACT

The study aimed to standardize the most suitable propagation method (budding and grafting) and optimal timing to achieve maximum success rates in bael under the semi-arid conditions of Uttar Pradesh, India. The findings revealed that the minimum number of days to bud sprouting (15.71 days) was observed with softwood grafting conducted on 15th April. This method and timing also resulted in the highest sprouting success rate (83.33%) and the greatest bud and graft success rate (56.67%). Furthermore, the highest survival percentage of grafted plants was recorded with softwood grafting on the same date. From this study, softwood grafting during the month of April is recommended for the successful propagation of bael in semi-arid regions of Uttar Pradesh.

Introduction

Bael (*Aegle marmelos* L.), a member of the Rutaceae family, is one of the most significant native fruit plants, known for its various therapeutic applications. It is referred to by several names, including Bengal quince, Bilva, Vilvam, and Bilpatre, and is valued for its medicinal, nutritional, and spiritual properties, as mentioned in religious scriptures. In India's tropical and subtropical climates, bael is naturally cultivated in mixed dry deciduous forests from seed. Bael seed contains 40.25% oil (Roy and Singh, 1979). The bael seed is viviparous (Singh *et al.*, 2019) and also recalcitrant in nature. Since bael is primarily propagated by seed, there is significant variability within its population. However, vegetative propagation ensures the multiplication of selected superior quality clones for commercial cultivation and conservation.

In-situ cultivation is beneficial for raising better plant stands with earlier bearing compared to nursery-raised planting material. Some information is available on the optimal time required for *in-situ* propagation of bael (Ghosh *et al.*, 2012). Chip budding is one of the primary grafting methods used for the asexual propagation of woody plants. It is the only budding system that can be performed on rootstocks with either active or dormant vascular cambium.

Bael was previously propagated by air layering (Misra, 1992; Mukherjee *et al.*, 1986), budding (Kumar *et al.*, 1994; Moti *et al.*, 1976), and grafting (Fairchild, 1930; Maiti *et al.*, 1999), with varying degrees of success. Propagation of bael through patch budding, chip budding, and softwood grafting has been reported with different success rates in various agro-climatic

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regions. Among the different methods of propagation, vegetative means have proven to be the most effective technique for maintaining genetic purity and uniformity in grafts. The success of budding and grafting varies depending on the duration of the operation, the methods used, and the agro-climatic conditions (Kumar *et al.*, 1994). These methods are employed to multiply plants identical to the desired parent trees, ensuring that the best-quality plants are propagated on rootstocks suitable for the region. Therefore, this study aims to standardize propagation methods and timings for nursery and field planting in bael, with a focus on the Bundelkhand region.

Material and Methods

The investigation was conducted at the main experimental nursery of the Department of Fruit Science, College of Horticulture, Banda University of Agriculture and Technology, Banda (U.P.) in 2023. The climate at the site is primarily subtropical, with long and hot summers. The average rainfall during the experiment was 77.5 cm, with 94% of it occurring between June and September. The average maximum and minimum temperatures from April to December were 33.98°C and 24.78°C, respectively, and the average relative humidity was 78.59%. The 12 to 18 months old rootstocks having 5-6 mm diameter were planted in polythene bags filled with a soil and farmyard manure mix (2:1). The rootstocks were raised from seeds for vegetative propagation. The propagation was performed on healthy and pests and diseases free rootstocks. The scion buds were collected from a healthy mother plant.

The experiment was designed using a completely randomized design with two factors: propagation methods (chip budding, patch budding, and softwood grafting) and propagation time (15th April, 15th May, 15th June, 15th July, 15th August and 15th September). A total of 18 treatments were used, each replicated three times, with 10 plants per replication. The experiment was carried out under shaded net house conditions. Observations on time taken for sprouting of bud and graft were recorded ten days after budding and grafting of the plants. The recorded data were subjected to statistical analysis and per Fisher (1925).

Results and Discussion

Sprouting in budding and grafting

The data presented in Table 1 and Fig. 1 clearly illustrate the influence of timing, method of propagation and duration required for bud sprouting. The results revealed that softwood grafted plants sprouted the earliest, requiring only 20.92 days, followed by chip-budded plants at 24.01 days, and patch-budded plants at 26.88 days. The timing of propagation also significantly affected the sprouting time. The shortest sprouting time was recorded for the 15th April propagation (18.22 days), which was significantly less than that observed on the 15th May (20.06 days) and other dates. The longest sprouting time occurred with propagation on the 15th July (29.70 days).

