*Pak. J. Biotechnol. Vol. 21(1), 219-227, **2024,*** http://doi.org/10.34016/pjbt.2024.21.01.891

Research Article

OPEN ACCESS

Available on http://www.pjbt.org
Pakistan Journal of Biotechnology
(PJBT)
(P-ISSN: 1812-1837 and E-ISSN: 2312-7791)

COMPARATIVE EFFECTS OF VARIETIES AND ROOTSTOCK AGE ON SUCCESS AND SURVIVAL RATE OF EPICOTYL GRAFTING IN MANGO (MANGIFERA INDICA L.)

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Article Received 25-12-2023, Article Revised 27-02-2024, Article Accepted 10-03-2024.

ABSTRACT

Epicotyl grafting is considered as the most efficient grafting technique in mango (*Mangifera indica* L.) and it is also well documented for timely seedling production of desired varieties. Therefore, the present study was perceived to assess the success and survival rate of epicotyl grafting. The study was conducted using a container-based setup and involved two factors: three varieties (Langra, Sindhri, and Chaunsa) and four different rootstock ages (20, 30, 40, and 50 days). The experiment was carried out in Completely Randomized Design (CRD) with 36 treatment combinations distributed equally in three replications. The findings revealed that all the studied traits were significantly affected by varieties and rootstock ages. It was further noted that Chaunsa variety showed best results for most of the studied traits except days to bud break and first flush while 50 days old rootstock demonstrated satisfying results for most of the parameters followed by 40 days old rootstock while the lowest results for all the traits were found in 20 days old rootstock except days to bud break and first flush. It is concluded that well established rootstock of 50 days and Chaunsa variety were found best for epicotyl grafting in mango.

Key words: Epicotyl grafting, rootstock, varieties, success, survival

INTRODUCTION

Mango (*Mangifera indica*) belongs to the Anacardiaceae family; it is the choicest, traded, popular and widely cultivated fruit in the world (Naik & Kumar, 2020). Due to its appealing color, delicious flavor, and high nutritional value, mango has long been regarded as the "king of fruits" and is currently thought to be the most valuable tropical fruit (Ullah *et al*., 2017). It has got its origin from the southern part of Asia, especially from eastern India, Burma and the Andaman Islands (Honja, 2014). Mango is being cultivated in all tropical and Sub-tropical regions of Pakistan with total production area of each province include Punjab (54,000 hectares), Sindh (46,000 hectares), Balochistan (11,000 hectares) and Khyber Pakhtunkhwa (2,000 hectares). The major mango producing districts in Sindh province are Hyderabad, Mirpurkhas, TandoAllahayar and Sanghar. Likewise, Multan and Bahawalpur are the leading mango producing districts of Punjab (Statistics, 2018-19). There are more than 200 varieties that are cultivated in Pakistan, among them only a few varieties namely, Sindhri, Chaunsa, Langra, Neelum, and Anwar ratol are considered as commercial mango cultivars in Pakistan (Islam, 2004)

Mango is highly cross-pollinated heterozygous in nature that's why sexually raised plants usually acquire huge genetic variation and fails to produce identical true to type plants. Stone-propagated plants also have a long juvenile phase and poor performance (Bobade *et al*., 2018). Therefore, it must be propagated asexually to produce true-to-type off-springs. Moreover, most commercial varieties of mango are mono-embryonic. Thus, the grafting technique is needed to produce genetically identical copies of desired cultivars (Minja *et al*., 2017)

Among the several asexual methods, grafting is proposed as the most appropriate technique to preserve the fidelity of a given variety, allowing the production of offspring with similar characteristics to the mother plant. It involves joining a scion and a rootstock together, growing as a single plant with the scion becoming the upper fruiting part of the grafted plant and the rootstock developing into a root system. (Prasanth *et al*., 2006; Ladon *et al*., 2020). According to Mukherjee & Litz (2009), rootstocks can influence a variety of physical and pomological characteristics of grafted plants, including yield, tree growth habit, fruit maturity time, and size. Grafting has several benefits including early fruiting, reduced stature, and bushy canopy (Hartman *et al*., 2010). The majority of

improved cultivars are mono-embryonic, necessitating grafting to produce trees that are true to type. Additionally, some perform poorly because they are unsuited to tropical conditions. In Pakistan, the most commonly used techniques for successful grafting are veneer and cleft grafting that are being practiced commercially from ages (Karim 2004). However, establishing a grafted mango orchard of better tree architecture is somewhat difficult when done by veneer grafted plants because this technique failed to produce erect and spout plants of uniform canopy which is pre-requisite for successful modern mango orcharding (Soleimani *et al*., 2010)

