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Effect of time of grafting and length of scion in *Annona reticulata* L. (Bullock's heart)

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Abstract
The present investigation entitled "Standardization of grafting technique in *Annona reticulata* L. (Bullock's heart)" was conducted at Custard Apple Research Station, Ambajogai during the year of 2024-2025. The investigation was carried out with twenty treatment combination comprising five different time of grafting (1st March, 15th March, 1st April, 15th April and 1st May) 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. Minimum days required for sprouting (12.63), days taken for first leaf opening (13.56) and mortality percentages after 30 and 120 days (5.31 and 10.00%), maximum leaf area (44.31, 50.31, 56.31 and 62.31 cm^2), length of shoot (8.94, 13.44, 17.94 and 21.25 cm), diameter of shoot (0.84, 1.69, 2.38 and 3.01 mm), number of leaves (14.44, 28.69, 36.19 and 38.44) at 30, 60, 90 and 120 DAG respectively. Maximum success rate (94.69 and 90.00%) at 30 and 120 days. Maximum length of root (27.00 cm), diameter of root (2.68 mm), fresh and dry weight of root (25.06 and 9.22 g) after 120 days was found when grafting can be made successfully on 15th March (G_2) and 10 cm (L_3) long scion sticks. From the results of present investigation, it can be inferred that softwood grafting in bullock's heart (*Annona reticulata* L.) can be done successfully when 10 cm long scion sticks were grafted on 15th March recording maximum number of sprouted grafts, minimum days taken for first leaf opening, maximum number of leaves per graft along with minimum mortality and highest percentage of survival.

Keywords: Bullock's heart, success, mortality, percentage, scion

Introduction
Bullock's heart (*Annona reticulata* L.) is an important dry land crop which is usually cultivated in homestead gardens in Konkan region. There are about 166 species in the genus *Annona*, of which a small number are extensively grown for their delicious fruits. Tropical America is the birthplace of Bullock's heart. The diploid Custard apple species *Annona reticulata* L. has chromosomal number 2n=14. Worldwide, there is a widespread cultivation of bullock's heart. It is grown for edible fruit throughout Southeast Asia and the West Indies (Jansen *et al*., 1991) [12]. Basically, it's a tropical fruit that needs a gentler temperature than *Annona squamosa*. It grows successfully to an altitude of 1200 meters. It favors a humid environment and is less drought tolerant than sugar apples (Jansen *et al*., 1991) [12]. The plant may thrive on a wide range of pH-range soil types. Since it cannot withstand water logging, it grows best in low-lying, rich, deep soil with adequate rainfall and good drainage (Lim, 2012) [16]. The fruit has 76.8% moisture, 1.4% protein, 0.2% fat, 0.7% minerals, 5.2% fiber, 15.7% carbohydrates, 0.01% calcium, 0.01% phosphorus and 0.006% iron, according to Gopalan *et al*. (1993) [8]. The insecticidal effects of an extract derived from the seeds were reported by Ohsawa *et al*. (1990) [20] from Japan. The need for Bullock's heart in local markets is growing, thus it is necessary to try methodical crop improvement, propagation and planting methods. Seeds are typically used for propagation, but budding can also be an effective method.

Materials and Methods
The experiment was conducted at Custard Apple Research Station, Ambajogai during the year of 2024-2025. 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 (1st March, 15th March, 1st April, 15th April and 1st May) were combined with length of scion (6, 8, 10 and 12 cm).

The various observations were recorded at 30 days intervals to the period of four months. The statistical analysis of data was done according to standard procedure given by Panse and Sukhatme (1996) [21]. Following treatment combination were employed.

Table 1: Treatment combination

Sr. No.	Treatment combination
1	G_1L_1
2	G_1L_2
3	G_1L_3
4	G_1L_4
5	G_2L_1
6	G_2L_2
7	G_2L_3
8	G_2L_4
9	G_3L_1
10	G_3L_2
11	G_3L_3
12	G_3L_4
13	G_4L_1
14	G_4L_2
15	G_4L_3
16	G_4L_4
17	G_5L_1
18	G_5L_2
19	G_5L_3
20	G_5L_4

Results and Discussion

Growth Character

Days required for sprouting

Effect of time

It is obvious from the data in table 2 that the grafts made on 15th March (G_2), took significantly the minimum (12.63) days to sprout followed by G_3 (12.69), G_1 (13.63) and G_4 (14.19), while the maximum (15) days were taken to sprout the grafts made on 1st May (G_5). These variations could be attributed due to genetic makeup of scions which influences the histological as well as metabolic processes at graft union. The higher cell activity resulted in early sprouting of scion similar result was obtained by Kudmulwar *et al*. (2008) [14] in custard apple. The variation regarding number of days required for sprouting of custard apple grafts has been reported by Khopade and Jadhav (2013) [13] variations in the range of 12.66 to 22.40 days for sprouting of custard apple grafts.

