



ISSN Print: 2618-060X
 ISSN Online: 2618-0618
 NAAS Rating (2026): 5.20
 IJRA 2026; 9(9): 965-972
www.agronomyjournals.com
 Received: 03-07-2026
 Accepted: 03-08-2026
 Published: 23-09-2026

MA Jadhav

PG Scholar, Department of Horticulture (Fruit Science), College of Agriculture, Latur-413512, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

GR Munde

Officer Incharge, Custard Apple Research Centre, Parbhani, Maharashtra, India

SS Ovhal

PG Scholar, Department of Horticulture (Fruit Science), College of Agriculture, Latur-413512, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

MN Magar

PG Scholar, Department of Horticulture (Fruit Science), College of Agriculture, Latur-413512, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

RS Bhujbal

PG Scholar, Department of Horticulture (Vegetable Science), College of Agriculture, Latur-413512, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:

MA Jadhav

PG Scholar, Department of Horticulture (Fruit Science), College of Agriculture, Latur-413512, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Standardization of grafting technique in *Annona atemoya* L. (Hanumanphal)

MA Jadhav¹, GR Munde², SS Ovhal³, MN Magar⁴, RS Bhujbal⁵

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i9m.6631>

ABSTRACT

The present study entitled "Standardization of Grafting Technique in *Annona atemoya* L. (Hanumanphal)" was undertaken at the Custard Apple Research Station, Ambajogai, during 2025–2026. The study was conducted to develop a suitable and reliable grafting technique for these two important *Annona* species under the local conditions. The investigation was carried out with twenty treatment combination comprising five different time of grafting (15th December, 1st January, 15th January, 1st February and 15th February) and four length (6, 8, 10 and 12 cm) of scion sticks were tried in Randomized Block Design with Factorial concept (FRBD) with 4 replications for *Annona atemoya*. Minimum days required for sprouting (12.81), days taken for first leaf opening (13.31) and mortality percentages after 30 and 90 days (5.06 and 10.13 %), maximum number of sprouts (3.75), leaf area (44.31, 48.13 and 56.19 cm²), at 30, 60 and 90 DAG respectively. Maximum success rate (94.88 and 90.31 %) at 30 and 90 days. Maximum fresh weight of shoot (26.38 g), Dry weight of shoot (9.25 g), length of root (27.00 cm), fresh and dry weight of root (24.81 and 9.41 g) after 90 days results indicated that successful grafting was achieved when grafting was carried out on 15th February (G₅) using 10 cm long scion sticks (L₃). From the result of present study revealed that softwood grafting in *Annona atemoya* L. (Hanumanphal) can be carried out successfully using 10 cm long scion sticks on 15th February. This treatment resulted in a higher number of sprouted grafts, earlier opening of the first leaves, greater number of leaves per graft, lower mortality and better graft survival.

Keywords: Hanumanphal, Success, Mortality, Percentage, Scion

Introduction

The atemoya is a member of the Annonaceae. The atemoya is a hybrid of the sugar apple (*Annona squamosa*) and cherimoya (*Annona cherimoya*), two members of the *Annona* family. The first cross was made by the horticulturist, P.J. Wester, at the United States Department of Agriculture's subtropical laboratory, Miami, in 1908. Seedlings were planted out in 1910.

Hanuman phal is widely cultivated across the world. In Brazil, the atemoya became popular and in 2011, around 1,200 hectares of atemoya were cultivated in Brazil. In Taiwan, the cultivating area of atemoya was 2,856.46 hectares in 2020, and Taitung County was the major place for cultivation having about 2,815.19 hectares.

The tree closely resembles that of the cherimoya; is fast-growing; may reach 25 to 30 ft (7.5- 9 m) and is short-bunked, the branches typically drooping and the lowest touching the ground. The leaves are deciduous, alternate, elliptical, leathery, less hairy than those of the cherimoya; and up to 6 in (15 cm) in length. The flowers are long-stalked, triangular, yellow, 2 3/8 in (6 cm) long and 1 1/2 to 2 in (4 - 5 cm) wide. The fruit is conical or heart-shaped, generally to 4 in (10 cm) long and to 3 3/4 in (9.5 cm) wide; some weighing as much as 5 lbs (2.25 kg); pale bluish-green or pea-green, and slightly yellowish between the areoles. The rind, 1/8 in (3 mm) thick, is composed off used areoles more prominent and angular than those of the sugar apple, with tips that are rounded or slightly upturned; firm, pliable, and indehiscent. The fragrant flesh is snowy-white, of fine texture, almost solid, not conspicuously divided into segments, with fewer seeds than the sugar apple; sweet and sub acid at the same time and resembling the cherimoya in flavor. The seeds are cylindrical, 3/4 in (2 cm) long and 5/16 in (8 mm) wide; so dark a brown as to appear black; hard and smooth.

The atemoya and bear hermaphroditic protogynous flowers and self - pollination is rare. The flower, in its female stage, opens between 2 and 4 o'clock in the afternoon. Between 3 and 5 o'clock on the following afternoon, the flower converts to its male stage. In cold and humid climates, it releases pollen even though it is sticky. Where the climate is hot and the humidity low at the blooming season, the carpels are short lived and the stigmatic surface soon dries up and insects are necessary to transfer the pollen.

Atemoya are adapted to a wide range of temperatures, from lowland tropical to cool subtropical climates. In south Florida during January 1977, young trees were killed or severely injured by prolonged temperatures

between -6.7° to -3.9 °C whereas mature trees withstood those temperatures with slight to moderate damage. Constant winds during late winter and

spring may cause young atemoya trees to either lean in the leeward direction and to develop canopy and limbs only on the leeward side giving trees an unbalanced canopy.