Currently, among several grafting methods, epicotyl grafting is well-documented as a quick, affordable, and effective technique. Numerous researchers have reported success with epicotyl grafting (Jaganath *et al*., 2014; Mukharjee *et al*., 2009; Simon *et al*., 2010). This technique has been widely adopted in hot and humid climates where temperature reaches up to 40-45 ºC. But in Central and Northern conditions, this method has yet not been popularized (Baita 2009). Further studies in different climate zones are needed before recommending it to nurseries. The success of epicotyl grafting is dependent on a number of variables, including rootstock age, temperature, relative humidity, light, soil moisture, time, method of grafting, and the grafter's skill (Memon and Jamali, 2022).

Epicotyl grafting involves grafting the scion on the stem of the young seedlings, just above the embryonic leaves, and allowing the scion to grow out of the seedling. The newly germinated seedling under juvenile stage, are usually taken for epicotyl grafting, which may result into greater success of grafts. In addition, the type and age of rootstock are also crucial factors affecting the success rate, survival, and growth of mango grafts (Ghosh & Bera, 2015).

In view of the above mentioned evidences, this study was aimed to investigate the appropriate rootstock age and best mango varieties for epicotyl grafting having maximum success and survivability percentage.

MATERIALS AND METHODS

The present study was conducted during, 2022 at Horticulture Garden, Department of Horticulture, Sindh Agriculture University Tandojam, in order to perceive the effect of varieties and rootstock age on success and survivability of epicotyl grafting in mango.

Design and layout of the experiment: The experiment was conducted in Completely Randomized Design (CRD) with factorial arrangements. The experiment consisted of two factors viz. rootstock age and varieties. There were 36 experimental units distributed in three replications. For present study the rootstock of 20, 30, 40 and 50 days old and three popular varieties viz. Sindhri, Langra and Chaunsa were selected and epicotyl grafting was practiced in the month of July, where the average temperature ranged from 32-38 ºC during the study period.

Raising of the rootstocks: For the production of rootstocks desi mango stones were collected from healthy commercial mango orchards during June 2022 and dried properly under shade house for 48 hours where average diurnal temperature ranged from 42-45 ºC. The collected stones were washed properly with fungicide (Thiophanate methyl 20% 2g per 1litre water) for 5 minutes and the soaked stones were immediately planted in the growing media. The growing media was prepared by mixing decomposed bagasse, coco peat and canal silt with the ratio of 65: 5:30, respectively. The sun solarization of prepared media @ 55-60 ^{0}C was done for twenty four hours by using polyethylene sheets. The plastic bags of size 9 x 13 inches were used with drainage holes maintained at the bottom side of the bags. Mango seeds were planted in the shade house to protect plants from insect pests, diseases and other harsh weather conditions. To avoid disease contamination through contact with soil, a barrier layer of 15-25 cm was developed by using gravel over the soil surface.

Collection of scion materials: The non-flowering shoots of about 12-20 cm long were chosen because they had swollen terminal buds, dark green, straight, healthy leaves. With the help of pruning shears, a few chosen scions of the desired varieties were cut from the mother plants, defoliated, and left with only a quarter of the petiole. To prevent the scions from drying out, the collected scion shoots were then immediately grafted on the raised rootstocks.

Data collection and analysis: The experimental site was visited on daily basis and data for following attributes were recorded.

Days required to bud break: Days to bud break is an important parameter used to measure the growth and development of grafted plants. To determine this parameter, the time between grafting and the first appearance of bud in the attached scion was recorded by counting the days from the day of grafting up to the bud break. The average values of the recorded days were calculated and used for further analysis.

Days required to first flush: By noting the number of days, it took for leaves to emerge from the broken bud, the days till the first flush were noted. The average values were calculated and used for further investigation.

Number of new leaves: To monitor the growth and development of grafted plants, the number of new leaves that developed on the grafted plants was counted at every 15 days for up to 90 days after the grafting procedure. Then the average values were calculated and used for further investigation.