Effect of length of scion stick

The data presented in Table 2 revealed that there were significant difference in days required to sprout the graft, when different length of scion sticks were used during the course of study. Significantly minimum (13.25) days were recorded to sprout, when 10 cm length of scion sticks (L_3) was used for grafting, while maximum (14.25) days were recorded to sprout, when 6 cm length of scion (L_1) was used for grafting. The results obtained by Purbiati *et al*. (1991) [21] and Gurudutta *et al*. (2004) [10] are in consonance with the present study.

Interaction effect

It is observed from the data shown in Table 2 that the statistical interaction effect between time and length of scion sticks were found significant with respect to days required to sprout the grafts. It was observed that the treatment G_2L_2, required minimum (11.50) days to sprout the grafts. On the contrary, Maximum (15.75) days were recorded to sprout the grafts when grafts were made on 1st May with 12 cm long scion sticks.

Days taken for first leaf opening

Effect of time

There was a significant difference in effect of time with regard to days taken for first leaf opening (Table 2). Minimum days (13.56) were recorded when graft made on 15th March (G_2), followed by G_1 (13.69), G_3 (14.50) and G_4 (14.69), whereas graft made on 1st May (G_5) took maximum days (15.38) for first leaf opening. The results obtained by Usare (2016) [32] are in consonance with the present study.

Effect of length of scion stick

The data showed in Table 2 revealed that there were significant difference in days taken for first leaf opening, when different length of scion sticks were used during the course of study. Significantly minimum (13.85) days were recorded to sprout, when 10 cm length of scion sticks (L_3) was used for grafting, while maximum (14.85) days were recorded to sprout, when 6 cm length of scion (L_1) was used for grafting. The results obtained by Purbiati *et al*. (1991) [21] and Gurudutta *et al*. (2004) [10] are in consonance with the present study.

Table 2: Effect of time and length of scion on days required for sprouting and days taken for first leaf opening

Treatment	Days required for sprouting	Days taken for first leaf opening
Time of grafting (G)		
G_1	13.63	13.63
G_2	12.63	13.56
G_3	12.69	14.50
G_4	14.19	14.69
G_5	15.00	15.38
SEm±	0.23	0.15
C.D. at 5%	0.65	0.43
Length of scion (L)		
L_1	14.25	14.85
L_2	13.30	14.05
L_3	13.25	13.85
L_4	13.70	14.65
SEm±	0.20	0.13
C.D. at 5%	0.58	0.38
Interaction effect (G x L)		
G_1L_1	15.25	13.75
G_1L_2	15.00	13.00
G_1L_3	12.50	14.50
G_1L_4	11.75	13.25
G_2L_1	13.00	14.50
G_2L_2	11.50	13.50
G_2L_3	12.50	12.00
G_2L_4	13.50	14.25
G_3L_1	13.25	14.00
G_3L_2	12.75	14.75
G_3L_3	12.50	13.50
G_3L_4	12.25	15.75
G_4L_1	15.00	15.50
G_4L_2	13.25	14.50
G_4L_3	13.25	13.75
G_4L_4	15.25	15.00
G_5L_1	14.75	16.50
G_5L_2	14.00	14.50
G_5L_3	15.50	15.50
G_5L_4	15.75	15.00
General Mean	13.62	14.35
SEm±	0.46	0.30
C.D. at 5%	1.30	0.86

Interaction effect

It is revealed from the data shown in Table 2 that the interaction effect between time of grafting and length of scion sticks were found significant with respect to days taken for first leaf opening. It was observed that significantly minimum days required for first leaf opening was recorded in treatment G_2L_3 (12.00), while maximum days (16.50) were recorded in G_5L_1.

Leaf area (cm^2)

Effect of time

At 30 DAG, the data showed in Table 3 in respect of leaf area per graft revealed that maximum leaf area was recorded in G_2 (44.31 cm^2) which was followed by G_1 (40.56 cm^2), G_3 (38.38 cm^2) and G_4 (36.19 cm^2), respectively. Minimum leaf area was recorded in G_5 (34.13 cm^2). At 60 DAG, maximum leaf area was recorded in G_2 (50.31 cm^2) which was followed by G_1 (46.56 cm^2), G_3 (44.25 cm^2) and G_4 (42.19 cm^2), respectively. Minimum leaf area was recorded in G_5 (40.13 cm^2). At 90 DAG, maximum leaf area was recorded in G_2 (56.31 cm^2) which was followed by G_1 (52.56 cm^2), G_3 (50.88 cm^2) and G_4 (48.19 cm^2), respectively. Minimum leaf area was recorded in G_5 (46.13 cm^2). At 120 DAG, maximum leaf area was recorded in G_2 (62.31 cm^2) which was followed by G_1 (58.56 cm^2), G_3 (56.88 cm^2) and G_4 (54.19 cm^2), respectively. Minimum leaf area was recorded in G_5 (52.13 cm^2). Similar result was observed by Gadekar *et al*. (2010) [6] who reported that, maximum leaf area (43.29) was found in jamun. Alam *et al*. (2006b) [1] and Ram *et al*. (2012) [26] also observed significant differences in leaf area in grafts of different mango varieties.