The tree thrives in various types of soil, from sandy loam to red basalt or heavy clay, but best growth and productivity occur in deep, rich loam of medium texture, with good organic content and a moderate amount of moisture. Good drainage is essential; waterlogging is fatal. Micronutrient deficiencies appear to be less of a problem in soils with a neutral to moderately acid pH. 5 to 7.

According to analyses made in Florida, the Philippines and at the University of New South Wales, *Annona atemoya* contains Calories- 94, Moisture-71.48 -78.7g, Protein- 1.07-1.4g, Fat- 0.4-0.6g, Carbohydrates-24g, Fiber- 0.05-2.5g, Iron- 0.3 mg, Calcium- 17 mg, Magnesium- 32 mg, α -carotene- 10 μ g, β -carotene- 10 μ g, Cryptoxanthin- 10 μ g, Ascorbic Acid-50 mg. Atemoyas may be propagated by seed, grafting, and budding. However, fruit quality and production of seedlings is extremely variable. Trees may be veneer, cleft or whip grafted (Morton, 1987) [1] and pre-graft preparation of budwood increases success. Grafted trees begin to produce fruit in 3 to 4 years. Grafting is done in the spring, using the whip or tongue graft. In India, the atemoya is usually grafted onto the custard apple or sugar apple. Cherimoya is used as a rootstock in Israel.

Little research has been conducted to determine the optimum fertilizer recommendations for atemoya. Current recommendations for mature trees an 8:1.3:7.5Kg NPK/tree or similar material should be applied 3 to 4 times per year at the rate of 450 g per tree per 2.5 cm of trunk diameter per application. To prevent micronutrient deficiencies, foliar application of magnesium, manganese, and zinc and soil drenches of chelated iron are typically made 2 to 4 times per year.

The atemoya, preferably chilled, is one of the most delicious of fruits. It needs no seasoning. It may be simply cut in half or quartered and the flesh eaten from the "shell" with a spoon. Slices or cubes of the pulp may be added to fruit cups or salads or various dessert recipes. Some people blend the pulp with orange juice, lime juice and cream and freeze as ice cream.

The seeds contain toxins which have been associated with neurological degeneration, they should be removed before consuming, and care should be taken to avoid breaking or otherwise damaging them as the toxins may leach out into the fruit. Some groups have found the crushed seeds of related species useful as a pesticide and for other similar applications. It is rich in vitamins C and B6, essential for immune function and brain health. The fruit also provides dietary fiber, promoting healthy digestion. Additionally, atemoya contains potassium, magnesium, and antioxidants, which contribute to overall heart health and help combat oxidative stress. The fruit and leaves have remedies for digestive issues and respiratory ailments. As the demand for Hanumanphal in local markets is ever increasing, the systematic efforts for its crop improvement, propagation and planting needs to be attempted. As seedlings are heterozygous, do not show true to type characteristics, hence vegetative propagated planting material is necessary for commercial plantations. Taking into consideration above

facts, the present investigation entitled "Standardization of Grafting Technique in *Annona atemoya* L. (Hanumanphal).

Materials and Methods

At the Custard Apple Research Station in Ambajogai, the experiment was carried out in a green shed net house. Geographically, it is located in latitude 18°44' North, longitude 76°23', and an elevation of 1500 feet above mean sea level.

A part of the Marathwada region and the district, which is located in the center west of Sambhajinagar, are often more than 1500 feet above mean sea level. Eight months of the year usually dry, but the southwest monsoon season bringing rain. The warmest month has a maximum temperature of 40 °C. Beginning in mid-November, the low temperature drops to 12 °C. The region typically receives 950–1000 mm of rain annually between June and September.

The experiment was laid out in Factorial Randomized Block Design with twenty treatment combination and each treatment was replicated four times. Treatment involved date of grafting (15th December, 1st January, 15th January, 1st February and 15th February) were combined with length of scion (6, 8, 10 and 12 cm). Observations were recorded on various

growth and grafting parameters including Days required for sprouting, Days for first leaf opening, Number of sprouts recorded at initial days, Leaf area (cm²) recorded at 30, 60 and 90 DAG. Success rate (%) and Mortality (%) at 30 and 90 DAG. Fresh weight of shoot (g), Dry weight of shoot (g), Length of root (cm), Fresh weight of root (g), Dry weight of shoot (g) at 90 DAG.

Table 1. Treatment combinations

Sr. No.	Treatment combination
1	G1L1
2	G1L2
3	G1L3
4	G1L4
5	G2L1
6	G2L2
7	G2L3
8	G2L4
9	G3L1
10	G3L2
11	G3L3
12	G3L4
13	G4L1
14	G4L2
15	G4L3
16	G4L4
17	G5L1
18	G5L2
19	G5L3
20	G5L4

$$\text{Leaf Area} = \text{Length} \times \text{Width} \times K (\text{Correction factor})$$

$$\text{Graft success} = \frac{\text{Number grafts of survived}}{\text{Total number of grafts}} \times 100$$

$$\text{Mortality percentage} = \frac{\text{Total number of grafts survived}}{\text{Total number of grafts sprouted}} \times 100$$

Growth Character

Days required for sprouting Effect of time

The data on the number of days required for sprouting of grafts as influenced by different times of grafting were presented in Table 2. The results showed that the time of grafting had a significant effect on the number of days required for sprouting.