Rootstock length (cm): After 20, 30, 40, and 50 days, the plants of each treatment were measured for their length from the ground surface (base) of the plant to the terminal growth. The following formula was used to calculate the rootstock length, which was

expressed in centimetres and was measured up to one month after grafting.
Rootstock length= (Final length of rootstock) - (Initial length of rootstock at the time of Grafting)
Scion length (cm): At intervals of 15 days, up to 3 months after grafting, the length of the graft was measured on a scale and computed from the grafting site to the tip of the terminal bud. The following formula was used to determine the length of scion. Scion length = (Final length of scion) – (Initial length of scion at the time of grafting).
Stionic height (cm): Stionic height was measured using a meter scale up to three months. The following formula was used to determine the stionic height Stionic height = (Height of tip of successful graft) – (Height of terminal end of scion at the time of grafting)
Scion diameter (mm): The digital Vernier Caliper was used to measure the scion diameter before and after grafting (5 cm above the grafting location).
Rootstock diameter (mm): Before and after grafting, a digital vernier caliper was used to measure the diameter of the rootstock from top, middle and bottom then average values were carried for further analysis.
Percentage of graft success: In the initial two months of grafting the number of successful grafts was counted on every five days, and the results were displayed as a percentage. The following formula was used to calculate the percentage of successful grafts:

$$\text{Graft success (\%)} = \frac{\text{Number of successful grafts}}{\text{Total number of grafted rootstocks}} \times 100$$

Graft survivability (%): After initial success the grafts were observed up to 3 months from the period of grafting success. The percentage of graft survival was calculated by using the following formula

$$\text{Grafts survival \%} = \frac{\text{Number of successful grafts – number of dead scions after grafting}}{\text{Total number of grafts}} \times 100$$

Statistical analysis: Experimental data collected for various parameters were compiled and tabulated in a manner suitable for statistical analysis. To analyze the data, statistical software (Statistics 8.1) was used to perform an analysis of variance (ANOVA). The purpose of the ANOVA was to determine significant differences among treatment groups. Additionally, the least significant difference (LSD) test, as suggested by Gomez and Gomez in 1993, was applied for mean comparison of the treatments.

RESULTS AND DISCUSSION

Effect of rootstock ages and varieties on days required to bud break: The analysis of variance showed that days required to bud break were significantly affected by varieties and rootstock ages (**Table 1**). The earliest bud break (10.50) was found in Langra variety while sindhri variety took maximum days (15.33) for bud break. For rootstock ages the maximum days for bud break (13.92 days) were observed in 50 days old rootstock and the minimum days required to bud break (10.22 days) were recorded in 20 days old rootstock. The findings of the study further revealed that the interactive effect of varieties and rootstock was non-significant for days required to bud break. Overall Langra variety and 20 days old rootstock exhibited good results for days required to bud break. The results of present study are in consistent with the findings of Bose *et al*. (2019) who observed that kachamitha variety took maximum days required to bud break (18.78 days) and the lowest days for bud break (16.13) were taken by Monilkara variety. The closeness in the results might be due to the rootstock ages and practice of same epicotyl grafting technique.

Table. 1. Effect of rootstock ages and scion on days required to bud break of grafts

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	8.66	13.66	8.33	**10.22±2.98 c**
A_2= 30	12.66	16.66	12.33	**12.22±2.41 b**
A_3= 40	10.66	16.33	13.66	**13.88±2.83 a**
A_4= 50	10.00	14.66	12.00	**13.92±2.33 a**
Mean±S.E	**10.50±1.66c**	**15.33±1.41 a**	**11.58±2.28 b**	

	Rootstock age	Varieties	A×V
SE±	0.5666	0.4907	0.9813
P-value	0.0000	0.0000	0.1565
LSD 0.05	1.1750	1.0176	2.0351

Effect of rootstock ages and varieties on days required to first flush: The interactive effect of varieties and rootstock was significant for days to first flush **(Table 2).** Results showed that maximum days required to first flush (26.66 days) were noted in Sindhri variety grafted onto 50 days old rootstock and the minimum days for first flush were observed in Langra variety in 20 days old rootstock. The varieties and rootstock ages also had significant effect on days required to first flush. The maximum days required to

first flush (25.91 days) were observed in Sindhri variety followed by chaunsa that showed (20.75 days) for first flush and the minimum days for first flush (18.91 days) were noted in Langra variety. The rootstock of 50 days took maximum days for first flush (21.77 days) and the lowest days (18.91 days) were taken by Langra variety. Moreover, the findings showed that grafts of Langra variety with 20 days old rootstock had better results for days required to first flush. The finding of the present study is in parallel with the outcomes of (Bose *et al*., 2019; Ghosh and Bera, 2015) who found that days required to first flush were significantly varied with varieties and ages of rootstock. Finding of their study also revealed that practice of epicotyl grafting on young plants resulted into early flush formation and initiation.