Effect of length of scion stick

Leaf area significantly influenced by different length of scion sticks. Maximum leaf area (40.90, 46.90, 53.40 and 59.40 cm^2) was recorded in L_3. While minimum (37.00, 43.00, 49.00 and 55.00 cm^2) leaf area was recorded in L_1 at 30, 60, 90 and 120 days after grafting respectively. This might be due to bigger size of the leaf. Similar results are in accordance with Nalage *et al*. (2010b) [19].

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) was non-significant at 30, 60, 90 and 120 days after grafting. Maximum leaf area (47.25, 53.25, 59.25 and 65.25 cm^2) was recorded in G_2L_3. While minimum (32.75, 38.75, 44.75 and 50.75 cm^2) leaf area was recorded in G_5L_1 at 30, 60, 90 and 120 DAG respectively.

Length of shoot (cm)

Effect of time

The data pertaining to length of shoot as influenced by different grafting time are presented in Table 4. After 30 days of grafting, there was significant variation in length of shoot. The highest length of shoot (8.94 cm) was recorded in G_2 followed by G_1 (8.00 cm), G_3 (7.06 cm). While minimum (6.44 cm) length of shoot was recorded in G_5 which was at par with G_4 (6.81 cm). After 60 days of grafting, there was significant variation in length of shoot. The highest length of shoot (13.44 cm) was recorded in G_2 followed by G_1 (12.5 cm), G_3 (11.56 cm). While lowest length of shoot (10.94 cm) was recorded in G_5 which was at par with G_4 (11.31 cm). After 90 days of grafting, there was significant variation in length of shoot. The highest length of shoot (17.94 cm) was recorded in G_2 followed by G_1 (17.00 cm), G_3 (16.06 cm). While lowest length of shoot (15.44 cm) was recorded in G_5 which was at par with G_4 (15.81 cm). After 120 days of grafting, there was significant variation in length of shoot. The highest length of shoot (21.25 cm) was recorded in G_2 followed by G_1 (19.75 cm). While lowest (18.19 cm) length of shoot was recorded in G_5 which was at par with G_3 (18.81 cm) and G_4 (18.56 cm). Maximum vegetative growth was observed in guava when grafted in August, according to Gotur *et al*. (2017) [9].

Table 3: Effect of time and length of scion on leaf area (cm^2) at 30, 60, 90 and 120 DAG

Treatment	30 DAG	60 DAG	90 DAG	120 DAG
Time of grafting (G)				
G_1	40.56	46.56	52.56	58.56
G_2	44.31	50.31	56.31	62.31
G_3	38.38	44.25	50.88	56.88
G_4	36.19	42.19	48.19	54.19
G_5	34.13	40.13	46.13	52.13
SEm±	0.47	0.47	0.54	0.54
C.D. at 5%	1.33	1.33	1.53	1.53
Length of scion (L)				
L_1	37.00	43.00	49.00	55.00
L_2	37.80	43.80	49.80	55.80
L_3	40.90	46.90	53.40	59.40
L_4	39.15	45.05	51.05	57.05
SEm±	0.42	0.42	0.48	0.48
C.D. at 5%	1.19	1.19	1.37	1.37
Interaction effect (G x L)				
G_1L_1	38.25	44.25	50.25	56.25
G_1L_2	39.00	45.00	51.00	57.00
G_1L_3	43.50	49.50	55.50	61.50
G_1L_4	41.50	47.50	53.50	59.50
G_2L_1	42.50	48.50	54.50	60.50
G_2L_2	43.75	49.75	55.75	61.75
G_2L_3	47.25	53.25	59.25	65.25
G_2L_4	43.75	49.75	55.75	61.75
G_3L_1	36.50	42.50	48.50	54.50
G_3L_2	37.00	43.00	49.00	55.00
G_3L_3	40.75	46.75	55.25	61.25
G_3L_4	39.25	44.75	50.75	56.75
G_4L_1	35.00	41.00	47.00	53.00
G_4L_2	35.50	41.50	47.50	53.50
G_4L_3	37.50	43.50	49.50	55.50
G_4L_4	36.75	42.75	48.75	54.75
G_5L_1	32.75	38.75	44.75	50.75
G_5L_2	33.75	39.75	45.75	51.75
G_5L_3	35.50	41.50	47.50	53.50
G_5L_4	34.50	40.50	46.50	52.50
General Mean	38.71	44.68	50.81	56.81
SEm±	0.94	0.94	1.08	1.08
C.D. at 5%	NS	NS	NS	NS

Effect of length of scion stick

The length of shoot was significantly influenced at 30, 60, 90 and 120 days after grafting. Maximum shoot length (8.80, 14.80, 20.80 and 24.75 cm) was recorded in L_3. While minimum (6.70, 9.70, 12.70 and 14.70 cm) shoot length was recorded in L_1 at 30, 60, 90 and 120 days after grafting respectively. Similar results are in accordance with Nalage *et al*., (2010b) [19].

