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REVIEW ARTICLE

Standardization of grafting techniques for superior clonal propagation of *Ceiba pentandra* (L.) Gaertn.: Potentiality in ecological and economic importance

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Abstract

Ceiba pentandra (Linn.) Gaertn. commonly known as kapok, is increasingly gaining importance as one of the major tree components in agroforestry systems due to its multipurpose nature. Its adaptability and productivity make it advantageous for promoting sustainable livelihood improvement among farmers. The study explores the ecological, economic and environmental significance of kapok, by assessing the effectiveness of wedge grafting methods and its successful propagation under controlled nursery conditions. Grafting was performed at six intervals (June-November) with two conditions: with polycap and without polycap. One-year-old scions with 3-4 healthy buds were grafted onto 6-8-month-old rootstocks. Various parameters, including graft take percentage, bud sprouting time, sprouting percentage, first leaf emergence time, sprout length, number of leaves and graft survival, were evaluated. The results highlighted the significant influence of timing and polycap usage on grafting success. November grafts with polycap exhibited the highest graft take (71.5%), while July grafts with polycap showed the shortest bud sprouting time (13.78 days) and longest sprout lengths. Graft survival was highest (79.8%) in October with polycap. Polycap usage enhanced outcomes by creating a humid microenvironment, reducing desiccation and supporting graft union formation. The findings emphasize the effectiveness of wedge grafting and polycap in improving vegetative propagation success in kapok. This technique offers a reliable method for clonal multiplication, ensuring high-quality planting stock for agroforestry and commercial applications.