Table. 2. Effect of rootstock ages and scion on days required to first flush of graft

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	15.66f	24.66abc	15.66f	**19.00±5.19 b**
A_2= 30	22.00bcd	25.00ab	21.33cd	**23.55±1.95 a**
A_3= 40	19.66de	25.00ab	24.66abc	**23.11±2.98 a**
A_4= 50	20.66d	26.66a	21.33cd	**21.77±3.28 a**
Mean±S.E	**18.91±2.73 c**	**25.91±0.90 a**	**20.75±3.73 b**	

	Rootstock age	Varieties	A×V
SE±	0.2627	0.2275	0.4551
P-value	0.0000	0.0000	0.0265
LSD 0.05	0.5449	0.4719	0.9437

Effect of varieties and rootstock ages on rootstock length (cm): Comparative effect showed that rootstock length of grafts was significantly varied by both factors viz. varieties and rootstock ages **(Table 3).** The interactive results showed that maximum rootstock length (22.06 cm) was noted in chaunsa variety grafted onto 50 days old rootstock followed by 40 days old rootstock that showed similar results for Sindhri (19.36 cm), Langra (19.36 cm) and chaunsa (19.43 cm) and the lowest rootstock length (12.86 cm) was noticed in 20 days old rootstock grafted with Langra variety. While on the basis of varietal mean chaunsa had highest rootstock length (18.57 cm), followed by Sindhri (17.44 cm) and the minimum rootstock length (16.13 cm) was noted in Langra variety. The analysis of variance also showed that rootstock length of grafts was significantly affected by rootstock ages at $p \geq 0.05$. Findings of the study showed statistically similar result 19.96 cm and 19.12 cm for 50- and 40-days old rootstock followed by 30 days old rootstock that showed (15.36 cm). The lowest rootstock length (15.07 cm) was recorded in 20 days old rootstock. It was noted that varieties and ages of rootstock had significant influence on rootstock length. Grafts of older ages comparatively had better rootstock length (cm) as compared to younger rootstocks. The variation among different rootstock ages for rootstock length may be due to strength and better establishment of rootstock. Younger rootstock showed slow growth and development with regards to rootstock length (Bhan *et al*., 2012).

Table. 3. Effect of rootstock ages and scion on rootstock length (cm) of grafts

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	12.86 fg	15.20 ef	15.10efg	**15.07±1.32 b**
A_2= 30	12.92g	15.46def	17.76cd	**15.36±2.42 b**
A_3= 40	19.43bc	19.36bc	19.36bc	**19.12±0.06 a**
A_4= 50	17.30 cde	20.53ab	22.06a	**19.96±2.43 a**
Mean±S.E	**16.13±3.27 c**	**17.44±2.69 b**	**18.57±2.91a**	

	Rootstock age	Varieties	A×V
SE±	0.6464	0.5598	1.1196
P-value	0.0000	0.0010	0.0180
LSD 0.05	1.3406	1.1610	2.3220

Effect of varieties and rootstock ages on rootstock diameter (mm): The analysis of variance showed that rootstock ages along with their interaction with varieties had significant effect on rootstock diameter (mm) (**Table 4)**. However the varietal mean was non-significant for rootstock diameter (mm). The rootstock diameter ranges from (4.17mm) to (6.10mm). The maximum rootstock diameter (6.10 mm) was recorded in 50 days rootstock grafted with chaunsa variety and the lowest rootstock diameter (4.17mm) was found in 20 days old rootstock grafted with Sindhri variety. On the basis of rootstock age the 50 days old exhibited highest rootstock diameter (6.03mm) followed by 40 and 30 days rootstock that resulted (5.74mm) and (5.18mm) rootstock diameter, respectively. The findings further showed that 50 and 40 days old rootstock had better rootstock diameter (mm), that might be due to well-developed root system and effective uptake of mineral nutrition. The

findings of present study are in consistent with the results of Simon *et al*. (2010) who reported that well established rootstock had positive effect on rootstock diameter (mm) of grafted plants in epicotyl grafting.

Table. 4. Effect of rootstock ages and scion on Rootstock diameter (mm) of grafts

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	4.35g	4.17g	4.19g	**4.24±0.09 d**
A_2= 30	5.01f	5.24ef	5.31de	**5.18±0.15 c**
A_3= 40	5.52cd	5.98ab	5.72bc	**5.74±0.23 b**
A_4= 50	6.03a	5.97ab	6.10a	**6.03±0.06 a**
Mean±S.E	**5.26±0.71**	**5.26±0.85**	**5.34±0.82**	

	Rootstock age	Varieties	A×V
SE±	0.0855	0.0741	0.1481
P-value	0.0000	0.5237	0.0194
LSD $_{0.05}$	0.1773	0.1536	0.3072