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to shoot length was non-significant at 30, 60, 90 and 120 days after grafting. Maximum shoot length (11.00, 17.00, 23.00 and 26.75 cm) was recorded in G_2L_3. While minimum (6.00, 9.00, 12.00 and 14.00 cm) shoot length was recorded in G_5L_1 at 30, 60, 90 and 120 DAG respectively.

Table 4: Effect of time and length of scion on length of shoot (cm) at 30, 60, 90 and 120 DAG

Treatment	30 DAG	60 DAG	90 DAG	120 DAG
Time of grafting (G)				
G_1	8.00	12.50	17.00	19.75
G_2	8.94	13.44	17.94	21.25
G_3	7.06	11.56	16.06	18.81
G_4	6.81	11.31	15.81	18.56
G_5	6.44	10.94	15.44	18.19
SEm±	0.20	0.20	0.20	0.31
C.D. at 5%	0.57	0.57	0.57	0.89
Length of scion (L)				
L_1	6.70	9.70	12.70	14.70
L_2	6.95	10.95	14.95	16.95
L_3	8.80	14.80	20.80	24.75
L_4	7.35	12.35	17.35	20.85
SEm±	0.18	0.18	0.18	0.28
C.D. at 5%	0.51	0.51	0.51	0.80
Interaction effect (G x L)				
G_1L_1	7.00	10.00	13.00	15.00
G_1L_2	7.50	11.50	15.50	17.50
G_1L_3	9.50	15.50	21.50	25.50
G_1L_4	8.00	13.00	18.00	21.00
G_2L_1	7.50	10.50	13.50	15.50
G_2L_2	8.25	12.25	16.25	18.25
G_2L_3	11.00	17.00	23.00	26.75
G_2L_4	9.00	14.00	19.00	24.50
G_3L_1	6.50	9.50	12.50	14.50
G_3L_2	6.25	10.25	14.25	16.25
G_3L_3	8.75	14.75	20.75	24.75
G_3L_4	6.75	11.75	16.75	19.75
G_4L_1	6.50	9.50	12.50	14.50
G_4L_2	6.50	10.50	14.50	16.50
G_4L_3	7.75	13.75	19.75	23.75
G_4L_4	6.50	11.50	16.50	19.50
G_5L_1	6.00	9.00	12.00	14.00
G_5L_2	6.25	10.25	14.25	16.25
G_5L_3	7.00	13.00	19.00	23.00
G_5L_4	6.50	11.50	16.50	19.50
General mean	7.45	11.95	16.45	19.31
SEm±	0.40	0.40	0.40	0.63
C.D. at 5%	NS	NS	NS	NS

Diameter of shoot (mm)

Effect of time

A perusal of data quantified in Table 5 clearly indicates that different time of grafting had a significant effect on average diameter of shoots at 30, 60, 90 and 120 days after grafting. Grafting performed on 15th March (G_2) recorded maximum diameter of shoot (0.84, 1.69, 2.38 and 3.01 mm) at 30, 60, 90 and 120 DAG respectively. However, grafting performed on 1st May (G_5) recorded minimum diameter of shoot (0.53, 1.39, 2.13 and 2.78 mm) at 30, 60, 90 and 120 DAG respectively. Similar results are in accordance with Singh and Singh (2007) [31].

Effect of length of scion stick

The data presented in Table 5 has clearly indicated that different length of scion had significant effect on average diameter of shoots at 30, 60, 90 and 120 days after grafting. Grafting performed on 10 cm length of scion (L_3) has recorded maximum diameter of shoot (0.77, 1.77, 2.62 and 3.35 mm) at 30, 60, 90 and 120 DAG respectively. However, grafting performed on 6 cm length (L_1) recorded minimum diameter of shoot (0.58, 1.28, 1.87 and 2.39 mm) at 30, 60, 90 and 120 DAG respectively. Similar result was obtained by Alam *et al*. (2006) [2].

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to diameter of shoot was non-significant at 30, 60, 90 and 120 days after grafting. Maximum diameter of shoot (1.05, 2.05, 2.70 and 3.35 mm) was recorded in G_2L_3. While minimum diameter of shoot (0.47, 1.17, 1.75 and 2.30 mm) was recorded in G_5L_1 at 30, 60, 90 and 120 DAG respectively.