The grafts prepared on 15th February (G_5) took the minimum time to sprout (12.81 days), followed by G_3 (12.94 days), G_4 (14.06 days) and G_2 (14.25 days). Grafts prepared on 1st December (G_1) took the maximum time (15.06 days) to sprout. The differences in sprouting time might have been due to variations in the physiological condition of the scions and the environmental conditions prevailing during grafting. Similar findings were reported by Kudmulwar *et al.* (2008) [2] in custard apple. Khopade *et al.* (2013) [3] also reported considerable variation in the number of days required for sprouting of custard apple grafts, ranging from 12.66 to 22.40 days, which supported the findings of the present study.

Effect of scion stick

The results presented in Table 2 indicated that the length of the scion stick influenced the time required for sprouting of the grafts. The grafts prepared with 10 cm long scion sticks (L_3) sprouted earlier and took the minimum time of (13.50) days was at par with L_4 (13.70) and L_2 (13.85). In comparison, grafts prepared with 6 cm long scion sticks (L_1) required the maximum time of (14.25) days to sprout. Similar results were reported by Purbiati *et al.* (1991) and Gurudutta *et al.* (2004) [4], which were in agreement with the findings of the present study.

Interaction effect

The data presented in Table 2 showed that the combined effect of time of grafting and length of scion sticks had a significant influence on the time required for sprouting. Among the different treatment combinations, G_{5L3} recorded the earliest sprouting, taking only (11.75) days was at par with G_{3L4} (12.25), G_{3L3} (12.50) and G_{5L2} (12.75). In contrast, the grafts made on 15th December using 12 cm long scion sticks took the longest time (15.75) days required for sprouting.

Table 2. Effect of time and length of scion stick on Days required for sprouting, Days for first leaf opening and Number of sprouts

Treatment	Days required for sprouting	Days for first leaf opening	Number of sprouts
Time of grafting (G)			
G_1	15.06	15.50	2.44
G_2	14.25	14.69	2.63
G_3	12.94	14.56	2.94
G_4	14.06	13.56	3.00
G_5	12.81	13.31	3.75
SEm±	0.27	0.19	0.18
C.D.at5%	0.77	0.55	0.52
Length of scion (L)			
L_1	14.25	14.80	1.25
L_2	13.85	13.95	2.20
L_3	13.50	13.80	5.00
L_4	13.70	14.65	3.35
SEm±	0.24	0.75	0.16
C.D.at5%	0.68	0.49	0.47
Interaction effect (G x L)			
G_{1L1}	14.75	14.80	0.75
G_{1L2}	14.25	13.95	2.00
G_{1L3}	15.50	13.80	4.00
G_{1L4}	15.75	14.65	3.00
G_{2L1}	15.00	0.75	1.00
G_{2L2}	13.50	0.49	2.25
G_{2L3}	13.25	14.80	4.00

Treatment	Days required for sprouting	Days for first leaf opening	Number of sprouts
G_{2L4}	15.25	13.95	3.25
G_{3L1}	13.25	13.80	1.75
G_{3L2}	13.25	14.65	2.25
G_{3L3}	12.50	0.75	4.50
G_{3L4}	12.25	0.49	3.25
G_{4L1}	15.25	14.80	1.00
G_{4L2}	15.50	13.95	2.00
G_{4L3}	13.75	13.80	5.50
G_{4L4}	12.75	14.65	3.50
G_{5L1}	13.00	0.75	1.75
G_{5L2}	12.75	0.49	2.50
G_{5L3}	11.75	14.80	7.00
G_{5L4}	13.50	13.95	3.75
General Mean	13.83	13.80	2.95
SEm±	0.54	14.65	0.37
C.D.at5%	1.54	0.75	1.05

No. of days for first leaf opening effect of time

The results presented in Table 2 showed that the time of grafting affected the number of days required for the opening of the first leaf. The grafts prepared on 15th February (G_5) opened their first leaf earliest, taking (13.31) days, was at par with G_4 (13.56 days) and followed by G_3 (14.56 days) and G_2 (14.69 days). Grafts prepared on 15th December (G_1) took the longest time, requiring (15.50 days) for the first leaf to open. The earlier opening of the first leaf in grafts performed on 15th February (G_5) may be attributed to the favourable temperature and environmental conditions, which enhanced cambial activity, callus formation and graft union development. Similar results were reported by Usare (2016), which supported the findings of the present study.

Effect of length of scion stick

The results presented in Table 2 showed that the length of the scion stick had a significant effect on the time taken for the opening of the first leaf. The grafts prepared with 10 cm long scion sticks (L_3) opened their first leaf earlier, taking (13.80) days was at par with L_2 (13.95), whereas grafts prepared with 6 cm long scion sticks (L_1) took the longest time of (14.80) days. The 10 cm scion stick (L_3) promoted early leaf opening possibly due to its adequate stored carbohydrate reserves, which supported rapid bud growth. Similar observations were reported by Purbiati *et al.* (1991) and Gurudutta *et al.* (2004) [4], which supported the findings of the present study.

Interaction effect

The results presented in Table 2 indicated that the interaction between the time of grafting and scion stick length significantly affected the time required for the first leaf to open. The grafts under the G_{5L3} treatment combination showed the earliest leaf opening, taking only (11.50) days and followed by G_{5L2} (13.00), G_{4L4} (13.25) and G_{4L1} (13.50). In contrast, the G_{1L1} treatment combination took the longest time, with (16.50) days required for the first leaf to open. The delayed leaf opening under 15th December grafting (G_1) and 6 cm scion length (L_1) may be due to lower temperature and comparatively limited food reserves, respectively.