Keywords

ecological importance; kapok; sustainable agroforestry; wedge grafting

Introduction

The ecological adaptability, economic potential and environmental benefits of *Bombax ceiba* and *Ceiba pentandra* (L.) Gaertn. underscore their importance as multipurpose tree species. Their contributions to biodiversity, soil enrichment, carbon sequestration and resource sustainability affirm their value in agroforestry and commercial applications. This species is diversely called silk cotton, kapok, or safed semal and belongs to the family Bombacaceae. *B. ceiba* is indigenous to India, while *C. pentandra* (L.) Gaertn. originates in South America and is cultivated in regions such as Northern Australia, Tropical Africa, Myanmar, Java, Sri Lanka and India (1, 2). These trees exhibit remarkable adaptability to diverse agro-climatic conditions and are essential components of agroforestry systems, contributing to ecological and economic sustainability. It is a large deciduous tree that can attain a height of 60 m. Its roots spread horizontally up to 10 m or more, predominantly within the upper 40-80 cm of soil. The trunk is typically cylindrical, reaching diameters of 200-240 cm, with whorled branches and spiny older growth (1, 2). The structural and physiological adaptations of these trees enable their survival and productivity across various terrains and climatic zones, reflecting their versatility and resilience. The optimal growth of kapok occurs at altitudes ranging from 0-900 m with a mean annual temperature between 18-38°C and rainfall of 400-3000 mm. This species thrives in deep, permeable volcanic loams, free from waterlogging and exhibits moderate tolerance to salinity (3). These trees prefer valleys, flat or undulating ground with deep soil and well-drained hill slopes. Their occurrence is widespread, particularly in the alluvial savanna forests of the Indian subcontinent, where they adapt to sandy loam soils derived from granite (1, 2). Propagation through seeds is the primary mode for *C. pentandra*, facilitated by pollination, which leads to the formation of fruits containing seeds and floss. The viability of seeds diminishes rapidly due to their oil reserves, necessitating prompt sowing. Each kilogram of seeds contains between 10000 to 45000 seeds, depending on their provenance. Seed storage under conventional conditions maintains viability for about a year (4). Kapok trees require minimal management due to their natural defense against pests and diseases, such as the hard spines on their trunks. The trees can be planted at a spacing of 4×4 m or 4×8 m to maximize yield under agro-silvicultural systems (5). With a productive lifespan of 30-60 years, mature trees can yield 15-18 kg of fiber and 30 kg of seeds annually, with fiber yields reaching 700 kg/ha under optimal conditions (6, 7). Kapok trees are renowned for their diverse applications. The wood, being light and porous, is used in plywood, packaging, construction and paper products. The fiber serves as a stuffing material and the seed oil, which contains significant levels of linoleic and oleic acids, is utilized in the production of biodiesel, paints and soaps (2, 8). Additionally, the pressed seed cake is employed as protein-rich cattle feed and the pods' pericarp is used as fuel in rural areas (9). The leaves of *C. pentandra* are utilized in traditional medicine for their antioxidant and wound-healing properties, attributed to their bioactive compounds, including phenolics, alkaloids and flavonoids (10). The seeds are a valuable source of edible oil, rich in essential fatty acids and minerals, making them suitable for both human and livestock consumption (11). Kapok trees are integral to agroforestry systems, being cultivated in boundary plantations, mixed cropping and pure block plantations. In Tamil Nadu, approximately 40,000 hectares are devoted to kapok cultivation in districts such as Coimbatore and Salem. These trees also contribute significantly to carbon sequestration, storing up to 38.7 tons of carbon per hectare in 12-year-old plantations, making them valuable for climate change mitigation (12). Vegetative propagation is widely regarded as an essential component of tree improvement programs for regeneration which aims to produce superior planting stock with high genetic quality (13–15). However, scientific research and literature on effective plant propagation techniques, particularly for the vegetative propagation of *C. pentandra*, remain scarce. Except for the work by (16), no studies have been reported on the propagation of *C. pentandra*. Kapok can be easily propagated through seeds; however, the seeds contain oil-based food reserves that spoil quickly, leading to a rapid decline in viability. As a result, long-term preservation of the seeds is not feasible. Additionally, seedlings grown from seeds are unlikely to retain the exact characteristics of the parent tree, such as floss yield, wood yield and seed oil content. To address these biological limitations associated with seed propagation, vegetative propagation offers a promising alternative for producing high-quality planting stock. Vegetative propagation through branch cuttings has also been explored, with reported success rates of 50-70%, highlighting its potential for producing genetically superior planting material (17-19). A study revealed the potential of IBA as a reliable hormone for improving the vegetative propagation of *C. pentandra* stem cuttings in nursery conditions (4). Wedge grafting, also referred to as cleft grafting, is particularly effective for apical shoots as it provides a strong mechanical union and promotes active growth. This method is considered one of the successful methods in propagating most of the horticultural crops, especially guava (20-22). Various researchers across the country have highlighted the significant potential of multiplying guava plants through wedge grafting, which can be performed year-round under both protected and open field conditions (21, 23). Wedge grafting has been identified as a rapid and effective technique, even in extreme climatic conditions, such as severe cold. Research and development in propagation techniques, genetic improvement and sustainable management can enhance the species' long-term benefits for both rural livelihoods and environmental conservation. Therefore, the current experiment was conducted to establish a standardized method for vegetative propagation using grafting methods.

Materials and Methods

Standardization of grafting techniques for clonal multiplication of kapok (C. pentandra)

The experiment was conducted at Forest College and Research Institute, Mettupalayam, from June to November to establish effective grafting techniques for the clonal propagation of kapok trees. It was laid out in Completely Randomized Design (Factorial) with three replications and twelve treatment combinations at the nursery. The study utilized specific rootstock and scion characteristics to determine optimal grafting methods for successful plant propagation.

Materials

To carry out the grafting technique, two major materials were used *viz* Rootstock and Scion. The rootstock plants used in the experiment were one-year-old seedlings. These seedlings were grown in polybags measuring 15 × 10 cm. The diameter of the rootstock was carefully maintained between 1.0 and 1.5 cm to ensure compatibility with the scion for grafting. Both apical shoots and terminal softwood shoots with 2-4 buds were used as scions. The scion's diameter was standardized at 1.0-1.5 cm to match the rootstock for successful union formation.