Table 5: Effect of time and length of scion on diameter of shoot (mm) at 30, 60, 90 and 120 DAG

Treatment	30 DAG	60 DAG	90 DAG	120 DAG
Time of grafting (G)				
G_1	0.69	1.54	2.29	2.96
G_2	0.84	1.69	2.38	3.01
G_3	0.66	1.51	2.27	2.94
G_4	0.63	1.48	2.23	2.87
G_5	0.53	1.39	2.13	2.78
SEm±	0.02	0.02	0.03	0.03
C.D. at 5%	0.07	0.07	0.09	0.10
Length of scion (L)				
L_1	0.58	1.28	1.87	2.39
L_2	0.61	1.41	2.12	2.81
L_3	0.77	1.77	2.62	3.35
L_4	0.72	1.62	2.42	3.12
SEm±	0.02	0.02	0.02	0.03
C.D. at 5%	0.06	0.06	0.08	0.09
Interaction effect (G x L)				
G_1L_1	0.62	1.32	1.92	2.42
G_1L_2	0.60	1.40	2.10	2.77
G_1L_3	0.77	1.77	2.67	3.50
G_1L_4	0.75	1.65	2.45	3.15
G_2L_1	0.70	1.40	2.00	2.50
G_2L_2	0.70	1.50	2.20	2.90
G_2L_3	1.05	2.05	2.70	3.35
G_2L_4	0.92	1.80	2.60	3.30
G_3L_1	0.55	1.25	1.85	2.35
G_3L_2	0.62	1.42	2.17	2.87
G_3L_3	0.75	1.75	2.65	3.45
G_3L_4	0.70	1.60	2.40	3.10
G_4L_1	0.52	1.22	1.82	2.35
G_4L_2	0.57	1.37	2.07	2.77
G_4L_3	0.75	1.75	2.65	3.30
G_4L_4	0.65	1.55	2.35	3.05
G_5L_1	0.47	1.17	1.75	2.30
G_5L_2	0.55	1.35	2.02	2.72
G_5L_3	0.52	1.52	2.42	3.12
G_5L_4	0.57	1.50	2.30	2.97
General Mean	0.67	1.52	2.26	2.91
SEm±	0.05	0.05	0.06	0.07
C.D. at 5%	NS	NS	NS	NS

Number of leaves per graft

Effect of time

Leaf is important photosynthetic site of plant and its primary function is carbon assimilation. The data regarding number of leaves per graft as affected by different time of grafting are presented in Table 6. After 30 days from grafting, there was significant variation in number of leaves per graft. Maximum number of leaves per graft (14.44) was found in G_2 followed by G_1 (13.44), G_3 (12.44) and G_4 (11.44). Lowest number of leaves per graft (10.56) was recorded in G_5. After 60 days from grafting, there was significant variation in number of leaves per graft. Maximum number of leaves per graft (28.69) was found in G_2 followed by G_1 (27.69), G_3 (26.06) and G_4 (25.69). Lowest number of leaves per graft (24.81) was recorded in G_5. After 90 days from grafting, there was significant variation in number of leaves per graft. Maximum number of leaves per graft (36.19) was found in G_2 followed by G_1 (35.19), G_3 (33.56) and G_4 (33.19). Lowest number of leaves per graft (32.31) was recorded in G_5. After 120 days from grafting, there was significant variation in number of leaves per graft. Maximum number of leaves per graft (38.44) was found in G_2 followed by G_1 (37.44), G_3 (35.81) and G_4 (35.44). Lowest number of leaves per graft (34.38) was recorded in G_5. This is in conformation with the findings of Das *et al*. (2006) [5] and Ghosh *et al*. (2010) [7] in sapota.

Effect of length of scion stick

The data presented in Table 6 has clearly indicated that different length of scion had significant effect on number of leaves per graft at 30, 60, 90 and 120 days after grafting. Grafting performed on 10 cm length of scion (L_3) produced highest number of leaves (14.00, 28.25, 35.75 and 38.10) at 30, 60, 90 and 120 DAG respectively. However, grafting performed on 6 cm length of scion (L_1) resulted in minimum number of leaves (10.75, 25.00, 32.50 and 34.75) at 30, 60, 90 and 120 DAG respectively. Similar results were obtained by Seshadri and Rao (1985) [29] and Gurudutta *et al*. (2004) [10] in cashew and mango, respectively are in agreement with the present findings.

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to number of leaves per graft was non-significant at 30, 60, 90 and 120 days after grafting. Maximum number of leaves (16.00, 30.25, 37.75 and 40.00) was recorded in G_2L_3. While minimum number of leaves (8.75, 23.00, 30.50 and 32.75) was recorded in G_5L_1 at 30, 60, 90 and 120 DAG respectively.