Number of sprouts effect of time

The results presented in Table 2 showed that the time of grafting had a significant effect on the number of sprouts produced by the grafts. The maximum number of sprouts was observed in grafts prepared on 15th February (G_5), with (3.75) sprouts per graft and followed by G_4 (3.00), G_2 (2.63) and G_3 (2.94). Minimum number of sprouts was recorded in grafts prepared on 15th December (G_1), with (2.44) sprouts per graft.

Effect of length on scion stick

The results presented in Table 2 indicated that the length of the scion stick influenced the number of sprouts produced by the grafts. The maximum number of sprouts was recorded with 10 cm long scion sticks (L_3) with (5.00 sprouts) per graft was followed by L_4 (3.35 sprouts) L_2 (2.20 sprouts). In contrast, the minimum number of sprouts (1.25) was recorded with 6 cm long scion sticks (L_1). This could be due to attributed to an adequate supply of healthy and matured scion sticks with possibly higher accumulation of carbohydrate and other biochemical. Besides this favourable weather conditions experienced during grafting date could have contributed to the activation of swollen buds. Similar findings were reported by Ghojage *et al.* (2011) [5] in jamun.

Interaction effect

The data presented in Table 2 showed that the combination of time of grafting and length of scion stick had a significant effect on the number of sprouts produced. Among the different treatment combinations, G_{5L3} recorded the highest number of sprouts (7.00) followed by G_{4L3} (5.50), G_{3L3} (4.50) and G_{2L3} (4.00). Whereas the lowest number of sprouts (0.75) was observed in G_{1L1} .

Leaf area (cm^2) effect of time

At 30 DAG, the data presented in Table 3 showed clear differences in leaf area per graft among the different times of grafting. The highest leaf area was recorded in G_5 (44.31) followed by G_4 (40.56), G_3 (38.38) and G_2 (36.19) while the lowest leaf area was observed in G_1 (34.13). At 60 DAG, G_5 continued to record the highest leaf area (48.13) was at par with G_4 (47.31), followed by G_3 (44.25) and G_2 (42.50). The minimum leaf area was recorded in G_1 (39.69).

At 90 DAG, the highest leaf area was again recorded in G_5 (56.19) followed by G_4 (52.81), G_3 (51.19) and G_2 (48.00), whereas G_1 recorded the lowest leaf area (45.88).

The higher leaf area in G_5 may be due to favourable temperature conditions that promoted graft establishment and vegetative growth. Similar findings were reported by Gadekar *et al.* (2010) [6], Alam *et al.* (2006a) [7] and Ram *et al.* (2012) in jamun and mango.

Effect of length of scion stick

Leaf area was significantly affected by the length of scion sticks used for grafting. Among the different scion lengths, L_3 recorded maximum leaf area of (40.90), (47.00) and (53.65) at 30, 60 and 90 days after grafting respectively. Minimum leaf area was recorded in L_1 , (37.00), (42.50) and (48.95) at 30, 60 and 90 DAG. The greater leaf area observed in L_3 might have been associated with better leaf growth and development of the grafts. Similar results were also reported by Nalage *et al.* (2010) [8].

Interaction effect

The interaction between time of grafting (G) and length of scion stick (L) was non-significant effect on leaf area at 30, 60 and 90 days after grafting. However, at 30 DAG maximum leaf area was recorded in G_{5L3} (47.25) and lowest area recorded in G_{1L1} (32.75).

At 60 DAG highest leaf area was recorded in G_{5L3} (52.50) was at par with G_{4L3} (50.25) and lowest area recorded in G_{1L1} (38.25).

At 90 DAG highest leaf area was recorded in G_{5L3} (59.75) and lowest area recorded in G_{1L1} (44.50).

Success rate (%) effect of time

The data presented in Table 4 revealed that the success percentage of Hanumanphal grafts was significantly influenced by the time of grafting. Among the different grafting times, G_5 recorded the highest graft success, with (94.88) at 30 DAG and (90.31) per cent at 90 DAG. This was followed by G_4 , which recorded (92.88) and (88.19) success at 30 and 90 DAG, respectively. G_3 recorded (89.63) and (84.38) success, while G_2 recorded (86.56) and (81.81) success at 30, 60 and 90 DAG respectively. Lowest graft success was observed in G_1 , with (82.88) at 30 DAG and (77.94) at 90 DAG. The better success ob-

served during the favourable grafting period might have been due to suitable environmental conditions that supported proper graft union formation and subsequent growth. Similar results were also reported by Kumar *et al.* (2012) [9], who recorded 96.4 per cent graft success in custard apple.

Effect of length of scion stick

The results presented in Table 4 showed that scion length had a significant influence on graft success at 30 and 90 DAG. Among the different scion lengths, the highest graft success was recorded with 10 cm long scions (L_3), which showed (92.85) and (89.25) success at 30 and 90 DAG, respectively. In contrast, the lowest graft success was observed with 6 cm long scions (L_1), recording (85.65) at 30 DAG and (79.40) at 90 DAG. The higher success obtained with 10 cm long scions might have been due to the better availability of stored food reserves, which helped the scion to establish and develop successfully after grafting. Similar findings were reported by Ratan *et al.* (1987), Radhamony *et al.* (1989) and Radha and Aravindakshan (1998), who observed better graft success with suitable scion length

Interaction effect

The interaction between time of grafting (G) and length of scion stick (L) was not significant for graft success at 30 and 90 DAG. However, some variation was observed among the different treatment combinations. The highest graft success was recorded in G_{5L3} , with (97.50) and (94.75) at 30 and 90 DAG, respectively. In comparison, the lowest success was recorded in G_{1L1} , with (78.25) and (71.50) at 30 and 90 DAG respectively. The results indicated that grafting at a suitable time with an appropriate scion length helped in obtaining better graft establishment and higher success. Although the combination G_{5L3} performed better, the interaction between the two factors was statistically non-significant.

