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SOIL & CROP SCIENCES | RESEARCH ARTICLE

Effect of grafting time and technique on the success rate of grafted Mango (*Mangifera indica L.*) in Kalu District of Amhara Region, North Eastern Ethiopia

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Abstract: Vegetative propagation through grafting is the recommended method for most fruit crops including mango. It involves the joining of scion and rootstock where the rootstock develops into the root system while the scion develops the upper fruiting part of the grafted tree. The study was conducted in Harbu fruit nursery site of Amhara Region from June 2015 to December 2016 with the objective of determining appropriate grafting time and technique that maximize the graft success of grafted mango using Apple variety as a scion. The treatments were laid out in factorial arrangement using Completely Randomized Design with three replications. The results of the present study generally indicated that both the main and the interaction effects of grafting time with grafting technique had a significant influence on days to bud break, rootstock diameters, scion diameters, scion length, rootstock length, number of leaves per graft and graft success of mango. The minimum required times for bud breaking were observed when mango was grafted with cleft grafting technique during March grafting time (17.37 days). The maximum success rate of grafting (100%) was obtained from treatment combination of June or March grafting time with cleft technique. Therefore, propagation of mango using cleft grafting technique during the month of March can be recommended for the study area and areas with similar agro-ecologies to increase the success rate of mango. Moreover, doing similar researches at different localities is recommended to

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PUBLIC INTEREST STATEMENT

Eastern part of Amhara Region including Kalu District is one of the most suitable areas for the production of mango where it is mostly produced by the smallholder farmers. Despite the socio-economic importance of the crop, its current production in the area is constrained by various problems. Unavailability of planting materials is among others the main challenges associated with the current low developmental status of mango in Ethiopia in general and in Eastern Amhara in particular. Thus, identification of suitable time and propagation techniques is necessary to enhance the expansion of mango and the income of smallholder producers.

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identify best-fit mango propagation techniques to improve mango production at regional level in particular and at national level in general.

Subjects: Agriculture & Environmental Sciences; Horticulture; Plant Reproduction; Plant & Animal Ecology

Keywords: cleft grafting; graft success; rootstock diameter; scion diameter; whip grafting

1. Introduction

Mango (*Mangifera indica* L.) is an ever-green fruit crop native to Southern Asia, especially Eastern India, Burma and the Andaman Islands (Honja, 2014). Currently, mango is one of the most widely cultivated and traded tropical and sub-tropical fruit crops in the world. It is grown in more than 85 countries of the world with total area coverage and annual production of 3.69 million hectares and 35 million tons, respectively (Honja, 2014).

Mango is claimed to be the most important tropical fruit and has been thought as 'king of all fruits' because of its attractive appearance and the very pleasant taste of selected cultivars. It is an important fruit for fresh consumption as well as input for processing industries. Ripe mangoes contain moderate level of vitamin C, are fairly rich in provitamin A, vitamins B_1 and B_2 and many essential minerals (Mukherjee & Litz, 2009). The protein content is generally a little higher than that of other fruits except the avocado. Mangoes are also a fairly good source of thiamine and niacin and contain some calcium and iron (Griesbach, 2003).

The time of introduction of mango to Ethiopia is not well known. Currently, the production of mango is mostly concentrated in Gambella, Benshangule-Gumuz Regions, Waamaa and Deddessa Valley, Southwestern Ethiopia (Bench-Majii, Shekicho, Illubabour), Central Rift Valley, North and South Omo Zones, Amhara Region and Eastern Ethiopian lowlands (Bezu, Woldetsadik, & Tana, 2014). According to Central Statistical Agency (CSA) (2013), about 107 890.60 hectares of land is under fruit crops in Ethiopia where mangoes contributed about 14.29% of the area. Moreover, out of 792 366.50 tons of fruits produced in the country, mangoes accounted 13.21% with the productivity of 6.79 tons ha^{-1}. The report also illustrated that the area coverage and total annual production of mango in Amhara region is only 1 031.67 ha and 5 656.35 tons, respectively, with productivity of 5.48 tons ha^{-1}.

Like many other fruit crops, mango can be propagated vegetatively as well as generatively using seeds. However, using seedling trees sourced from seeds have many drawbacks. Fruit trees that have grown from seedlings will be mostly tall and bear the first fruit in about 6 to 8 years after planting; while vegetatively propagated trees will give the first yield usually starting from the third year of planting and have manageable tree size (Honja, 2014). Moreover, vegetative propagation such as grafting is a suitable technique to maintain true-to-type of a given variety that enables to transfer quality parameters from mother to the offspring (Nakasone & Paull, 1998).

