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Optimising rootstock age and propagation methods in avocado (*Persea americana*) under naturally ventilated polyhouse conditions

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ABSTRACT

Avocado (*Persea americana* Mill.), renowned for its exceptional nutritional and medicinal benefits, has seen a surge in popularity. There has been a huge demand for quality planting material for commercial cultivation. Hence, there is an urgent need for identification of successful propagation methods in avocado. Therefore, the present study was carried out during 2021–23 at ICAR-Central Horticultural Experiment Station, Chettalli, Karnataka to assess the suitability of different propagation methods (soft wood grafting, chip budding and patch budding) on rootstocks of varied age (2–8 months old) of avocado for growth and success at sub humid tropics of Coorg region. Softwood grafting on two months old rootstocks recorded the highest success (94.67%), when compared with other treatments, while it was the lowest in patch budding on two months old rootstocks (3.67%). Among different propagation methods, softwood grafting was found superior (61.43%) compared to chip (32.62%) and patch budding (32.67%). Rootstock age significantly impacted on sprouting and success rates, with eight-month-old rootstocks showing the quickest initial sprouting and seven-month-old rootstocks exhibiting the highest success rates. Additionally, rootstock age and girth were analysed through linear regression, revealing varying impacts on success rates across propagation methods. The success of softwood grafting decreased with increasing rootstock girth and age while chip and patch budding success increased as the rootstock age and girth advanced up to seven months. In conclusion, softwood grafting using two months old rootstocks is ideal for large scale multiplication of quality planting material. The chip and patch budding can also be utilised on 7–8 months old rootstocks and where there is shortage of scion.

Keywords: Avocado, Chip budding, Grafting, Patch budding, Rootstock

Avocado (*Persea americana* Mill.) is a renowned fruit crop with inherent potential to adapt to diverse agro-climatic conditions. This crop is extensively cultivated in many tropical and sub-tropical countries of the world i.e. Mexico, Colombia, Peru, Indonesia, Dominican Republic, Kenya, Brazil, Haiti, Vietnam, Chile, West Indies, Spain, Florida, California, Israel, India and others. Avocado was introduced to India during the 19th century by American missionaries. In recent years, global demand for avocado fruit has surged due to its numerous health benefits (Muralidhara *et al.* 2023). It has various applications in foods, frozen items, ice creams, oils and cosmetic products (Muralidhara *et al.* 2025b). In India, avocados are majorly grown as homestead crop or mixed crop in coffee plantations of Tamil Nadu, Kerala and Karnataka (Tripathi *et al.* 2022). Recently, there has been a growing interest in the commercial cultivation of avocados as solo crop, largely driven by the fruit's nutritional qualities and its high market value.

Avocado is a cross pollinated crop and traditionally propagated through seeds, leading to wide variation among the derived seedlings, which in turn extends the juvenile phase and induces uncertainty in the fruit quality (Whiley and Whiley 2005, Muralidhara *et al.* 2024). Hence, there is need for true to type vegetative propagated plants that could provide orchard uniformity, early bearing, superior fruit quality and improved ecological adaptability (Leonardi and Romano 2004). The success of vegetative propagation mainly depends on a large number of factors including the propagation method and age of rootstocks (Agasimani *et al.* 2019). The previous workers tried softwood grafting, cleft grafting and other methods and did not observe much success (Tripathi and Karunakaran 2019). The success of grafting relies on propagation technique and age of the rootstocks, which collectively impact plant growth and performance. Therefore, there is an urgent need for development of a viable propagation technique in avocado to meet the farmers' demand. Hence, present study was carried out to identify suitable propagation method and apt

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age of rootstocks for large scale multiplication of planting materials.