Mortality (%) effect of time

The data presented in Table 4 revealed that the mortality of Hanumanphal grafts was influenced by the time of grafting. The lowest mortality was recorded in G_5 , with (5.06) and (10.13) at 30 and 90 days after grafting (DAG), respectively. This was followed by G_4 , which recorded (7.88) and (12.38) mortality, while G_3 recorded (10.88) and (16.13) mortality at 30 and 90 DAG respectively. G_2 showed comparatively higher mortality of (14.00) and (18.69) at 30 and 90 DAG, respectively. The highest mortality was observed in G_1 , with (17.63) at 30 DAG and (22.75) at 90 DAG. The lower mortality observed with G_5 might have been associated with more favourable conditions during graft establishment. Similar observations were reported by Mulla *et al.* (2011) [10] in jamun and Raghvendra *et al.* (2011) in wood apple, supporting the findings of the present study.

Effect of length on scion stick

The results presented in Table 4 showed that the length of the scion stick significantly influenced graft mortality at 30 and 90 DAG. The lowest mortality was recorded when 10 cm long scions (L_3) were used, (7.60) and (11.20) at 30 and 90 DAG, respectively. In contrast, the highest mortality was observed with 6 cm long scions (L_1), which recorded (14.75) and (21.10) mortality at 30 and 90 DAG respectively. The lower mortality with longer scions might have been due to their better physiological condition and greater availability of stored food reserves, which helped in maintaining the graft until successful union was established. Similar results were reported by Ratan *et al.* (1987) and Radhamony *et al.* (1989), which were in agreement with the present findings

Interaction effect

The data presented in Table 4 showed that the interaction between time of grafting (G) and length of scion stick (L) did not significantly affect graft mortality at 30 or 90 DAG. However, differences were observed among the various treatment combinations. The lowest mortality was recorded in G_{5L3} , with (2.00) and (5.75) at 30 and 90 DAG, respectively.

Table 3. Effect of time and length of shoot on leaf area (cm²)

Treatment	30DAG	60DAG	90DAG
Time of grafting (G)			
<i>G</i> ₁	34.13	39.69	45.88
<i>G</i> ₂	36.19	42.50	48.00
<i>G</i> ₃	38.38	44.25	51.19
<i>G</i> ₄	40.56	47.31	52.81
<i>G</i> ₅	44.31	48.13	56.19
SEm ±	0.47	0.54	0.55
C.D.at5%	1.33	1.55	1.57
Length of scion (L)			
<i>L</i> ₁	37.00	42.50	48.95
<i>L</i> ₂	37.80	43.20	49.60
<i>L</i> ₃	40.90	47.00	53.65
<i>L</i> ₄	39.15	44.80	51.05
SEm ±	0.42	0.49	0.49
C.D.at5%	1.19	1.38	1.40
Interaction effect (G x L)			
<i>G</i> _{1L1}	32.75	38.25	44.50
<i>G</i> _{1L2}	33.75	39.75	45.50
<i>G</i> _{1L3}	35.50	41.00	47.25

Treatment	30DAG	60DAG	90DAG
<i>G</i> _{1L4}	34.50	39.75	46.25
<i>G</i> _{2L1}	35.00	41.00	46.25
<i>G</i> _{2L2}	35.50	41.75	47.00
<i>G</i> _{2L3}	37.50	44.50	50.00
<i>G</i> _{2L4}	36.75	42.75	48.75
<i>G</i> _{3L1}	36.50	42.50	49.00
<i>G</i> _{3L2}	37.00	43.00	49.25
<i>G</i> _{3L3}	40.75	46.75	55.50
<i>G</i> _{3L4}	39.25	44.75	51.00
<i>G</i> _{4L1}	38.25	45.50	50.75
<i>G</i> _{4L2}	39.00	45.75	51.00
<i>G</i> _{4L3}	43.50	50.25	55.75
<i>G</i> _{4L4}	41.50	47.75	53.75
<i>G</i> _{5L1}	42.50	45.25	54.25
<i>G</i> _{5L2}	43.75	45.75	55.25
<i>G</i> _{5L3}	47.25	52.50	59.75
<i>G</i> _{5L4}	43.75	49.00	55.50
General Mean	38.71	44.38	50.81
SEm ±	0.94	1.09	1.11
C.D.at5%	NS	NS	NS

Table 4. Effect of time and length of scion stick on success rate and Mortality (%) at 30 and 90 DAG

Treatment	Success rate (%)		Mortality	
Time of grafting (G)				
G ₁	82.88	77.94	17.63	22.75
G ₂	86.56	81.81	14.00	18.69
G ₃	89.63	84.38	10.88	16.13
G ₄	92.88	88.19	7.88	12.38
G ₅	94.88	90.31	5.06	10.13
SEm ±	0.23	0.27	0.18	0.24
C.D.at5%	0.66	0.76	0.52	0.69
Length of scion (L)				
L ₁	85.65	79.40	14.75	21.10
L ₂	88.55	83.40	12.00	17.35
L ₃	92.85	89.25	7.60	11.20
L ₄	90.40	86.05	10.00	14.40
SEm ±	0.20	0.24	0.16	0.21
C.D.at5%	0.59	0.68	0.47	0.62
Interaction effect (G x L)				
G ₁ L ₁	78.25	71.50	21.75	28.75
G ₁ L ₂	81.75	76.25	18.75	24.25
G ₁ L ₃	87.50	83.50	13.50	17.50
G ₁ L ₄	84.00	80.50	16.50	20.50
G ₂ L ₁	82.75	76.75	17.50	23.75
G ₂ L ₂	85.75	81.00	15.00	20.00
G ₂ L ₃	90.00	86.75	10.50	13.25
G ₂ L ₄	87.75	82.75	13.00	17.75
G ₃ L ₁	86.00	79.50	14.50	20.75
G ₃ L ₂	89.00	83.25	11.50	17.50
G ₃ L ₃	93.00	88.75	7.50	11.75
G ₃ L ₄	90.50	86.00	10.00	14.50
G ₄ L ₁	89.25	83.00	11.50	17.50
G ₄ L ₂	91.75	87.25	8.75	13.50
G ₄ L ₃	96.25	92.50	4.50	7.75
G ₄ L ₄	94.25	90.00	6.75	10.75
G ₅ L ₁	92.00	86.25	8.50	14.75