Grafting is the recommended vegetative propagation method for most fruit crops including mango. It involves the joining of scion and rootstock where the rootstock develops into the root system while the scion develops the upper fruiting part of the grafted tree. Rootstocks can be seedlings, rooted cuttings or layered plants. Rootstocks may influence various characteristics of grafted plants including the size and growth habits of the tree, yield, size and time of fruit maturity (Mukherjee & Litz, 2009).

Grafting is an ancient horticultural technique that is indispensable to modern horticulture as the technique enables us to exploit the various advantages of grafted trees. The advantages include early flowering in comparison to seedling trees, the size of the trees are generally smaller than seedling trees because they begin to bear fruit earlier (Janick, Scofied, & Goldschmit, 2010).

Several grafting techniques such as side, cleft, wedge, splice (whip) grafting methods are used to propagate horticultural crops including mango where their suitability differs among environmental conditions and type of crops (Simon, Akinnifesi, Sileshi, & Ajayi, 2010). The success rate of grafting can be improved by selection of rootstock and grafting time of the year based on the desirable growing conditions (Simon et al., 2010) and by improving the skills and knowledge of people who undertake the practice of grafting (Akinnifesi et al., 2008). Furthermore, degree of graft success is also affected by grafting techniques applied (Soleimani, Hassani, & Rabiei, 2010).

Almost all methods of grafting can be adapted for mango. Among these, two popular methods for mangoes are the cleft grafting and the whip grafting (Mukherjee & Litz, 2009). Cleft grafting is easier to use than whip grafting and seems an easy graft to do, and so is often the initial choice of novice grafters. The architecture of cleft-grafted plants is usually much better than trees propagated by other methods including whip grafting (Ram, 1997).

A lot of study on the relative efficiency of the different techniques and time of grafting had been studied in different countries and had been standardized for specific areas (Ghosh & Bera, 2015). Such studies are however very scarce under Ethiopian conditions for the production of fruits in general and for that of mango in particular. Standardizing the grafting techniques and determining the best time of grafting is vital for the rapid multiplication of mango to improve mango production in the country. Thus, this study was undertaken to investigate the relative efficacy of the most commonly used grafting techniques (cleft and splice or whip) and to standardize the time of grafting operation of mango which results in the maximum success rate of grafted mango for supporting the expansion of mango production in the study area and other similar agro-ecologies.

2. Materials and methods

2.1. Description of the study area

The experiment was conducted at Kalu district of South Wollo Zone in Harbu fruit nursery site from June 2015 to December 2016. Harbu fruit nursery site is one of the biggest governmental nursery sites multiplying planting materials of tropical and sub-tropical fruits and supplying for smallholder fruit-producing farmers in Amhara Region, Northeastern Ethiopia. Accordingly, mango, papaya, some citrus species, banana and avocado are multiplied in this nursery site.

The experimental site is located 360 km North East of Addis Ababa which lies on latitude of 10° 55′ N and longitude of 39° 46′ E with an elevation of 1484 m above sea level (Figure 1). It has minimum and maximum temperatures of 13.19°C and 27.65°C, respectively, and an average annual rainfall of 1144.80 mm (Table 1).

2.2. Experimental treatments, design and procedures

In this experiment, the effects of time and grafting techniques were assessed whereby cleft, and whip or splice grafting and 12 grafting dates at the middle of each month of a year were used. Treatments were laid out in factorial arrangement using Completely Randomized Design (CRD) with three replications. Each treatment consisted of 10 seedlings where apple mango cultivar and a polyembryonic local mango mother tree were used as scion and rootstock, respectively (Table 2).

During the experimentation, rootstocks from seeds of ploy embryonic local mango mother trees which are adaptable to the environment and tolerant to soil borne disease were raised five months before every grafting operation. Seeds were sown in pots (25 cm x 30 cm and 20 mm thickness) containing media consisted of soil, sand and decomposed farmyard manure in the ratio of 2:1:1 which was solar sterilized.

Figure 1. Geographical location of the experimental site.