Methods

The study investigated wedge grafting in kapok seedlings grown in polythene bags under controlled conditions. Grafting was performed in six different months: June, July, August, September, October and November. Two conditions were evaluated: with polycap (P1) and without polycap (P2). One-year-old scion shoots, approximately pencil-thick with 3 to 4 healthy buds, were chosen for grafting. Seven days before detachment, the scions were partially debladed (three -quarters of the foliage removed) on the mother plant and their apical tips were pruned. Kapok seedling rootstocks aged 6-8 months and 1 to 1.5 cm in diameter were used. The rootstock was cut 15-18 cm above the soil surface using a sterilized, sharp knife and a vertical slit, 3.5-4.0 cm deep, was made in the stem. Hardened scion wood was collected after seven days, shaped into a tapered wedge (3.5-4.0 cm long) at the base and inserted into the rootstock's slit. The graft union was secured with polythene strips, which were removed after successful union formation to prevent girdling (Fig. 1). The study assessed several parameters, including graft take percentage, time for bud sprouting, sprouting percentage, time for first leaf emergence, sprout length, number of leaves per sprout and graft survival.

Results

Graft take

The results showed that the timing of wedge transplantation and the use of polycap significantly influenced the transplantation success (Table 1, Fig. 2 & 4). The highest graft yield (71.5%) was observed when a wedge graft was performed in November with the graft junction covered with a polycap, followed by a polycap in October (70.10%). On the other hand, the lowest graft harvest (42.30%) was recorded when the transplant was performed in June without polycap. The higher success rate in early spring is due to optimal temperatures, minimal fluctuations in humidity and ideal conditions for transplantation. These factors probably facilitated the early establishment of cambium contact between rootstock and shoot and favored callus formation and subsequent growth under favorable environmental conditions.

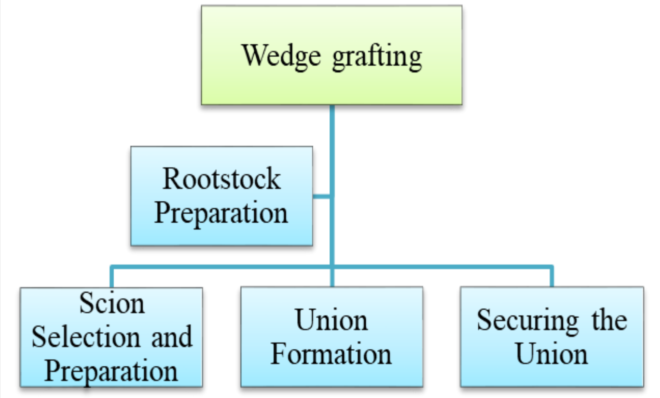

Fig. 1. Flowchart representing steps in wedge graft preparation.

Time taken for bud sprouting

Data on the influence of grafting time and the use of polycaps on the time required for bud germination, as shown in Table 1 and Fig. 2 & 4, showed a significant influence. October showed better germination in both cases, namely with polycap and without polycap. The wedge transplant carried out in July with polycap gave the shortest bud germination time (13.78 days), which was statistically similar to those carried out in August (12.89 days), September (11.87 days) with polycap and in July without polycap (11.98). In contrast, the longest bud germination time (22.67 days) was observed when wedge grafting was performed in October without polycap.

Table 1. Effect of time of wedge grafting and use of polycap on graft take (%), time taken for bud sprouting (days), sprout percent (%), time taken for first leaf emergence (days) and graft survival (%)