MATERIALS AND METHODS

The study was carried out during 2021–23 at ICAR-Central Horticultural Experiment Station, Chettalli (12°23.472′ N, 75°50.714′ E; at an elevation of 940 m amsl), Karnataka under naturally ventilated polyhouse. The study site located in the sub humid tropics of Western Ghats region. It experiences humid tropical climate, receiving nearly 1500 mm of annual rainfall, with mean temperatures ranging from 19°C–32°C. The preliminary studies were carried out during 2021–22 on different vegetative propagation methods, viz. softwood grafting, patch budding, chipping and cutting (soft, semi and hard wood) and positive results were observed for softwood, patch and chip budding but couldn't observed through cuttings. Hence, systematic study was carried out in the year 2022–23 to evaluate three different propagation methods i.e. softwood grafting (T_1), chip budding (T_2) and patch budding (T_3), using avocado rootstocks of various ages, including two (M_1), three (M_2), four (M_3), five (M_4), six (M_5), seven (M_6) and eight (M_7) months. The cv. Arka Supreme was used as scion material in the experiment (Muralidhara *et al.* 2025a).

The healthy and large-sized seeds were collected from avocado variety Arka Supreme trees and the freshly extracted seeds were utilised to raise the rootstocks using a regular potting mixture i.e. sand, soil and farm yard manure (1:2:1). The current season mature shoots aged 3–4 months old, were collected for grafting and budding in the month of December. Softwood grafting, patch and chip budding were followed as per Narayan and Thangam (2013) in the month of December.

The experiment followed a factorial complete block design with 21 treatments of three replications and 45 plants were used for each treatment. The observations were recorded on graft and budding success, number of days taken for sprouting, 50% sprouting and complete sprouting. Similarly, after three months of grafting or budding (March) scion growth parameters such as sprout length, sprout girth and number of leaves were recorded. The experimental data were statistically analysed using WASP 2.0 (Web Agri Statistical Package) software and mean values were compared at a significance level of 5%. Correlation studies were performed among all propagation methods using linear regression models.

RESULTS AND DISCUSSION

Effect of method of propagation and age of rootstocks on scion sprouting and success: The present investigation revealed a significant effect of the age of rootstocks and the propagation method on sprouting and success in avocado (Table 1). The eight-month-old rootstocks took the minimum days for the first sprouting (16.56 days) which was on par with six and seven-months-old rootstock. Whereas, seven-month-old rootstocks took minimum days for 50% sprouting (21.56 days) and last sprouting (24.67 days) which was on

Table 1 Effect of propagation methods and age of rootstock on scion sprouting and success (%)

	Days taken for first sprouting				Days taken for 50% sprouting				Days taken for last sprouting				Success (%)			
	T_1	T_2	T_3	Mean (M)	T_1	T_2	T_3	Mean (M)	T_1	T_2	T_3	Mean (M)	T_1	T_2	T_3	Mean (M)
M_1	20.33	22.67	23.00	22.00	25.00	23.33	24.67	24.33	31.67	26.00	27.00	28.22	94.67	4.00	3.67	34.11
M_2	21.33	21.67	22.00	21.89	27.67	24.67	24.00	25.44	31.00	26.67	25.67	27.78	80.67	10.00	10.67	33.78
M_3	22.33	17.67	21.67	20.56	26.33	22.67	23.33	24.11	31.33	27.00	25.00	27.78	73.33	18.67	16.00	36.00
M_4	21.67	18.33	19.33	19.78	27.33	24.33	24.33	25.33	33.33	30.67	26.67	30.22	65.33	36.00	38.67	46.67
M_5	19.67	15.00	15.33	16.67	30.00	19.67	20.67	23.44	32.00	24.00	23.00	26.33	44.00	38.67	40.67	41.11
M_6	19.00	16.00	16.00	17.00	25.00	18.00	21.67	21.56	28.67	20.67	24.67	24.67	38.67	64.00	63.33	55.33
M_7	18.33	15.67	15.67	16.56	28.00	19.00	20.00	22.33	32.00	22.00	22.67	25.56	33.33	57.00	55.67	48.67
Mean (T)	20.43	18.14	19.05		27.05	21.67	22.67		31.43	25.29	24.95		61.43	32.62	32.67	
	T	M	T × M		T	M	T × M		T	M	T × M		T	M	T × M	
CD (p=0.05)	0.91	1.38	2.40		0.94	1.44	2.49		1.08	1.64	2.84		1.75	2.67	4.63	
CV (%)		7.56				6.34				6.33				6.64		