Effect of varieties and rootstock ages on scion length (cm)*:* The study showed that the interactive effect of varieties and rootstock ages regarding scion length (cm) was statistically at par (**Table 5**). Whereas varietal mean exhibited significant difference for scion length (cm). Chaunsa variety gained maximum scion length (8.14 cm) after three months of grafting followed by Langra (7.78 cm). The lowest scion length (6.78 cm) was noted in Sindhri. However, these results are at par ($p>0.05$) with the findings obtained in Langra variety. Furthermore, the analysis of variance determined that scion length was significantly varied in response to difference rootstock ages. The 50 days old rootstock had maximum scion length (9.64cm) and the minimum scion length (5.37cm) was noted in 20 days old rootstocks. Overall, chaunsa variety and 50 days old rootstock had satisfactory results with regards to scion length (cm). Our results are in line with the results of Gurudutta *et al*. (2004) who conducted an experiment on the mango cultivars Langra, Dashehari, Amrapali and Mollika at Raipur, Chhattisgarh, India and reported that Mollika exhibited highest scion length compared with other cultivars. The highest length of scion noticed in the variety Mollika onto 30 days old rootstock was probably due to earlier callus formation and maximum cambial continuity between rootstock and scion.

Table. 5. Effect of rootstock ages and scion on scion length (cm) of grafts.

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	5.29	4.73	5.29	**5.37±0.32 d**
A_2= 30	6.21	6.20	6.95	**6.4±0.43 c**
A_3= 40	7.69	7.44	8.88	**8.01±0.76 b**
A_4= 50	9.55	8.73	10.64	**9.64±0.95 a**
Mean±S.E	**7.18±1.86 b**	**6.78±1.71 b**	**8.14±2.32 a**	

	Rootstock age	Varieties	A×V
SE±	0.3437	0.2976	0.5953
P-value	0.0000	0.0010	0.1071
LSD $_{0.05}$	0.7128	0.2976	1.2345

Effect of varieties and rootstock ages on scion diameter (mm): The analysis of variance showed that scion diameter (mm) varied significantly in response to varieties and rootstock ages at $p\geq 0.05$. While their interaction had non-significant results for scion diameter (mm). The scion diameter ranged from (4.09 to 4.34 mm). The maximum scion diameter (4.34mm) was noted in Chaunsa variety followed by Sindhri (4.15 mm). While the lowest scion diameter (4.09 mm) was recorded in Langra variety. The results of Sindhri and Langra variety are statistically non-significant with each other. The results pertaining to rootstock ages exhibited that 50 days old rootstock had better results for scion diameter (5.04 mm), followed by 40 and 30 days old rootstock recorded (4.53mm) and (3.89mm) results for rootstock diameter. The increase in scion diameter with increased rootstock age after grafting might be due to the enhanced photosynthetic and other biochemical activities in plants. Moreover 50 days old rootstock was possibly strong enough to sustain the impact of the grafting shock with an excellent sap flow and continued food supply from the stored food that enhanced the graft union process that resulted in higher growth in scion diameter

Table. 6. Effect of rootstock ages and scion on scion diameter (mm) of grafts.

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	3.25	3.33	3.38	**3.32±0.06 d**
A_2= 30	3.73	3.83	4.11	**3.89±0.19 c**
A_3= 40	4.57	4.22	4.80	**4.53±0.29 b**
A_4= 50	5.03	5.00	5.10	**5.04±0.05 a**
Mean±S.E	**4.09±0.80 b**	**4.15±0.70 b**	**4.34±0.76a**	

	Rootstock age	Varieties	A×V
SE±	0.0855	0.0741	0.1481
P-value	0.0000	0.0063	0.1489
$LSD_{0.05}$	0.1773	0.1536	0.3072

Effect of varieties and rootstock ages on stionic height (cm): The analysis of variance demonstrated that stionic height (cm) was significantly affected by varieties and rootstock ages. While their interaction was statistically at par (p>0.05). The highest stionic height (38.57 cm) was recorded in chaunsa variety followed by Langra variety that showed (36.81 cm) result for stionic height. Whereas Sindhri variety had comparatively lowest stionic height (34.36 cm). On the basis of rootstock ages, stionic height ranged from 41.43 to 32.13cm (Table-8). Rootstock age 50 had highest stionic height (41.43cm) followed by 40- and 30-days old rootstock that resulted (37.57cm) and (35.06cm) stionic height, while the lowest stionic height (32.13cm) was noted in 20 days old rootstock. Results of our study are in consistent with the findings of Karim *et al*., (2004) who evaluated different varieties and rootstock ages by applying epicotyl grafting. Mollika variety showed the maximum stionic height. 46.24 cm followed by Langra 40.23 cm when grafted on 30 and 40 days old rootstock. This might be due to manufacturing of food materials through its 5-7 leaves after second flash within 30 days after germination. As a result, it was strong enough to cope with grafting shock with an excellent sap flow that enhanced the graft union process resulting maximum increment in stionic height.