Success rate (%)

Effect of time

The data presented in Table 7 in respect of success percent of Bullock's heart grafts was affected by different time of grafting. Maximum success was recorded in G_2 (94.69 and 90.00 percent) was followed by G_1 (92.50 and 88.00 percent), G_3 (89.31 and 84.19 percent) and G_4 (86.31 and 81.50 percent) at 30 and 120 DAG respectively. However minimum (82.56 and 77.63 percent) success was recorded in G_5 at 30 and 120 DAG respectively. Similar finding was also reported by Kumar and Shukla (2012) [15] in custard apple (96.4%).

Table 6: Effect of time and length of scion on number of leaves per graft at 30, 60, 90 and 120 DAG

Treatment	30 DAG	60 DAG	90 DAG	120 DAG
Time of grafting (G)				
G_1	13.44	27.69	35.19	37.44
G_2	14.44	28.69	36.19	38.44
G_3	12.44	26.06	33.56	35.81
G_4	11.44	25.69	33.19	35.44
G_5	10.56	24.81	32.31	34.38
SEm±	0.18	0.34	0.34	0.35
C.D. at 5%	0.53	0.98	0.98	0.99
Length of scion (L)				
L_1	10.75	25.00	32.50	34.75
L_2	12.00	26.25	33.75	36.00
L_3	14.00	28.25	35.75	38.10
L_4	13.10	26.85	34.35	36.35
SEm±	0.16	0.31	0.31	0.31
C.D. at 5%	0.47	0.87	0.87	0.89
Interaction effect (G x L)				
G_1L_1	11.75	26.00	33.50	35.75
G_1L_2	13.00	27.25	34.75	37.00
G_1L_3	15.00	29.25	36.75	39.00
G_1L_4	14.00	28.25	35.75	38.00
G_2L_1	12.75	27.00	34.50	36.75
G_2L_2	14.00	28.25	35.75	38.00
G_2L_3	16.00	30.25	37.75	40.00
G_2L_4	15.00	29.25	36.75	39.00
G_3L_1	10.75	25.00	32.50	34.75
G_3L_2	12.00	26.25	33.75	36.00
G_3L_3	14.00	28.25	35.75	38.00
G_3L_4	13.00	24.75	32.25	34.50
G_4L_1	9.75	24.00	31.50	33.75
G_4L_2	11.00	25.25	32.75	35.00
G_4L_3	13.00	27.25	34.75	37.00
G_4L_4	12.00	26.25	33.75	36.00
G_5L_1	8.75	23.00	30.50	32.75
G_5L_2	10.00	24.25	31.75	34.00
G_5L_3	12.00	26.25	33.75	36.50
G_5L_4	11.50	25.75	33.25	34.25
General Mean	12.46	26.58	34.08	36.30
SEm±	0.37	0.69	0.69	0.70
C.D. at 5%	NS	NS	NS	NS

Effect of length of scion stick

The data presented in Table 7 has clearly indicated that different length of scion had significant effect on success rate at 30 and 120 days after grafting. Grafting performed on 10 cm length of scion (L_3) had highest success rate (92.55 and 89.10 percent) at 30 and 120 DAG respectively. However, grafting performed on 6 cm length of scion (L_1) resulted in minimum success rate (85.40 and 79.15 percent) at 30 and 120 DAG respectively. Ratan *et al*. (1987) [27], Radhamony *et al*. (1989) [24] and Radha and Aravindakshan (1998) [23] also found the similar findings, which are in conformity with those of present study.

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to success rate was non-significant at 30 and 120 days after grafting. Maximum success rate (97.75 and 94.50 percent) was recorded in G_2L_3. While minimum success rate (78.25 and 71.50 percent) was recorded in G_5L_1 at 30 and 120 DAG respectively.

Mortality (%)

Effect of time

The data presented in Table 7 in respect of mortality of Bullock's heart grafts was affected by different length of scion. Minimum mortality was recorded in G_2 (5.31 and 10.00 percent) followed by G_1 (7.50 and 12.00 percent), G_3 (10.69 and 15.81 percent) and G_4 (13.69 and 18.50 percent) at 30 and 120 DAG respectively. However maximum mortality (17.44 and 22.38 percent) was recorded in G_5 at 30 and 120 DAG respectively. Similar result reported by Mulla *et al*. (2011) [18] in jamun and Raghvendra *et al*. (2011) in wood apple, which confirms the present findings.

Effect of length of scion stick

The data presented in Table 7 has clearly indicated that different length of scion had significant effect on mortality at 30 and 120 days after grafting. Grafting performed on 10 cm length of scion (L_3) had minimum mortality (7.45 and 10.90 percent) at 30 and 120 DAG respectively. However, grafting performed on 6 cm length of scion (L_1) resulted in maximum mortality (14.60 and 20.85 percent) at 30 and 120 DAG respectively. Ratan *et al*. (1987) [27], Radhamony *et al*. (1989) [24] also found the similar findings, which are in conformity with those of present study.