Treatment details are given under Materials and Methods. T, Method of propagation; M, Age of rootstock.

par with eight-month-old rootstocks. Among the different propagation methods, the minimum time taken for first sprouting (18.14 days) and 50% sprouting (21.67 days) was observed in chip budding on par with patch budding, while the softwood grafted plants took more time for the appearance of first sprouting (20.43 days), 50% sprouting (27.05 days) and the last sprout (31.43 days). Similarly, the interaction of chip budding onto six-month-old rootstocks resulted in the earliest sprouting (15 days). The time taken for the first sprouting (23 days) was higher in patch budding on two-month-old rootstocks. The minimum time for 50% sprouting (18 days) and last sprouting (20.67 days) was observed in chip budding onto seven-month-old rootstocks. The fastest sprouting from chip budding was observed, which indicated its efficiency in promoting early growth and the establishment of the graft. Similarly, patch budding showed the minimum time for last sprouting, which indicated that it is suitable for promoting prolonged growth and establishment of the graft, potentially leading to a more extended period of active growth. Skene *et al.* (1983) and Gustafson and Morrissey (2003) reported that chip budding yielded superior cambial contact and more rapid healing, which resulted in complete union of the xylem and continuous activities of cambial tissue as compared to other budding techniques. The comparatively longer duration of sprouting might be attributed due to differences in physiological characteristics between softwood grafting and the budding methods.

The success rate of graft or bud intake was significantly influenced by the age of the rootstocks and the method of propagation. Among the various ages of rootstocks evaluated, the maximum success rate (55.33%) was observed in seven-month-old rootstocks, while the minimum (33.78%) success rate was observed in three-month-old rootstocks. Among propagation methods, the highest success rate (61.43%) was observed in softwood grafting, while the lowest success rate (32.62%) was observed in chip budding. Further, among the interactions of propagation methods and age of rootstocks, the maximum success rate was obtained in softwood grafting onto two-month-old rootstocks (94.67%), while the minimum success was recorded in patch budding onto two-month-old rootstocks (3.67%). In general, grafting success rates were high with the use of comparatively younger rootstocks (2–4 months old), while budding success rates were high with mature rootstocks of 7–8 months old.

These findings suggest that the selection of appropriate propagation method and rootstock age is crucial for optimising success in grafting and budding. The highest success rate was observed with softwood grafting, although it may take a longer period for sprouting to occur. This grafting method had relatively high survival and establishment rates. In contrast, the lower success rate seen with three-month-old seedlings suggests that this age group may be less suitable for grafting, potentially due to physiological immaturity or other factors affecting graft compatibility. Notably, softwood grafting with two-month-old seedlings displayed the highest success rate, highlighting the compatibility and effectiveness of this combination. Meanwhile, chip and patch budding were found to perform better with 7–8 month-old seedling rootstocks, as it indicated higher success rates in this age group. Previous studies by Tripathi and Karunakaran (2019) reported highest success rate of 32.5% for cleft grafting in avocado, outperforming other methods. Additionally, optimum softwood grafting in avocado has been observed using 60–70 g seed size (rootstock) and 90 days old scion (Subash *et al.* 2023). Nakakawa (2021) and Ndagire (2021), reported the wider variations for sprouting and success percentage in avocado and also similar finding was reported in other fruit crops (Devi *et al.* 2018, Deepak *et al.* 2019, Yadav *et al.* 2019).

Propagation methods and age of rootstocks on scion

Table 2 Effect of propagation methods and age of rootstock on scion growth parameters