Table. 7. Effect of rootstock ages and scion on stionic height (cm) of grafts.

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	32.79	30.19	33.41	**32.13±1.70d**
A_2= 30	35.69	32.95	36.55	**35.06±1.88c**
A_3= 40	37.94	35.55	39.21	**37.57±1.85b**
A_4= 50	40.82	38.35	45.12	**41.43±3.42a**
Mean±S.E	**36.81±3.40 b**	**34.26±3.49 c**	**38.57±4.96 a**	

	Rootstock age	Varieties	A×V
SE±	0.7861	0.6808	1.3616
P-value	0.0000	0.0000	0.1011
LSD 0.05	1.6304	1.4119	2.8239

Effect of varieties and rootstock ages on number of leaves plant^{-1}: Number of leaves plant^{-1} was significantly affected by both factors viz. varieties and rootstock ages. The combined effect also showed significant difference for number of leaves plant^{-1} at p≥ 0.05. Results revealed that Chaunsa variety grafted onto 50 days old rootstock had maximum leaves plant^{-1} (10.33) followed by 40 days rootstock. The Chaunsa variety had comparatively also better result 9.33 for number of leaves plant^{-1}. While the lowest number of leaves plant^{-1} 5.00 were recorded in Sindhri variety grafted onto 20 days old rootstock. On the basis of rootstock mean maximum number of leaves 8.33 were observed in 50 days old rootstock it was noted that number of leaves plant^{-1} decreased considerably with age of rootstocks. Likewise, the lowest number of leaves 6.00 recorded by 20 days old rootstock. Findings of the study further showed that chaunsa variety had relatively maximum leaves 8.75 followed by Langra variety that showed 6.92 number of leaves plant^{-1} and lowest number of leaves 5.83 was noted in Sindhri variety. The research of Islam *et al*., (2004) validated the findings of our study, who observed a significant variation in the production of leaves at every date of counting due to the interaction effect of the varieties and ages of rootstock. Moreover, he reported that number of leaves was higher in Mollika and Gopalbuog than Langra. The interaction effect of two factors employed in the experiment indicated that cumulative effect of varieties and ages of rootstock caused variation in average leaf number of new growth

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Table. 8. Effect of rootstock ages and scion on leaves plant^{-1} of grafts

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	5.66fg	5.00g	6.00ef	**6.00±0.50 D**
A_2= 30	6.33def	6.33def	8.66bc	**6.88±1.34 C**
A_3= 40	7.00d	6.667de	9.33b	**7.44±1.45 B**
A_4= 50	8.00c	8.667 bc	10.33a	**8.33±1.19 A**
Mean±S.E	**6.92±0.99 B**	**5.83±1.51 C**	**8.75±1.85 A**	

	Rootstock age	Varieties	A×V
SE±	0.2627	0.2275	0.4551
P-value	0.0000	0.0000	0.0265
LSD 0.05	0.5449	0.4719	0.9437

Effect of varieties and rootstock ages on success percentage (%): Success percentage (%) of grafts was significantly affected by both factors viz, varieties and rootstock ages. However, their interaction was non-significant. **(Table 9).** Chaunsa variety showed highest success percentage (68.84 %), followed by Langra variety showed (62.79%) success of grafts. The lowest success percentage was noted in Sindhri variety. The rootstock of 50 days old had maximum success percentage (70.25%), followed by 40 days old rootstock and 30 days old rootstock that exhibited (63.47%) and (57.19%) success of the grafts, respectively. The lowest success percentage (55.46 %) was noted in 20 days rootstock However, these results are statistically similar with the results of 30 days old rootstock Overall. the rootstock of 50 days and chaunsa variety showed highest success percentages than the rest of factors. Similar results were also found by Sultana *et al*. (2014) who carried out an experiment on the response of mango varieties to epicotyl grafting method of propagation and they observed the grafting success 66.1% in the Monilkara and 64.6% in the cultivar Dashehari respectively. Findings of her study validated the results observed from present investigation.

Table. 9. Effect of rootstock ages and scion on success (%) of grafts.