Interaction effect

Interaction effect between time of grafting (G) and length of scion stick (L) with regards to mortality was non-significant at 30 and 120 days after grafting. Minimum mortality (2.25 and 5.50 percent) was recorded in G_2L_3. However maximum mortality (21.75 and 28.50 percent) was recorded in G_5L_1 at 30 and 120 DAG respectively.

Root Character

Length of root (cm)

Effect of time

The data showed in Table 8 in regards to time of grafting revealed that maximum length of root (27.00 cm) was recorded in the G_2 which was followed by G_1 (24.88 cm), G_3 (22.69 cm) and G_4 (20.38 cm) respectively. Minimum length of root (19.00 cm) was recorded in G_5. The variation in length of root in cashew grafts has been also reported by Sardar *et al*. (1991) [30] and Roshan *et al*. (2013) [28] in aonla, which supports the present findings.

Effect of length of scion stick

The data showed in Table 8 in regards to different length of scion revealed that maximum length of root (23.80 cm) was recorded in the L_3 which was followed by L_4 (22.80 cm) and L_2 (22.65 cm) respectively. Minimum length of root (21.90 cm) was recorded in L_1. Similar result was reported by Amrita *et al*. (2019) [3].

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 cm) was recorded in G_2L_3. However minimum length of root (18.22 cm) was recorded in G_5L_1.

Diameter of root (mm)

Effect of time

The data showed in Table 8 in regards to time of grafting revealed that maximum diameter of root (2.68 mm) was recorded in the G_2 which was followed by G_1 (2.33 mm), G_3 (2.11 mm) and G_4 (1.80 mm) respectively. Minimum diameter of root (1.37 mm) was recorded in G_5. Similar result was reported by Makavana (2021) [17].

Effect of length of scion stick

The data showed in Table 8 in regards to different length of scion revealed that maximum diameter of root (2.73 mm) was recorded in the L_3 which was followed by L_4 (2.10 mm) and L_2 (1.82 mm) respectively. Minimum diameter of root (1.58 mm) was recorded in L_1. Similar result was reported by Amrita *et al*. (2019) [3].

Table 7: Effect of time and length of scion on success rate and mortality of graft at 30 and 120 DAG

Treatment	Success rate		Mortality rate	
	30 DAG	120 DAG	30 DAG	120 DAG
Time of grafting (G)				
G_1	92.50	88.00	7.50	12.00
G_2	94.69	90.00	5.31	10.00
G_3	89.31	84.19	10.69	15.81
G_4	86.31	81.50	13.69	18.50
G_5	82.56	77.63	17.44	22.38
SEm±	0.13	0.22	0.13	0.22
C.D. at 5%	0.37	0.62	0.37	0.62
Length of scion (L)				
L_1	85.40	79.15	14.60	20.85
L_2	88.20	83.00	11.80	17.00
L_3	92.55	89.10	7.45	10.90
L_4	90.15	85.80	9.85	14.20
SEm±	0.11	0.19	0.11	0.19
C.D. at 5%	0.33	0.55	0.33	0.55
Interaction effect (G x L)				
G_1L_1	88.75	82.75	11.25	17.25
G_1L_2	91.75	86.75	8.25	13.25
G_1L_3	95.75	92.75	4.25	7.25
G_1L_4	93.75	89.75	6.25	10.25
G_2L_1	91.50	85.50	8.50	14.50
G_2L_2	93.75	88.75	6.25	11.25
G_2L_3	97.75	94.50	2.25	5.50
G_2L_4	95.75	91.25	4.25	8.75
G_3L_1	85.75	79.50	14.25	20.50
G_3L_2	88.50	83.00	11.50	17.00
G_3L_3	92.75	88.50	7.25	11.50
G_3L_4	90.25	85.75	9.75	14.25
G_4L_1	82.75	76.50	17.25	23.50
G_4L_2	85.50	80.50	14.50	19.50
G_4L_3	89.75	86.50	10.25	13.50
G_4L_4	87.25	82.50	12.75	17.50
G_5L_1	78.25	71.50	21.75	28.50
G_5L_2	81.50	76.00	18.50	24.00
G_5L_3	86.75	83.25	13.25	16.75
G_5L_4	83.75	79.75	16.25	20.25
General Mean	89.07	84.26	10.92	15.73
SEm±	0.26	0.44	0.26	0.44
C.D. at 5%	NS	NS	NS	NS

Interaction effect

Interaction effect between time of grafting (G) and length of scion (L) with regards to diameter of root was non-significant. Maximum diameter of root (3.50 mm) was recorded in G_2L_3. However minimum diameter of root (1.10 mm) was recorded in G_5L_1.

Fresh weight of root (g)

Effect of time

The data showed in Table 8 in regards to time of grafting revealed that maximum fresh weight of root (25.06 g) was recorded in the G_2 which was followed by G_1 (23.94 g), G_3 (22.34 g) and G_4 (22.97 g) respectively. Minimum fresh weight of root (22.19 g) was recorded in G_5. Hussain and Bukhari (1997) [11] observed significant difference in fresh weight of roots in sapota grafts. Roshan *et al*. (2013) [28] also observed such difference in sapota grafts, which confirms present finding.