	Sprout length (cm)				Sprout girth (cm)				No. of leaves			
	T_1	T_2	T_3	Mean (M)	T_1	T_2	T_3	Mean (M)	T_1	T_2	T_3	Mean (M)
M_1	16.33	12.67	13.33	14.11	0.36	0.31	0.26	0.31	11.67	10.33	09.67	10.56
M_2	15.67	13.00	13.67	14.11	0.31	0.32	0.27	0.30	11.33	10.67	10.67	10.89
M_3	15.33	14.33	15.00	14.89	0.26	0.35	0.28	0.30	09.33	11.67	10.67	10.55
M_4	14.00	16.00	16.67	15.56	0.29	0.34	0.36	0.33	10.67	12.00	10.33	11.00
M_5	12.00	18.00	16.00	15.33	0.37	0.41	0.41	0.40	12.00	10.67	10.67	11.11
M_6	13.67	19.67	18.67	17.33	0.36	0.42	0.39	0.39	10.00	11.00	10.00	10.33
M_7	12.67	18.00	19.00	16.56	0.38	0.41	0.36	0.38	10.33	10.33	10.00	10.22
Mean (T)	14.24	15.95	16.05		0.33	0.36	0.33		10.76	10.95	10.29	
	T	M	T × M		T	M	T × M		T	M	T × M	
CD (p=0.05)	1.22	1.87	3.23		0.01	0.02	0.04		NS	NS	2.40	
CV (%)		12.69				6.51				13.66		

Treatment details are given under Materials and Methods. T, Method of propagation; M, Age of rootstock.

growth parameters: The study revealed a significant effect rootstock ages and propagation methods on the growth parameters of the scion (Table 2). Among the different ages of rootstocks, the highest sprout length (17.33 cm) was observed in seven-months-old rootstocks, while the lowest sprout length (14.11 cm) was observed in two and three-months-old rootstocks. The maximum sprout girth (0.4 cm) and number of leaves (11.11) were observed in six-months-old rootstocks, whereas the minimum sprout girth (0.3 cm) was recorded in three and four-month-old rootstocks and the minimum number of leaves (10.22) were recorded in eight-months-old rootstocks. Among the different propagation methods, patch-budded plants exhibited the maximum sprout length (16.05 cm), while chip-budded plants exhibited the maximum sprout length (19.67 cm) and number of leaves (10.95). This suggests that patch budding may result in slightly slower initial growth compared to rest of the propagation techniques. On the other hand, softwood grafting leads to more robust early growth and development of the grafted plants. In the context of the interaction between rootstock ages and propagation methods, various combinations exhibited both the highest and lowest values. The maximum sprout length (19.67 cm) and sprout girth (0.42 cm) were recorded in chip budding onto seven-months-old rootstocks. Similarly, the maximum number of leaves (12) was observed in softwood grafting onto six-months-old rootstocks and chip budding onto five-months-old rootstocks. These findings indicated that six-months-old seedlings are more suitable for promoting higher initial growth and foliage development, while older or younger seedlings may exhibit less favourable growth outcomes under the given experimental conditions. Overall, these results suggest that the effectiveness of a specific propagation method may vary depending on the age of the seedlings, which aligns with previous studies on mango (Karna *et al.* 2018), jackfruit (Kumar *et al.* 2021) and avocado (Shindre *et al.* 2023).

Linear regression studies: The study investigated the effect of rootstock girth and rootstock age on the success among propagation methods, as evidenced by the analysis of linear regression curves (Fig. 1, 2 and 3). It was found that a negative correlation was observed between the success of softwood grafting and rootstock girth and age of the seedling, with an increasing value of these parameters resulting in decreased success (Fig. 1). The highest level of success was observed with a rootstock girth of 0.48 cm, while the lowest was associated with a rootstock girth of 0.55 cm. This observation implies that as the rootstock's girth and age increased, the likelihood of achieving successful grafting decreased. This suggests