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	52.9	52.24	61.24	**55.46±5.01 c**
A_2= 30	54.23	60.45	56.90	**57.19±3.12 c**
A_3= 40	61.88	67.10	61.44	**63.47±3.14 b**
A_4= 50	67.58	71.58	71.58	**70.25±2.30 a**
Mean±S.E	**62.79±6.87 b**	**54.15±8.41c**	**68.84±6.22 a**	

	Rootstock age	Varieties	A×V
SE±	2.0321	7.2996	3.5198
P-value	0.0000	0.0065	0.1603
LSD 0.05	4.2144	3.6498	7.2996

Effect of varieties and rootstock ages on survival percentage (%): The findings showed that variety and rootstock ages had significant effect on survival percentage of grafts. While the interaction was non-significant at p≥ 0.05. With respect to variety the survival percentages ranges from 65.53 % to 53.65%. The maximum survival percentage 65.53 % was recorded in chaunsa variety and the lowest survival (53.65%) was exhibited by Langra variety. Moreover, on the basis of rootstock mean comparison survival percentage of grafts ranges from 68.82% to 51.94%, the results further demonstrated that survival chances augmented with increase in the ages of rootstocks. Likewise, the maximum survival percentage (68.82%) was observed in 50 days old rootstock followed by 40 and 30 days old rootstock that revealed 61.23% and 55.92% survival rate of grafts, respectively. The rootstock of 20 days old had the lowest results (51.94%) survival rate of grafts. Overall Chaunsa variety and 50 days old rootstock had excellent results for survival rate of grafts. These findings are in line with the study of (Soleimani *et al*. 2010) who evaluated the response of 14 mango cultivars to the epicotyl grafting method of propagation and reported that an average survival of 62.98% was noticed 6 months after grafting. Same results were also obtained by Alam *et al*. (2008) who stated that the highest percentage of graft survivability was recorded in the variety Mollika (66.24%) followed by variety Langra (63.17%).

Table-10 Comparative effect of rootstock ages and scion on survivability (%) of grafts

Rootstock ages in days	Varieties			Mean±S.E
	Langra	**Sindhri**	**Chaunsa**	
A_1= 20	52.83	51.50	51.50	**51.94±0.76 d**
A_2= 30	55.99	54.66	57.12	**55.92±1.23 c**
A_3= 40	61.22	60.17	61.31	**61.23±1.07 b**
A_4= 50	66.97	68.30	71.18	**68.82±2.15 a**
Mean±S.E	**53.65±6.20 c**	**59.25±7.35 b**	**65.53±8.36 a**	

	Rootstock age	Varieties	A×V
SE±	1.0216	0.8847	1.7695
P-value	0.0000	0.0204	0.1204
LSD 0.05	2.1187	1.8348	3.6696

CONCLUSION

This study emphasizes the importance of epicotyl grafting for the rapid multiplication of mango plants. All the traits examined in this study were significantly influenced by the scion and age of the rootstocks. The results revealed that the Chaunsa variety showed significantly better results for all parameters, except for the days required for bud break and first flush, which were highest in the Langra variety. The findings of this study also demonstrated that the 50-days-old rootstock yielded promising results for almost all attributes when grafted with the Chaunsa variety.

RECOMMENDATION

Based on the findings of this study, it is recommended to use rootstock ages of 40 and 50 days for achieving efficient results in epicotyl grafting. Additionally, it is suggested to evaluate rootstocks of different ages from various cultivars and explore the timing of grafting to uncover more information about the success and survivability of epicotyl grafting.

ACKNOWLEDGEMENT

The author conveys his thanks to Dr. Noor-un-Nisa Memon for her supervision, technical guide and colossal assistance, without which the trial would not have been successful.

AUTHOR'S CONTRIBUTION

MFJ, conducted field research and set the paper. **NNM**, supervised the research study and designed field trial. **NAW and WA** provided technical inputs and helped in revised manuscript and gave final shape for publication, **FAJ, HAM and AA** Managed field trial and assist in write-up.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Alam, M.A. Standardization of the methods of vegetative propagation for quality propagule. (2008). production in mango. Ph. D. Thesis, Dept. of Hort. BAU. Mymensingh. **57**-146

Bairwa, S., Singh, V., Mahawer, L. N. and Regar, A. L. (2018). Effect of media and age of rootstock on epicotyl grafting of mango (Mangifera indica L.) cv. Amrapali. *Int J Chem Studies*, **6**(3), 3239-43

Baita, H. U. (2009). Evaluation of different morphotypes for use as rootstock in production of Main production *indica* L.) seedling. Unpublished M.Sc. Dissertation. Bayero University, Kano. Nigeria.