Time of Wedge Grafting	Graft-take (%)			Bud sprouting (days)			Sprout per cent (%)			First leaf emergence (days)			Graft survival (%)		
	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean
June	63.25	42.3	52.75	12.5	15.38	13.94	58.9	35.54	47.22	17.89	19.98	18.93	67.89	56.78	62.33
July	67.89	44.67	56.28	13.78	11.98	12.88	71.9	42.98	57.44	15.68	17.8	16.74	72.34	67.34	69.84
August	68.9	45.56	57.23	12.89	15.69	14.29	61.87	39.8	50.83	16.55	18.87	17.71	73.72	63.54	68.63
September	69.97	46.89	58.43	11.87	16.76	14.31	54.34	37.65	45.99	18.89	19.7	19.29	71.2	66.74	68.97
October	70.1	47.78	58.94	15.65	22.67	19.16	50.19	29.78	39.98	23.45	25.4	24.42	79.8	69.78	74.79
November	71.5	49.88	60.69	14.78	19.8	17.29	52.38	32.33	42.35	18.97	24.67	21.82	75.67	57.32	66.49
Mean	68.60	46.18		13.57	17.04		58.26	36.34		18.57	21.07		73.43	63.58	
CD (p=0.05)															
Time of grafting (T)		3.54			1.25			3.23			1.51			3.07	
Use of polycap (P)		1.56			0.45			1.98			0.76			1.78	
T*P		4.35			2.11			5.67			2.13			4.35	

Sprout percentage

The data presented in Table 1 show that the timing of wedge grafting significantly influenced the germination percentage. The highest germination percentage (71.90%) was observed when corner grafting was done in July with polycap, followed by grafting in August (61.87%) with polycap. In contrast, the lowest germination percentage (29.78%) was found when the wedge transplant was performed in October without polycap, which was statistically similar to the transplant in August (39.80%) and July (42.98%) without polycap was comparable (Fig. 2).

Emergence of first leaf

The data recorded on wedge transplants performed at different time points showed a significant impact on the time required for first leaf emergence, as shown in Table 1 and Fig. 2. The shortest time (15.68 days) for first leaf emergence was observed when a corner transplant was performed in July with polycap, which was statistically comparable to the transplantation performed in November (18.97 days), October (23.45 days) with polycap and October (23.45 days) without polycap. However, the longest time (25.40 days) for the first leaves to sprout was during corner grafting in October without polycap.

Graft survival

The results shown in Table 1 regarding the effect of wedge grafting on survival indicate that the timing of grafting and the use of polycap significantly influenced graft survival. The highest graft survival rate (79.80%) was observed in wedge grafting performed with polycap in October, followed in November (75.67%) (Fig. 2). In contrast, the lowest graft survival rate (56.78%) was recorded when the wedge transplant was performed in June without polycap, which was statistically comparable to the transplant performed in November (57.32%).

Length of sprout

Table 2 shows the effect of the timing of wedge grafting and use of polycap on shoot length at 30, 45, 60, 75 and 90 days after transplantation.

Sprout length at 30, 45, 60, 75 and 90 days after grafting

The time of wedge grafting significantly influenced sprout length at 30, 45, 60, 75 and 90 days after grafting. The month of July results in maximum sprout length (2.45 cm, 3.45 cm, 5.82 cm, 8.26 cm and 8.94 cm), while the minimum value observed in the month of (1.38 cm, 1.43 cm, 3.15 cm, 4.27 cm and 6.10 cm) at 30, 45, 60, 75 and 90 days after grafting, respectively (Fig. 3). Regardless of the grafting time, the use of polycap also had a significant effect on sprout length at all observed intervals. The plants grafted with polycap showed the maximum sprout length (1.89 cm, 2.61 cm, 4.34 cm, 6.86 cm and 7.12 cm), while the minimum sprout length (1.82 cm, 2.19 cm, 4.07 cm, 6.51 cm and 6.99 cm) was observed in plants grafted without polycap at 30, 45, 60, 75 and 90 days after grafting, respectively. The interaction between the time of grafting and the use of polycap had a non-significant effect on sprout length at all observed intervals. Grafted plants covered with polycap showed better growth compared to those without polycap. This could be due to the favorable environmental conditions inside the polycap, which promoted earlier sprouting and leaf emergence, leading to faster graft growth. The polyhouse environment likely provided optimal temperature and higher humidity, which accelerated photosynthesis, resulting in better food availability and continuous graft flushing.