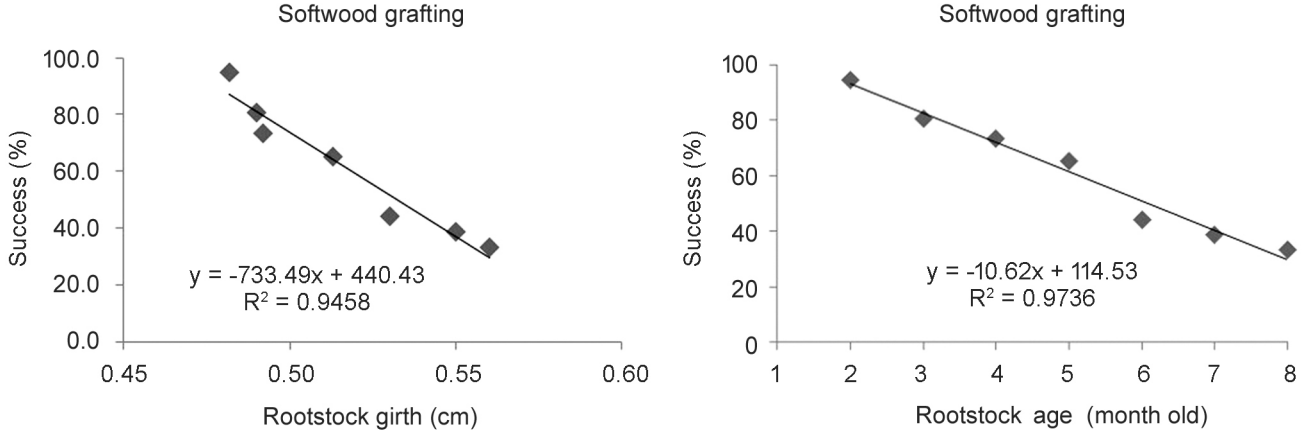

Fig. 1 Effect of rootstock girth and age on success of softwood grafting.

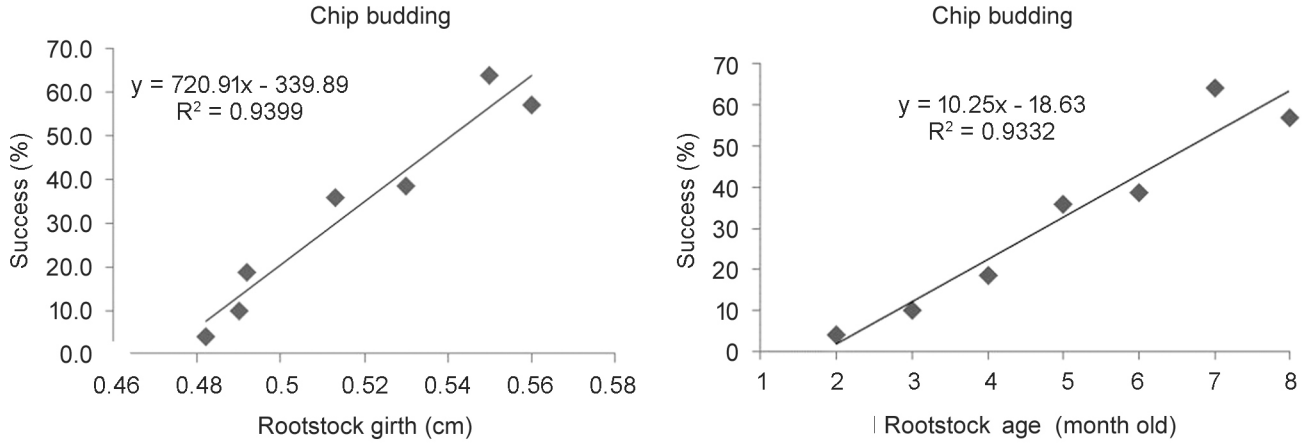

Fig. 2 Effect of rootstock girth and age on success of chip budding.