Effect of length of scion stick

The data showed in Table 8 in regards to different length of scion revealed that maximum fresh weight of root (24.63 g) was recorded in L_3 which was followed by L_4 (23.68 g) and L_2 (23.10 g) respectively. Minimum fresh weight of root (22.60 g) was recorded in L_1. Similar result was reported by Amrita *et al*. (2019) [3] and Ashok *et al*. (2020) [4].

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 (26.25 g) was recorded in G_2L_3. However minimum fresh weight of root (21.37 g) was recorded in G_5L_1.

Dry weight of root (g)

Effect of time

The data showed in Table 8 in regards to time of grafting revealed that maximum dry weight of root (9.22 g) was recorded in the G_2 which was followed by G_1 (8.59 g), G_3 (8.19 g) and G_4 (7.13 g) respectively. Minimum dry weight of root (6.13 g) was recorded in G_5. The similar result regarding dry weight of roots in aonla grafts has been reported by Roshan *et al*. (2013) [28] which support the present finding.

Effect of length of scion stick

The data showed in Table 8 in regards to different length of scion revealed that maximum dry weight of root (8.65 g) was recorded in L_3 which was followed by L_4 (8.00 g) and L_2 (7.63 g) respectively. Minimum dry weight of root (7.13 g) was recorded in L_1. Similar result was reported by Amrita *et al*. (2019) [3] and Ashok *et al*. (2020) [4].

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 (10.00 g) was recorded in G_2L_3. However minimum dry weight of root (5.50 g) was recorded in G_5L_1.

Table 8: Effect of time and length of scion on length, diameter, fresh and dry weight of root at 120 DAG

Treatment	Length of root (cm)	Diameter of root (mm)	Fresh weight of root (g)	Dry weight of root (g)
Time of grafting (G)				
G_1	24.88	2.33	23.94	8.59
G_2	27.00	2.68	25.06	9.22
G_3	22.69	2.11	23.34	8.19
G_4	20.38	1.80	22.97	7.13
G_5	19.00	1.37	22.19	6.13
SEm±	0.28	0.14	0.13	0.07
C.D. at 5%	0.82	0.39	0.38	0.21
Length of scion (L)				
L_1	21.90	1.58	22.60	7.13
L_2	22.65	1.82	23.10	7.63
L_3	23.80	2.73	24.63	8.65
L_4	22.80	2.10	23.68	8.00
SEm±	0.25	0.12	0.12	0.06
C.D. at 5%	0.73	0.35	0.34	0.18
Interaction effect (G x L)				
G_1L_1	22.75	1.67	23.25	7.87
G_1L_2	24.50	2.12	23.25	8.25
G_1L_3	26.50	3.07	25.25	9.37
G_1L_4	25.75	2.45	24.00	8.87
G_2L_1	26.25	2.00	24.25	8.37
G_2L_2	27.00	2.45	24.75	9.12
G_2L_3	27.75	3.50	26.25	10.00
G_2L_4	27.00	2.75	25.00	9.37
G_3L_1	22.75	1.55	22.25	7.37
G_3L_2	22.75	1.95	22.75	7.75
G_3L_3	23.25	2.80	24.75	8.87
G_3L_4	22.00	2.12	23.62	8.75
G_4L_1	19.50	1.57	21.87	6.50
G_4L_2	20.75	1.45	22.62	7.00
G_4L_3	21.25	2.37	24.25	8.00
G_4L_4	20.00	1.80	23.12	7.00
G_5L_1	18.24	1.10	21.37	5.50
G_5L_2	18.25	1.12	22.12	6.00
G_5L_3	20.25	1.87	22.62	7.00
G_5L_4	19.25	1.37	22.62	6.00
Mean	22.79	2.05	23.50	7.85
SEm±	0.57	0.28	0.26	0.14
C.D. at 5%	NS	NS	NS	NS

Conclusion

Based on present investigation entitled "Standardization of grafting technique in *Annona reticulata* L. (Bullock's heart)", it can be concluded that minimum days required for sprouting, days taken for first leaf opening and mortality percentages, maximum leaf area, length of shoot, diameter of shoot, number of leaves, success rate, length of root, diameter of root, fresh and dry weight of root can be made successfully on 15th March (G_2) and 10 cm (L_3) long scion sticks. Whereas, maximum days required for sprouting, days taken for first leaf opening and mortality percentages, minimum leaf area, length of shoot, diameter of shoot, number of leaves, success rate, length of root, diameter of root, fresh and dry weight of root were recorded when graft made on 1st May (G_5) and 6 cm (L_1) long scion sticks.

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