Number of leaves

The results regarding the effect of the time of wedge grafting and the use of polycap on the number of leaves at 30, 45, 60, 75 and 90 days after grafting are presented in Table 3.

Number of leaves at 30, 45, 60, 75 and 90 days after grafting

Regardless of the use of polycap, the time of wedge grafting had a significant effect on the number of leaves produced at 30, 45, 60, 75 and 90 days after grafting (Fig. 5). The maximum number of leaves (3.47, 3.80, 5.23, 6.45 and 6.99) was observed when wedge grafting was performed in September, while the

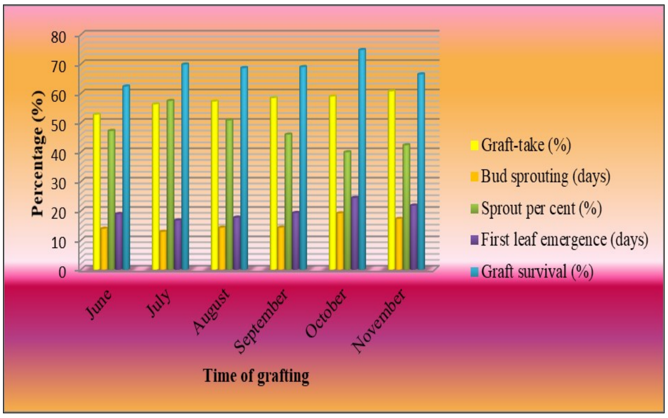

Fig. 2. Effect of time of wedge grafting and use of polycap on graft take (%), time taken for bud sprouting (days), sprout percent (%), time taken for first leaf emergence (days) and graft survival (%).

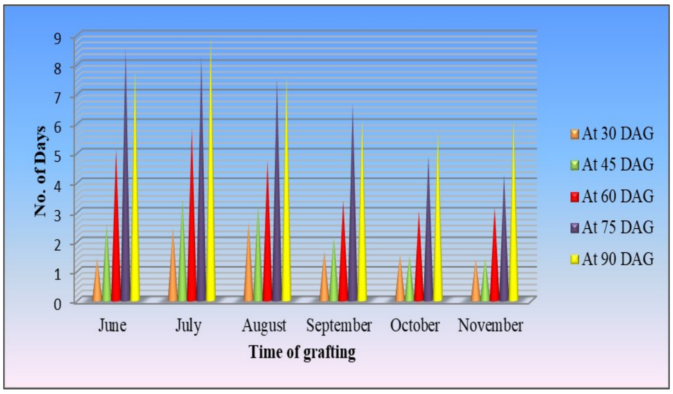

Fig. 3. Effect of time of wedge grafting and use of polycap on sprout length at 30, 45, 60, 75 and 90 days after grafting.

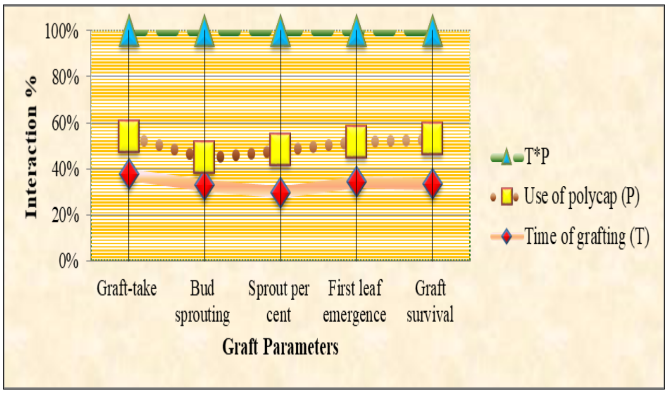

Fig. 4. Interaction of time of grafting (T) and use of polycap (P).