The interaction between propagation time and method also influenced the bud sprouting time. The quickest sprouting (15.71 days) was observed with softwood grafting on 15th April, followed by 17.45 days on 15th May, and 18.29 days with chip budding on 15th April. The minimum sprouting time for bael was reported to be 21.65 days with patch budding by Tripathi *et al.* (2004), and 23.8 days for softwood grafting in wood apple, as noted by Raghavendra *et al.* (2009).

Table 1. Effect of time on the number of days taken for bud sprouting in budding and grafting

Time (D)	Softwood grafting (M_1)	Patch budding (M_2)	Chip budding (M_3)	Mean (Time)
15th April (D_1)	15.71	20.65	18.29	18.22
15th May (D_2)	17.45	22.54	20.18	20.06
15th June (D_3)	19.32	26.35	22.46	22.71
15th July (D_4)	27.23	31.89	29.98	29.70
15th August (D_5)	21.63	28.91	25.14	25.23
15th September (D_6)	24.20	30.96	28.00	27.72
Mean (Method)	20.92	26.88	24.01	
		SEm±	CD at 5%	
Method (M)		0.12	0.35	
Time (D)		0.17	0.49	
M x D		0.30	0.85	

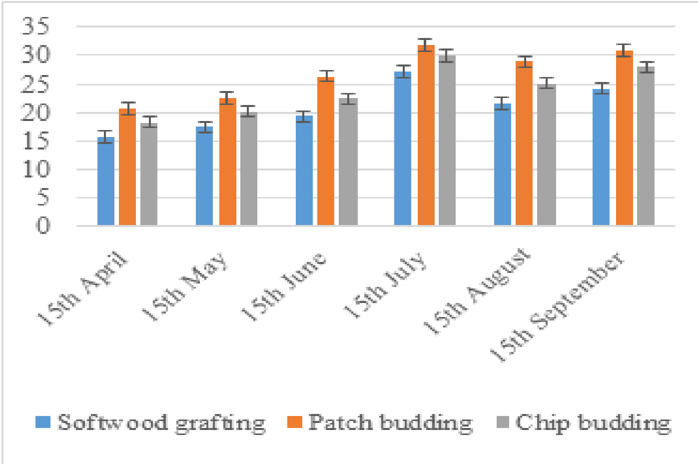

Fig. 1. Days taken to bud sprouting

Sprout percentage

A view of Table 2 and Fig. 2 indicates that the method of propagation significantly affected the bud sprout percentage. The highest sprouting rate (60.0%) was observed with softwood grafting, followed by chip budding (47.77%) and patch budding (42.22%). Regarding the timing of propagation, the 15th April was found to be the most effective, with a sprout percentage of 72.22%, followed by 15th May (64.44%), 15th June (54.44%), 15th September (53.55%), 15th August (46.66%), and 15th July (26.66%).

Although the interaction between the method and timing was not statistically significant, the highest sprouting rate (83.33%) was recorded with softwood grafting on 15th April, while the lowest (20.0%) was observed with patch budding on 15th July. In this study, the comparatively higher percentage of scion sprouting in softwood grafting may be due to the more secure attachment of the stock and scion, while in patch and chip budding, the scion is not as firmly attached to the rootstock. Additionally, climatic factors may have adversely affected bud attachment and sprouting. Similar results were reported by Syamal *et al.* (2013), who found that patch budding in bael resulted in a maximum graft sprout percentage of 72.5%. Singh and Singh (2009) also observed a higher sprouting rate (95.16%) with patch budding compared to modified ring budding.