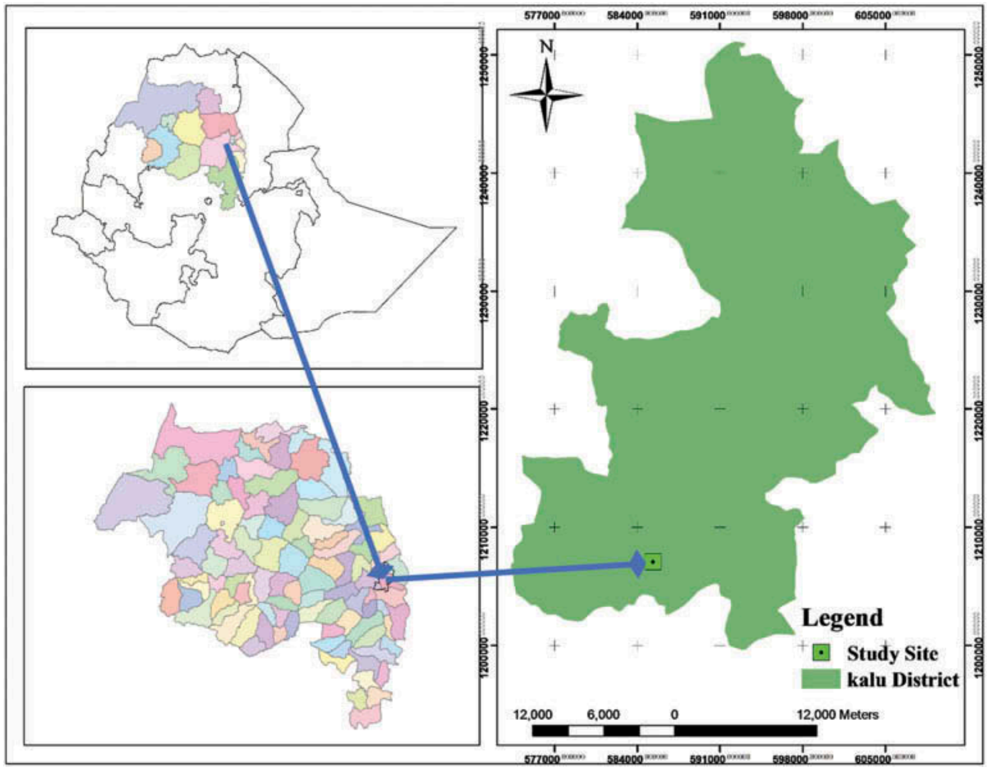

Table 1. Mean air temperature, rainfall, relative humidity, wind and sunshine hours at the experimental site *during the experimental year*

Month	Min Temp (°C)	Maximum Temp (°C)	Rain fall (mm)	RH (%)	Wind (Km day^{-1})	Sunshine (Hours)
October	11.85	27.61	12.20	54.58	0.59	8.68
November	11.33	26.07	0.00	61.76	0.59	7.95
December	12.34	24.92	14.60	65.45	0.69	6.51
January	13.15	24.64	21.60	68.61	0.74	5.67
February	11.31	27.26	11.30	52.72	0.86	9.09
March	14.61	30.52	20.30	51.87	0.84	8.32
April	16.21	27.65	155.80	67.27	0.75	6.32
May	14.88	28.86	107.70	53.55	0.75	6.32
June	15.09	30.83	64.20	42.70	0.93	7.89
July	15.89	28.28	276.10	60.55	0.80	5.57
August	15.21	27.38	346.40	66.52	0.67	6.11
September	14.41	27.58	119.20	63.90	0.58	6.40
October	11.03	27.38	7.60	53.35	0.61	8.84
November	8.64	26.24	14.00	52.43	0.66	9.12
December	7.85	25.23	0.60	52.10	1.18	9.25

Source: National Meteorology Agency, Kombolcha branch.

As soon as the rootstocks attained pencil size, healthy and uniform-sized scions (15 cm long) harvested from 4- to 5-years old respective varieties of mother plants were grafted using the respective grafting techniques in the morning (12:00–10:00 AM). After grafting, the graft unions

Table 2. The treatment combinations used for the experiment.

Treatment number	Treatment combinations	Treatment number	Treatment combinations
1	Mid of September + Cleft grafting	13	Mid of March + Cleft grafting
2	Mid of September + Whip grafting	14	Mid of March + Whip grafting
3	Mid of October + Cleft grafting	15	Mid of April + Cleft grafting
4	Mid of October + Whip grafting	16	Mid of April + Whip grafting
5	Mid of November + Cleft grafting	17	Mid of May + Cleft grafting
6	Mid of November + Whip grafting	18	Mid of May + Whip grafting
7	Mid of December + Cleft grafting	19	Mid of June + Cleft grafting
8	Mid of December + Whip grafting	20	Mid of June + Whip grafting
9	Mid of January + Cleft grafting	21	Mid of July + Cleft grafting
10	Mid of January + Whip grafting	22	Mid of July + Whip grafting
11	Mid of February + Cleft grafting	23	Mid of August + Cleft grafting
12	Mid of February + Whip grafting	24	Mid of August + Whip grafting

were tied using polyethylene plastics and smeared with paraffin to create airtight condition and to facilitate joining of the attached parts. Furthermore, two leaves were retained below the graft union for all treatments in uniform manner.