Table 2. Effect of time of wedge grafting and use of polycap on sprout length at 30, 45, 60, 75 and 90 days after grafting

Time of Wedge Grafting	At 30 DAG			At 45 DAG			At 60 DAG			At 75 DAG			At 90 DAG		
	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean
June	1.56	1.28	1.42	2.76	2.46	2.61	5.67	4.56	5.11	8.9	8.18	8.54	7.55	8.12	7.83
July	2.59	2.31	2.45	3.45	3.45	3.45	5.98	5.67	5.82	8.43	8.1	8.26	9.13	8.76	8.94
August	2.45	2.89	2.67	3.36	3.15	3.25	4.6	4.89	4.74	7.68	7.32	7.5	7.87	7.34	7.60
September	1.67	1.67	1.67	2.45	1.87	2.16	3.45	3.32	3.38	6.75	6.57	6.66	6.17	6.08	6.12
October	1.55	1.54	1.54	1.87	1.15	1.51	2.9	3.15	3.02	4.96	4.87	4.91	5.86	5.59	5.72
November	1.54	1.23	1.38	1.77	1.09	1.43	3.44	2.87	3.15	4.48	4.07	4.27	6.14	6.07	6.10
Mean	1.89	1.82		2.61	2.19		4.34	4.07		6.86	6.51		7.12	6.99	
CD (p=0.05)															
Time of grafting	0.76			0.33			0.47			0.65			0.62		
Use of polycap	0.54			0.19			0.33			0.51			0.34		
T*P	NS			NS			NS			NS			NS		

Table 3. Effect of time of wedge grafting and use of polycap on number of leaves at 30, 45, 60, 75 and 90 days after grafting

Time of Wedge Grafting	At 30 DAG			At 45 DAG			At 60 DAG			At 75 DAG			At 90 DAG		
	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean	With polycap (P1)	Without polycap (P2)	Mean
June	2.97	2.43	2.7	3.67	3.52	3.59	4.93	4.59	4.76	5.89	5.64	5.76	9.88	6.69	8.28
July	3.76	2.71	3.23	4.78	3.9	4.34	5.8	4.75	5.27	7.59	6.74	7.16	9.97	7.81	8.89
August	2.9	3.5	3.2	3.86	3.07	3.46	5.4	4.55	4.97	7.25	5.87	6.56	8.65	7.65	8.15
September	3.43	3.52	3.47	4.16	3.44	3.8	5.68	4.78	5.23	6.79	6.12	6.45	7.11	6.88	6.99
October	3.15	2.98	3.06	2.97	2.72	2.84	4.51	4.15	4.33	6.7	6.39	6.54	7.68	6.72	7.2
November	3.23	2.76	2.99	2.42	2.39	2.40	5.27	3.79	4.53	6.43	6.16	6.29	6.89	6.54	6.71
Mean	3.24	2.98		3.64	3.17		5.26	4.43		6.77	6.15		8.36	7.04	
CD (p=0.05)															
Time of grafting	0.55			0.41			0.38			0.57			1.15		
Use of polycap	0.43			0.28			0.21			0.27			0.75		
T*P	NS			NS			NS			NS			NS		

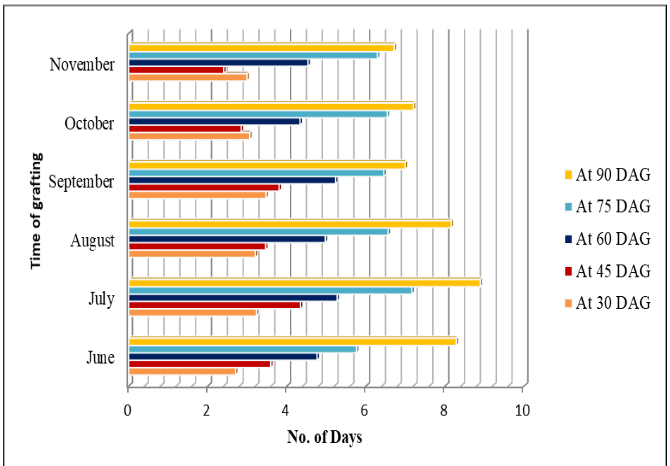

Fig. 5. Effect of time of wedge grafting and use of polycap on number of leaves at 30, 45, 60, 75 and 90 days after grafting.