Table 2. Effect of time on sprout percentage in softwood grafting, patch budding and chip budding

Time (D)	Softwood grafting (M_1)	Patch budding (M_2)	Chip budding (M_3)	Mean (Time)
15th April (D_1)	83.33	63.33	70.00	72.22
15th May (D_2)	73.33	56.67	63.33	64.44
15th June (D_3)	63.67	46.67	53.33	54.44
15th July (D_4)	36.67	20.00	23.33	26.66
15th August (D_5)	56.67	40.00	44.33	46.66
15th September (D_6)	46.67	26.67	33.33	53.55
Mean (Method)	60.00	42.22	47.77	
		SEm±		CD at 5%
Method (M)		1.757		5.059
Time (D)		2.485		7.155
M x D		4.303		NS

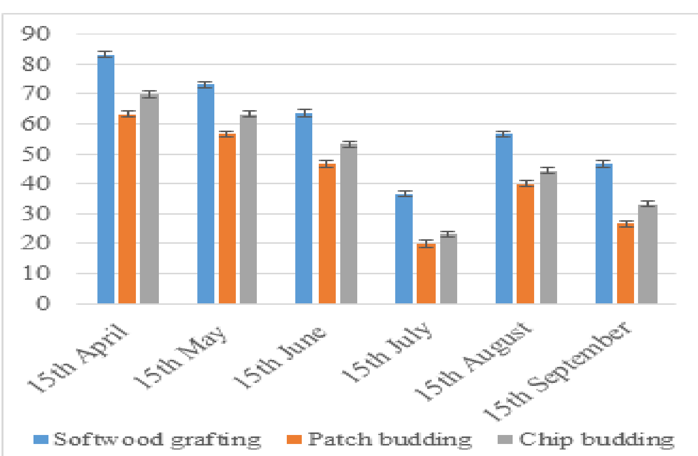

Fig. 2. Sprout % in softwood grafting, patch budding and chip budding

Budding and grafting success rate

Observations on the bud sprouting percentage of budded plants are presented in Table 3 and Fig. 3. The data indicate that the sprouting of buds was significantly influenced by the method of propagation. Softwood grafting resulted in the highest sprouting percentage (37.22%), followed by chip budding (18.89%) and patch budding (17.78%). Only the results from patch budding were on par with chip budding. The best sprouting success is typically achieved in early spring, just as the rootstock buds are beginning to swell, but before active growth has started, and callus formation occurs before the buds begin to lead out. If performed later, the leaf surface may lack sufficient moisture, leading to desiccation and death (Hartmann *et al.*, 2002).

The timing of propagation also had a significant impact on success rate of budding and grafting. The maximum success rate was observed on 15th April (37.77%), followed by 15th May and 15th June (32.22%), 15th August (23.33%), and 15th September (20.0%). The lowest success rate was recorded on 15th July (11.11%). Similar to the sprouting percentage, the interaction between propagation method and timing was not statistically significant. However, the highest success rate for budding and grafting (56.67%) was recorded with softwood grafting on 15th April, while the lowest success rate (10.0%) was observed with both chip budding and patch budding on 15th July. Singh *et al.* (2016) reported a 95% success rate with *in-situ* patch budding using one-month-old scions of bael in western India, while softwood grafting yielded more than 85% success.

Table 3. Effect of time and methods on the success percentage of budding and grafting in bael

Time (D)	Softwood grafting (M_1)	Patch budding (M_2)	Chip budding (M_3)	Mean (Time)
15th April (D_1)	56.67	26.66	30.00	37.77
15th May (D_2)	50.00	23.33	23.33	32.22
15th June (D_3)	40.00	16.67	13.33	23.33
15th July (D_4)	13.33	10.00	10.00	11.11
15th August (D_5)	33.33	16.67	20.00	23.33
15th September (D_6)	30.00	13.33	16.68	20.00
Mean (Method)	37.22	17.78	18.89	
	SEm±		CD at 5%	
Method (M)	1.98		5.69	
Time (D)	2.80		8.05	
M x D	4.84		NS	