(continued on next page)

Treatment	Success rate (%)		Mortality	
G ₅ L ₂	94.50	89.25	6.00	11.50
G ₅ L ₃	97.50	94.75	2.00	5.75
G ₅ L ₄	95.50	91.00	3.75	8.50
General Mean	89.36	84.53	11.09	16.01
SEm ±	0.46	0.54	0.37	0.49
C.D.at5%	NS	NS	NS	NS

In contrast, the highest mortality was observed in G₁L₁, recording (21.75) and (28.75) at 30 and 90 DAG, respectively. Overall, the G₅L₃ combination resulted in comparatively lower graft mortality, whereas G₁L₁ showed the highest mortality under the conditions of the study.

Fresh weight of shoot (g) effect of time

The data showed in Table 5 in regards to time of grafting revealed that maximum fresh weight of shoot (26.38) was recorded in the G₅ which was at par with G₄ (24.81) and followed by G₃ (24.56) and G₂ (24.50) respectively. Minimum fresh weight of shoot (22.19) was recorded in G₁.

Effect of length of scion stick

The data showed in Table 5 in regards to different length of scion revealed that maximum fresh weight of shoot (27.15) was recorded in L₃ which was followed by L₄ (24.70) and L₂ (23.85) respectively. Minimum fresh weight of shoot (22.25) was recorded in L₁. This might be attributed to the maximum scion height, number of leaves and leaf area resulting in a greater accumulation of glucose necessary for vegetative development of the plant and a higher shoot weight. Roshan *et al.* (2013) in anola and Pawar *et al.* (2018) in custard apple observed a similar result regarding the fresh weight of shoots in custard apple grafts.

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to fresh weight of root was non-significant. Maximum fresh weight of shoot (28.25) was recorded in G₅L₃, was at par with G₄L₃ (27.50), G₂L₃ (27.00), G₁L₃ (26.75), and G₅L₄ (26.25). However minimum fresh weight of root (18.00) was recorded in G₁L₁. The higher fresh shoot weight recorded in G₅L₃ may be attributed to better graft establishment and stronger vegetative growth, which promoted greater photosynthetic activity and accumulation of assimilates in the developing shoots. Similar observations were reported by Pawar *et al.* (2018) in custard apple.

Dry weight of shoot (g) effect of time

The results presented in Table 5 indicated that the time of grafting influenced the dry weight of the shoot. The highest shoot dry weight was recorded in G₅ (9.25) was at par with G₄ (8.71) and followed by G₃ (8.62) and G₂ (8.60). The lowest shoot dry weight was observed in G₁ (7.75).

Table 5. Effect of time and length of scion stick on fresh weight of shoot and dry weight of shoot (g)

Treatment	Fresh weight of shoot	Dry weight of shoot
Time of grafting (G)		
G ₁	22.19	7.75
G ₂	24.50	8.60
G ₃	24.56	8.62
G ₄	24.81	8.71
G ₅	26.38	9.25
SEm ±	0.58	0.20
C.D.at5%	1.65	0.58

Treatment	Fresh weight of shoot	Dry weight of shoot
Length of scion (L)		
L ₁	22.25	7.85
L ₂	23.85	8.31
L ₃	27.15	9.54
L ₄	24.70	8.66
SEm ±	0.52	0.18
C.D.at5%	1.47	0.52
Interaction effect (G x L)		
G ₁ L ₁	18.00	6.48
G ₁ L ₂	21.00	7.07
G ₁ L ₃	26.75	9.38
G ₁ L ₄	23.00	8.06
G ₂ L ₁	21.75	7.64
G ₂ L ₂	24.00	8.43
G ₂ L ₃	27.00	9.47
G ₂ L ₄	25.25	8.82
G ₃ L ₁	23.50	8.25
G ₃ L ₂	24.00	8.40
G ₃ L ₃	26.25	9.23
G ₃ L ₄	24.50	8.58
G ₄ L ₁	23.00	8.08
G ₄ L ₂	24.25	8.48
G ₄ L ₃	27.50	9.66
G ₄ L ₄	24.50	8.61
G ₅ L ₁	25.00	8.75
G ₅ L ₂	26.00	9.12
G ₅ L ₃	28.25	9.92
G ₅ L ₄	26.25	9.19
General Mean	24.49	8.59
SEm ±	1.16	0.41
C.D.at5%	NS	NS

Effect of length of scion stick

The results presented in Table 5 indicated that the length of the scion had a noticeable influence on shoot dry weight. The highest dry weight of shoot was recorded with 10 cm long scions (L₃), which was (9.54) followed by L₄ (8.66) and L₂ (8.31). Lowest shoot dry weight was recorded with 6 cm long scions (L₁), at (7.85). Similar observations were reported by Pawar *et al.* (2018) in custard apple, where successful softwood grafting resulted in greater shoot dry matter accumulation, improved graft survival and vigorous shoot growth.