minimum number of leaves (2.99, 2.40, 4.53, 6.29 and 6.71) was recorded when wedge grafting was performed in November at 30, 45, 60, 75 and 90 days after grafting, respectively. The use of polycap also significantly influenced the number of leaves at all observed intervals. The maximum number of leaves (3.24, 3.64, 5.26, 6.77 and 8.36) was recorded in plants grafted with polycap, whereas the minimum number of leaves (2.98, 3.17, 4.43, 6.15 and 7.04) was observed in plants not covered with polycap at 30, 45, 60, 75 and 90 days after grafting, respectively. The interaction between the time of wedge grafting and the use of polycap had a non-significant effect on the number of leaves at all observed intervals.

Discussion

Vegetative propagation plays a crucial role in conserving and mass-producing economically and ecologically valuable tree species such as *C. pentandra*. The findings of this study highlight the importance of environmental conditions and technical measures in improving the success rates of wedge grafting, especially through the application of polycap and the selection of optimal timing. The following discussion integrates the study's results with recent research to offer a detailed analysis of the factors affecting grafting outcomes.

Graft take success

The findings indicated that grafting timing plays a crucial role in graft take success, with November showing the highest success rate when the graft union was covered with polycap. This supports previous research emphasizing the impact of seasonal variations in cambial activity and environmental conditions on grafting outcomes (24, 25). The favorable temperature and consistent humidity in November likely contributed to improved cambium contact and callus formation, both essential for establishing a strong graft union (26). The use of polycap proved beneficial by reducing transpiration and maintaining high humidity levels around the graft union, protecting the sensitive tissues from drying (27). Additionally, polycap created a humid microenvironment that minimized desiccation and supported callus tissue development. Recent studies have similarly emphasized the importance of controlled environments in enhancing grafting success in tropical species (28, 29). By reducing water loss and maintaining suitable conditions for cellular activity, the polycap provided critical support during the early stages of graft union formation. This observation aligns with previous studies, which attribute the higher success rates of longer scions to their larger surface area, facilitating optimal physiological conditions for graft union healing (25, 30). Additionally, the choice of grafting technique significantly impacts success rates. Cleft grafting, in particular, has been shown to produce rapid bud break and high success rates across various plant species, including mango, teak, tamarind and neem (31, 32).

Bud sprouting and leaf emergence

The shortest duration for bud sprouting and the emergence of the first leaf was observed in grafts performed in July and covered with polycap. This suggests that the physiological compatibility of the rootstock and scion, coupled with optimal environmental conditions, plays a significant role in these processes. High relative humidity and moderate temperatures during July likely stimulated sap flow and meristematic activity, accelerating bud sprouting and leaf development (24). These findings align with (33), who observed that elevated humidity promotes cell division and elongation, resulting in faster bud sprouting in grafted plants. Additionally, the polycap's role in maintaining adequate moisture levels around the graft union is critical, as it prevents desiccation and supports the physiological processes required for successful sprouting (34). The early sprouting, higher sprout percentage and quicker leaf emergence observed can be attributed to enhanced sap movement, active meristematic cells and favorable temperature and humidity conditions. The relative humidity significantly influences early sprouting and subsequent leaf development. Furthermore, robust rootstocks grown under polyhouse conditions contributed to improved graft union formation and sprouting success (35).

Sprout percentage and length

The highest sprout percentage and longest sprout lengths were recorded in July grafts covered with polycap, underscoring the importance of maintaining controlled environmental conditions to optimize vegetative growth. The polycap likely enhanced photosynthetic activity and nutrient movement, resulting in superior growth performance (35). Recent studies support these results, highlighting the impact of controlled environments on grafting success (30, 32). The interaction between environmental conditions and the physiological readiness of the scion and rootstock appears to be a key determinant of sprout percentage and growth. July, characterized by moderate temperatures and high humidity, emerges as an ideal period for wedge grafting in *C. pentandra*.