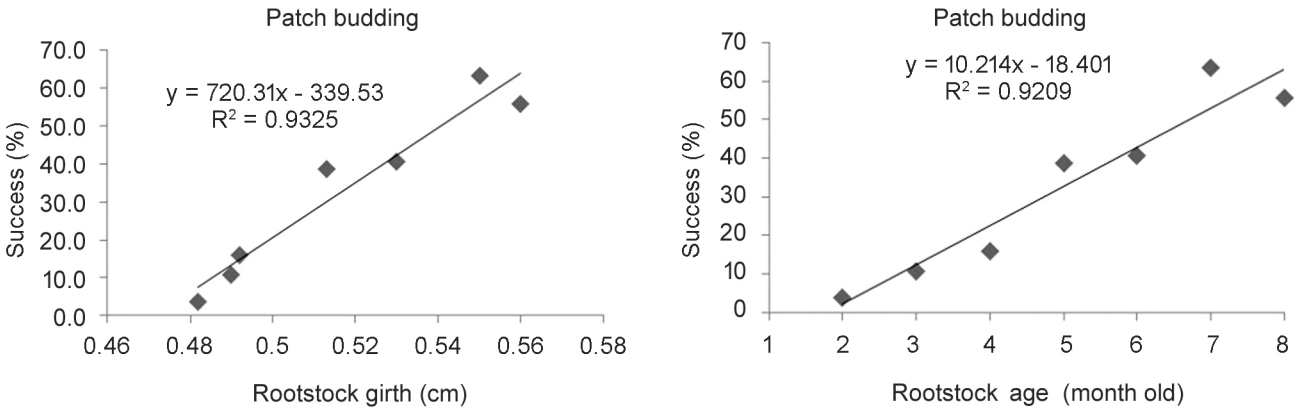

Fig. 3 Effect of rootstock girth and age on success of patch budding.

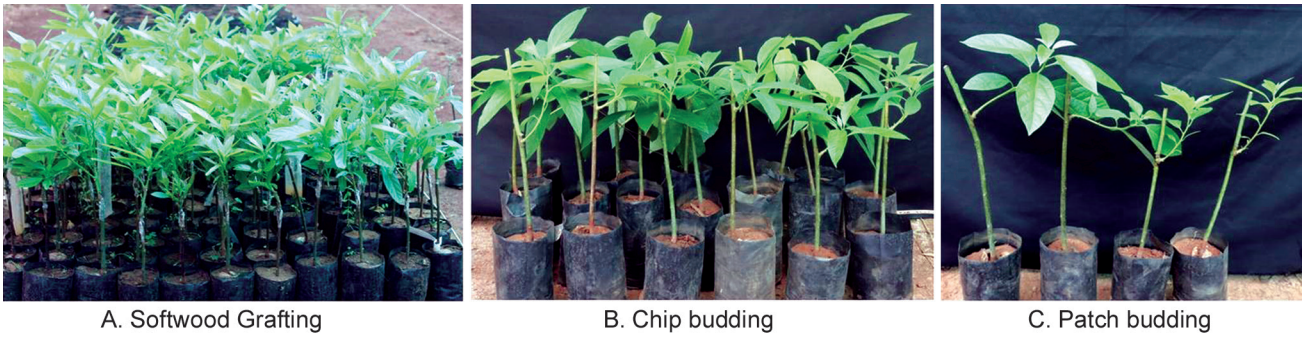

Fig. 4 Successful propagation methods in avocado.

that selecting rootstocks with a girth closer to 0.48 cm may be advantageous for optimising success (Fig. 4A) under the softwood grafting technique. However, the regression analysis also showed a negative correlation between rootstock girth, age and the success of softwood grafting, implying that the decreased success may be due to some interruption of physiological factors.

Conversely, rootstock girth and age of the seedling exhibited positive linear regressions with respect to the success of chip and patch budding (Fig. 2 and 3). Notably, an increase in rootstock girth and rootstock age led to an increase in the success of chip and patch budding. The maximum success rate was observed at 0.55 cm rootstock girth for seven months old rootstocks (64% and 63.3%, respectively) and the lowest success rate at 0.48 cm rootstock girth for two-month-old rootstocks (4.00% and 3.67%, respectively). These findings suggest that when utilising the chip and patch budding technique, selecting rootstocks with a girth closer to 0.55 cm is advantageous to optimise success (Fig. 4B and 4C). This may be attributed to the enhanced vascular development and nutrient transport capabilities of older, larger rootstocks, which can facilitate better healing and integration of the scion. The present results aligned with the findings of Devi *et al.* (2018) in jamun and Muralidhara and Gowda (2019) in Coorg mandarin.

In conclusion, the appropriate propagation approach and desired age of the seedlings must be utilised to enhance the grafting success. The softwood grafting on two months old rootstocks could be commercially utilised for large scale multiplication of quality planting material. The rootstocks which are not fit for softwood grafting can be effectively utilised for chip and patch budding and these methods are also useful where there is shortage of scion wood. The generated information could be helpful to the horticulturists and nursery practitioners to enhance the more sapling production in avocado crop.

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