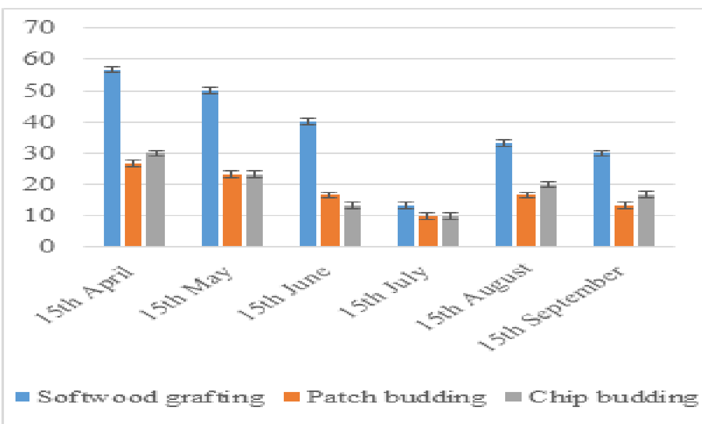

Fig. 3. Success percentage of budding and grafting in bael

Survival percentage of budded and grafted plants

The data on the survival percentage of plants propagated through softwood grafting, patch budding, and chip budding at different times are analyzed and presented in Table 4 and Fig. 4. Statistically, the method of propagation significantly influenced the survival percentage of plants. The highest survival percentage was observed with softwood grafting (35.0%), followed by chip budding (18.33%), while the lowest survival percentage was recorded with patch budding (14.44%). Propagation method and timing both had a statistically significant effect on survival rates. The highest survival percentage was recorded on April 15th (35.56%), followed by May 15th (30.0%) and June 15th (23.33%). The lowest survival percentage (7.78%) was observed on July 15th. The interaction between propagation method and timing also showed a significant effect. The highest survival percentage (53.33%) was achieved with softwood grafting conducted on April 15th, whereas the lowest survival percentage (3.33%) was recorded with chip budding on July 15th. This variation may be attributed to the use of healthy and mature bud sticks combined with favourable humid climatic conditions. Similar findings were reported by Rahman *et al.* (2011) in bael, where grafting resulted in a plant survival percentage of 56.11%.

Table 4. Effect of time and methods on survival percentage of budded and grafted plants after 90 days

Time (D)	Softwood grafting (M_1)	Patch budding (M_2)	Chip budding (M_3)	Mean (Time)
15th April (D_1)	53.33	23.33	30.00	35.56
15th May (D_2)	46.67	20.00	23.33	30.00
15th June (D_3)	40.00	16.67	13.33	23.33
15th July (D_4)	13.33	3.33	6.67	7.78

15th August (D_5)	30.00	13.33	20.00	21.11
15th September (D_6)	26.67	10.00	16.67	17.78
Mean (Method)	35.00	14.44	18.33	
		SEm±		CD at 5%
Method (M)		2.222		6.40
Time (D)		3.143		9.05
M x D		5.443		N.S.

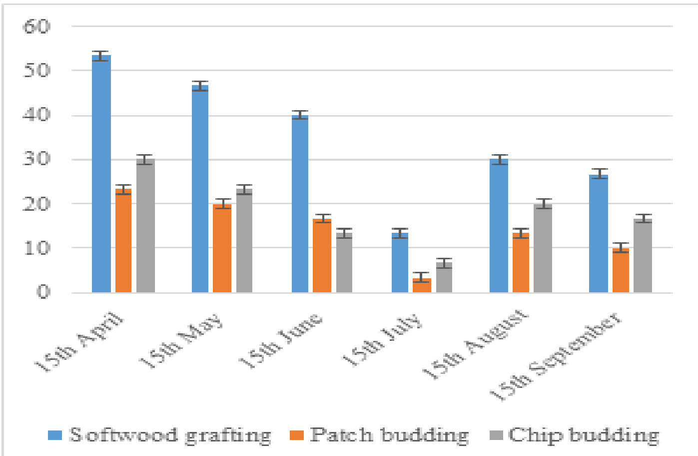

Fig. 4. Survival percentage of budded and grafted plants after 90 days

Conclusion

Based on the results of the research, it can be concluded that softwood grafting under shade net house conditions is the most effective propagation method for bael. This conclusion is supported by positive outcomes across various plant growth parameters, including days taken for bud sprouting, sprouting percentage, budding and grafting success percentage and survival percentage of the plants. Among the propagation months, April showed the best performance, followed by May, June, August, September, and July. Therefore, softwood grafting in April month is recommended for farmers, researchers, and nursery growers, particularly under the semi-arid conditions of the Banda district in Uttar Pradesh.

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Conflict of Interest

The authors have no conflict of interest.

Data Sharing

All relevant data are within the manuscript.

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