Graft survival

Graft survival, a critical indicator of propagation success, was highest in October grafts with polycap. This outcome supports the idea that stable environmental conditions and protection from desiccation are essential for graft survival (31). The polycap likely contributed to a stable microenvironment, aiding graft union formation and reducing stress after grafting. Conversely, lower survival rates were observed in June grafts without polycap, highlighting the susceptibility of grafted tissues to environmental stress and desiccation (25). The protective role of polycap in mitigating these challenges has been well-documented, emphasizing its importance in successful vegetative propagation.

Number of leaves

The number of leaves produced by grafted plants reflects their vegetative growth and overall health. The highest leaf production was observed in September grafts, regardless of polycap usage. This suggests that the physiological state of the plant during this period is highly conducive to growth. Similarly, favorable late-summer conditions promoted leaf production in tropical species (36). The influence of polycap on leaf production was evident, as grafts covered with polycap consistently produced more leaves than those without. This aligns with findings from (30), who highlighted the role of regulated humidity and temperature in promoting leaf emergence and growth. The polycap's ability to maintain a stable microenvironment likely enhanced nutrient uptake and photosynthesis, leading to increased leaf production. The increased leaf count in September can be attributed to favorable climatic conditions and higher food reserves, which supported early scion sprouting and rapid graft growth (Fig. 6). Similar trends were observed in sapota (36) and jamun (37). In guava, successful graft establishment was linked to the development of cambial tissues between the stock and scion. However, some grafts failed due to weak graft union formation. Removing the polycap disrupted temperature and humidity regulation, hindering growth (26). Polycap usage improved graft survival by providing nourishment and protecting against desiccation (38, 39). The findings of this study have important implications for the propagation of kapok and other plant species. The wedge or cleft grafting technique, combined with the use of taller rootstocks and longer scions, offers a reliable method for achieving high grafting success rates. Additionally,

A) Initial stage of grafting **B)** At 30 days after grafting **C)** At 45 days after grafting

D) At 60 days after grafting **E)** At 75 days after grafting **F)** At 90 days after grafting

Fig. 6. Growth of Kapok grafts A) Initial stage of grafting B) At 30 days after grafting C) At 45 days after grafting D) At 60 days after grafting E) At 75 days after grafting F) At 90 days after grafting.

the results underscore the importance of selecting healthy scion sticks and performing grafting during periods of moderate temperatures and high humidity. These practices can help optimize grafting outcomes and support the clonal multiplication of Kapok and other valuable tree species.

Conclusion

Wedge grafting conducted in November and covered with polycap resulted in the highest graft take and graft survival under protected conditions. However, wedge grafting showed superior vegetative growth, with better performance in parameters such as early bud sprouting, first leaf emergence, sprout length and the number of leaves. The study confirms that the timing of wedge grafting and the use of polycap are critical determinants of vegetative propagation success in *C. pentandra*. November grafting with polycap emerged as the most effective combination for achieving high graft take and survival rates, while July grafting with polycap yielded the best results for early sprouting and vegetative growth. These findings provide a valuable basis for developing standardized propagation protocols for *C. pentandra*, with implications for its conservation and commercial cultivation. Thus, this method has proven to be effective for the vegetative propagation of *C. pentandra* and holds significant potential for broader application in tree propagation programs. The study demonstrated that the timing of grafting and the use of polycap significantly enhance grafting success, with notable improvements in graft take percentage, bud sprouting, leaf emergence, sprout growth and overall graft survival. Adopting wedge grafting in vegetative propagation programs can significantly enhance the productivity and genetic quality of economically and ecologically important tree species. This method offers a reliable and scalable approach to meeting the demands of afforestation, agroforestry and commercial forestry initiatives.

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Authors' contributions

SS, IS and HBR conceptualized the study and performed the formal analysis. SS, IS and HBR worked together with MS, JS, KTP and RR in structuring the methodology. IS supervised and validated the study. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: All the authors declare no conflict of interest.

Ethical issues: None

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