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to dry weight of shoot was non-significant. Maximum dry weight of shoot (9.92) was recorded in G₅L₃ was at par with G₄L₃ (9.66), G₂L₃ (9.47), G₁L₃ (9.38), G₃L₃ (9.23), G₅L₄ (9.19) (9.12) and G₅L₁ (8.75). However minimum dry weight of shoot (6.48) was recorded in G₁L₁.

B) Root character

The data showed in Table 4.27 in regards to time of grafting revealed that maximum length of root (27.00) was recorded in the G_5 which was followed by G_4 (24.75), G_3 (22.88) and G_2 (20.56) respectively. Minimum length of root (18.94) was recorded in G_1 . The greater root length observed in G_5 may be due to favourable environmental conditions that supported better graft establishment and improved nutrient uptake, thereby encouraging root growth. The variation in length of root in cashew grafts has been also reported by Sardar *et al.* (1991) and Roshan *et al.* (2013) in aonla, which supports the present findings.

Effect of length of scion

The data showed in Table 4.27 in regards to different length of scion revealed that maximum length of root (23.60) was recorded in the L_3 which was followed by L_4 (22.90) and L_2 (22.70) respectively. Minimum length of root (21.10) was recorded in L_1 . The better performance of L_3 may be attributed to sufficient food reserves and vigorous scion growth, which provided more assimilates for root development. Similar result was reported by Amrita *et al.* (2019) [11].

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to length of root was non-significant. Maximum length of root (27.75) was recorded in G_{5L3} , was at par with G_{5L2} (27.00), G_{5L4} (26.75) and G_{5L1} (26.50). However minimum length of root (17.75) was recorded in G_{1L1} . The highest root length in G_{5L3} may therefore be the result of favourable grafting conditions combined with an optimum scion length.

Fresh weight of root (g) effect of time

The data showed in Table 6 in regards to time of grafting revealed that maximum fresh weight of root (24.81) was recorded in the G_5 which was followed by G_4 (24.13), G_3 (23.41) and G_2 (22.94) respectively. Minimum fresh weight of root (22.09) was recorded in G_1 . The higher fresh root weight in G_5 may be due to favourable growing conditions that encouraged better root growth and biomass accumulation. Hussain *et al.* (1997) [12] observed significant difference in fresh weight of roots in sapota grafts. Roshan *et al.* (2013) also observed such difference in sapota grafts, which confirms present finding.

Effect of scion stick

The data showed in Table 6 in regards to different length of scion revealed that maximum fresh weight of root (24.65) was recorded in L_3 which was followed by L_4 (23.40) and L_2 (23.18) respectively. Minimum fresh weight of root (22.68) was recorded in L_1 . The greater value with L_3 may be attributed to better graft establishment and healthy plant growth, which supported stronger root development. Similar result was reported by Amrita *et al.* (2019) [11] and Ashok *et al.* (2020) [13].

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to fresh weight of root was non-significant. Maximum fresh weight of root (25.75) recorded in G_{5L3} , was at par with G_{4L3} (25.50) and G_{5L2} (24.75). However minimum fresh weight of root (21.37) was recorded in G_{1L1} . The highest fresh root weight in G_{5L3} may therefore be due to the combined benefit of suitable grafting conditions and optimum scion length.

Dry weight of root (g) effect of time

The data showed in Table 6 in regards to time of grafting revealed that maximum dry weight of root (9.41) was recorded in the G_5 which was followed by G_4 (8.47), G_3 (8.03) and G_2 (7.25) respectively. Minimum dry weight of root (5.94) was recorded in G_1 . The higher root dry weight in G_5 may be due to better root activity and efficient use of available nutrients, which helped in building up more dry mat-

ter. The similar result regarding dry weight of roots in aonla grafts has been reported by Roshan *et al.* (2013) which support the present finding.

Effect of scion stick

The data showed in Table 6 in regards to different length of scion revealed that maximum dry weight of root (8.75) was recorded in L_3 which was followed by L_4 (7.83) and L_2 (7.75) respectively. Minimum dry weight of root (6.95) was recorded in L_1 . The greater root dry weight with L_3 may be attributed to stronger root growth and better movement of food materials towards the roots, resulting in increased dry matter accumulation. Similar result was reported by Amrita *et al.* (2019) [11] and Ashok *et al.* (2020) [13].

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to dry weight of root was non-significant. Maximum dry weight of root (10.50) was recorded in G_{5L3} . However minimum dry weight of root (5.00) was recorded in G_{1L1} . The maximum value in G_{5L3} may be because of a better balance between shoot and root growth, which favoured greater dry matter accumulation in the roots.

Table 6. Effect of time and length of scion stick on length of root (cm), Dry weight of root and fresh weight of root (g).