Bobade, D. H., R. H. Ingole and A. S. Kadam, (2018). Effect of different scion varieties of mango on growth and biomass production per formance of stone grafts (Mangifera indica L.). Int. J. Current Microbiol. Appl. Sci. 6: 1642-1648

Bose, S. K., Ghosh, K. and Howlader, P. (2019). Effect of Variety and Rootstock Age on the Success and Survivability of Epicotyl Grafting in Mango. *Journal of Agricultural Research Advances*, **1(**1), 13-25

Ghosh, S. N. and Bera, B. (2015). Studies on standardization of propagation methods of some minor fruit crops in India. *International Journal of Minor Fruits, Medicinal and Aromatic Plants*, **1**(1), 31-36

Gomez, K. A. and Gomez, A. A. (1993). Statistical procedure for Agriculture Research (2nded.). Jhan and Sons, New York. 272-279

Gurudutta, P. S., Jain, V. and Singh, P. N. (2004). Response of mango cultivars to epicotyl grafting. *Indian Journal of Horticulture*, **61**(3), 267-267

Hartmann, H. T., Dale, E. K., Davies, F. T. and Geneve, R. L. (2010). (Plant Propagation, Principles and Practice. 7 edition Pp 145

Honja, T. (2014). Review of mango value chain in Ethiopia. *Journal of Biology, Agriculture and Healthcare*, **4**(25), 230-239

Islam, M. N., Rahim, M. A. and Farooque, A. M. (2004). Standardization of time and grafting techniques in mango under Bangladesh condition. *Asian Journal of Plant Sciences*

Islam, M. R. and Rahim, M. A. (2010) Performance of epicotyl grafting in different varieties of mango. *Journal of Agroforest Environment*, **4(**1), 45-50

Jaganath, B., Subramanyam, K., Mayavan, S., Karthik, S., Elayaraja, D., Udayakumar, R. and Ganapathi, A. (2014). An efficient in planta transformation of Jatropha curcas (L.) and multiplication of transformed plants through in vivo grafting. *Protoplasma*, **251**(3), 591-601

Karim, R., Rahim, M. A. and Alam, M. S. (2004) Effect of leaf and node retention in rootstock on epicotyle grafting in mango. *M. Sc.(Ag.) thesis, Horticulture. Department. BAU, Mymensingh*, 30-53

Ladon, T., Chandel, J. S. and Verma, P. (2020). Epicotyl grafting: A new method for propagation in walnut (Juglans regia L.). *Indian Journal of Ecology*, **47**(1), 72-76

Mukherjee, S. K. and Litz, R. E. (2009). Introduction: botany and importance. in *the mango: Botany, production and uses* (pp. 1-18). Wallingford UK: CABI

Minja, R., A. Kimaro and G. Nyalusi, (2017). Effects of rootstock type and scion cultivar on grafting success and growth of mango (Mangifera indica L.) seedlings. J. Hortic. Sci. **32**(2), 179-189

Naik, M. A. K., & Kumar, N. V. A. (2020). Review on Recent Developments on Propagating Mango (Mangifera indica L.) through Grafting. *International Journal of Current Microbiology & Applied Science*, **9**(11), 3481-3487

Noor-Un-Nisa, M., and Jamali, M. F. (2023). Epicotyl Grafting in Mango. *Hortimag*, **11**(2), 11-12

Prasanth, J. M., Reddy, P. N., Pampanagouda, B. and Patil, S. R. (2006). Effect of Cultivars and Time of Grafting on Per Cent Success and Survival Percentage of veneer grafting in mango (*Mangifera Indica* L.). *International Journal of Agricultural sciences*, **2**(1), 19-21

Simon A, Mng'omba, Akinnifesi FK, Sileshi G and Ajayi OC. (2010). Rootstock growth and development for increased graft success of mango (*Mangifera indica*) in the nursery. *African Journal of Agriculture* **9**(9): 1317–132

Soleimani, A., Rabiei, V. and Hassani, D. (2010). Effect of different techniques on walnut (J. regia L.) grafting. *Journal of Food, Agriculture & Environment*, **8**(29), 544-546

Sultana, A., Chowdhury, M. F. and Pervez, A. K. M. K. (2014). Present status of mango cultivation in Bangladesh: Case of Shibgonj upazilla of Chapainawabgonj district. *Journal of Agricultural and Rural Research*, **2**(3), 47-55

Ullah, S. S., Malik, S., Kumar, R. and Kumar, M. (2017). Effect of Time and Technique of Grafting for Quality Production of Nursery Plants of Dashehari Mango (Mangifera indica L.). *International Journal Current Microbiology and Applied Sciences*, **6**(10), 685-90