Treatment	Length of root(cm)	Fresh weight of root (g)	Dry weight of root (g)
Time of grafting (G)			
G_1	18.94	22.09	5.94
G_2	20.56	22.94	7.25
G_3	22.88	23.41	8.03
G_4	24.75	24.13	8.47
G_5	27.00	24.81	9.41
SEm $\pm$	0.26	0.18	0.16
C.D.at 5%	0.75	0.51	0.46
Length of scion (L)			
L_1	21.10	22.68	6.95
L_2	22.70	23.18	7.75
L_3	23.60	24.65	8.75
L_4	22.90	23.40	7.83
SEm $\pm$	0.23	0.16	0.14
C.D.at 5%	0.67	0.46	0.41
Interaction effect (G x L)			
G_{1L1}	17.75	21.37	5.00
G_{1L2}	18.50	22.00	6.25
G_{1L3}	20.25	22.87	6.75
G_{1L4}	19.00	22.12	5.75
G_{2L1}	19.50	21.75	6.25
G_{2L2}	20.75	22.05	7.75
G_{2L3}	21.25	24.50	8.25
G_{2L4}	19.75	23.00	6.75
G_{3L1}	22.75	22.75	7.50
G_{3L2}	22.75	22.87	7.37
G_{3L3}	23.00	24.62	8.75
G_{3L4}	22.00	23.37	8.50
G_{4L1}	23.25	23.25	7.62
G_{4L2}	24.50	23.75	8.12
G_{4L3}	25.75	25.50	9.50
G_{4L4}	25.00	24.00	8.62
G_{5L1}	26.50	24.25	8.37

(continued on next page)

Treatment	Length of root(cm)	Fresh weight of root (g)	Dry weight of root (g)
G ₅ L ₂	27.00	24.75	9.25
G ₅ L ₃	27.75	25.75	10.50
G ₅ L ₄	26.75	24.50	9.50
General	22.70	23.48	7.82
Mean			
SEm ±	0.53	0.36	0.32
C.D.at 5%	NS	NS	NS

Conclusion

Based on present investigation entitled “Standardization of grafting technique in *Annona atemoya* L. (Hanumanphal)”, it can be concluded that minimum days required for sprouting, days taken for first leaf opening and mortality percentages, maximum number of sprouts, leaf area, success rate, fresh weight of shoot, dry weight of shoot, length of root, fresh and dry weight of root can be made successfully on 15th December (G₅) and 10 cm (L₃) long scion sticks. Whereas, maximum days required for sprouting, days taken for first leaf opening and mortality percentages, minimum number of sprouts, leaf area, success rate, fresh weight of shoot, dry weight of shoot, length of root, fresh and dry weight of root were recorded when graft made on 15th December (G₁) and 6 cm (L₁) long scion sticks.

References

1. Morton JF. Custard Apple. In: Fruits of warm climates. Miami, USA: Julia F. Morton; 1987:80-83.
2. Kudmulwar RR, Kulkarni RM, Bodamwad SG, Katkar PB, Dugmod SB. Standardization of soft wood grafting season on success of custard apple (*Annona squamosa* L.). The Asian J. Hort. 2008;3(2):281-282.
3. Khopade R, Jadhav RG. Effect of different grafting dates and wrapping materials on success of softwood grafting in custard apple (*Annona squamosa* L.) cv. local selection. Int. J. of Agri. Sci. 2013;9(2):806-808.
4. Gurudutta PS, Jain V, Singh PN. Response of mango, cultivars to epicotyl grafting. Indian J. Hort. 2004;61(3):267.
5. Ghojage AH, Swamy GSK, Kanamadi VC, Jagdeesh RC, Kumar P, Patil CP, et al. Effect of season on softwood grafting in jamun (*Syzygium cumini*, Skeels.). Acta Horticulturae. 2011;890:123-127.
6. Gadekar A, Bharad SG, Mane VP, Sarika Patil SP. Seasonal variation in success of softwood grafting of jamun under Akola conditions. 2010.
7. Alam MA, Islam MS, Uddin MZ, Barman JC, Quamruzzaman AKM. Effect of Age of Seedling and Variety of Scion in Stone Grafting of Mango. Int. J. Sustain. Crop Prod. 2006;1(2):27-32.
8. Nalage NA, Magar SD, Bhosale SS, Mhetre DA. Study on the effect of length of scion stick on success of epicotyl grafting in mango (*Mangifera indica* L.) cv. Kesar. The Asian Journal of Horticulture. 2010;5(2):506-509.
9. Kumar, Shukla AK. Standardization of bench grafting in Custard apple. Hort. flora Reaserch Spectrum. 2012;1(2):149-152.
10. Mulla BR, Angadi SG, Mathad JC, Patil VS, Mummigatti UV. Studies on softwood grafting in jamun (*Syzygium cumini* Skeels). Karnataka J. Agric. Sci. 2011;24(3):366-368.
11. Amrita T, Dilip RK, Nesara B, Khamrang M, Sabastian KS. Influence of grafting height and scion length on healing of graft union and growth characteristics of *Citrus reticulata* cv. Nagpur Mandarin grafted on Rough Lemon rootstocks. Int. J. Curr. Microbiol. App. Sci. 2019;8(3):2066-2074.
12. Hussain Amir, Bukhari Mushtaq Ahmad. Performance of different grafting methods in chiku (Acharas sapota). Pak. J. Bot. 1997;9(1):47-57.
13. Ashok K, Devender C, Arvind M, Sarita D, Bishnoi OP. Effect of rootstock thickness on wedge grafting in guava (*Psidium guajava* L.) under different growing conditions. The Pharma Innovation J. 2020;9(12):162-169.
14. Chovatia RS, Singh SP. Effect of time on budding and grafting success in jamun (*Syzygium cumini* Skeel). Indian Journal of Horticulture. 2000;57(3):255-258.

How to cite this article: Jadhav M, Munde G, Ovhal S, Magar M, Bhujbal R. Standardization of grafting technique in *Annona atemoya* L. (Hanumanphal). *International Journal of Research in Agronomy*. 2026;9(9):965-972. doi: <https://www.doi.org/10.3354/5/2618060X.2026.v9.i9m.6631>