Since the success rate of grafting is influenced by skills of grafters, grafting of mango seedlings was done by well-experienced personnel with above 10 years of experiences. Additionally, all necessary measures were adopted to make the polybags free from weeds and create a favorable environment to ensure proper growth and development of the grafted plants.

The grafts just after their placement in a shade were irrigated on a daily base using a watering can.

2.3. Data collection and analysis

The success of grafting, days to bud break and growth of grafted seedlings were collected using the standard procedures as described below.

2.3.1. Days required to bud break or first flush (days)

Days to first bud break was recorded by counting the days elapsed from days to grafting until to the first bud break from the scion in each treatment and the mean values were computed and used for further analysis.

2.3.2. Percentage of graft success (%)

The number of successful grafts in each treatment was counted at 30 days interval up to 90 days after grafting. Emergence of shoots from the terminal buds of scions were considered as success of grafting. Grafted scions which produced shoots were counted and expressed in percentage using the formula below as described by Rafikul (2013).

$$\text{Percentage of graft success} = \frac{\text{Number of successful grafts}}{\text{Total number of grafted rootstocks}} X\ 100$$

2.3.3. Mean number of leaves on new growth (count/graft)

The total number of new leaves was counted from randomly selected five plants from each treatment where grafting was successful at 30 days interval starting from 30 days after the date of grafting up to 90 days of grafting and the mean values per graft were calculated.

2.3.4. Height of rootstock (cm)
The lengths of five randomly selected rootstocks per treatment were measured from ground level to the middle of the graft union using meter scale at 30 days interval starting from 30 days after the date of grafting up to 90 days of grafting and the mean values were calculated and used for further analysis.

2.3.5. Height of scion (cm)
The lengths of five randomly selected scions per treatment were measured from the middle of the graft union to the apex of the terminal bud using meter scale at 30 days interval starting from 30 days after the date of grafting up to 90 days of grafting and the mean values were calculated and used for further analysis.

2.3.6. Diameter of scion (mm)
The diameters of five randomly selected scions from each treatment were measured about 5 cm above the graft union using caliper at 30 days interval starting from 30 days after the date of grafting up to 90 days of grafting and the mean values were calculated and used for further analysis.

2.3.7. Diameter of rootstock (mm)
The diameters of five randomly selected rootstocks from each treatment were measured at the middle height using caliper at 30 days interval starting from 30 days after the date of grafting up to 90 days of grafting and the mean values were calculated and used for further analysis.

Before proceeding to data analysis, the data on number of leaves per graft and graft success at different days after grafting were transformed with Logarithmic and Square root transformation methods, respectively, so as to fulfill the assumption of ANOVA as described by (Gomez. & Gomez, 1984). Then after, all collected data were subjected to analysis of variance (ANOVA) using SAS computer statistical software (Version 9.0).

3. Results and discussion

3.1. Effect of time and grafting techniques on days required to bud break
The main effect of grafting time was highly significant ($P < 0.01$) on days required to bud break (Table 3). The minimum time (19.25 days) required for bud breaking was recorded on grafting time of March while the maximum time (29.29 days) was on grafting time of July (Table 4).

The main effect of grafting technique was highly significant ($P < 0.01$) on days required to bud break (Table 3). The minimum time (21.40 days) required for bud breaking was observed on cleft grafting technique whereas, the maximum time (28.36 days) was on Whip grafting technique (Table 5).

Days required for bud breaking of mango was highly significantly ($P < 0.01$) influenced by the interaction effect of grafting time and techniques (Table 3). The results of days required for bud breaking as affected by the interaction effect have been presented in (Table 6). The maximum time required for bud breaking (34.56 days) was recorded from whip grafting technique which was grafted in January while the minimum (17.37 days) from March grafting and cleft grafting technique. The combined effect of June grafting time and cleft grafting technique required the second lowest time (18.87 days) to bud break followed by November and May grafted plants using clef grafting which required 19.04 days and 19.71 days, respectively. The findings of the current study are in accordance with the findings obtained by Razzaque (2005). He has reported that the minimum time required for bud breaking was 17.00 days in case of June grafted Amrapali cultivar of mango plants using cleft grafting technique. However, the present results are not in agreement with Singh, Karuna, Kumar, and Mankar (2012) who observed earliest sprouting when grafting was done in July and August.

Table 3. Mean square of analysis of variance for days required to bud break, number of leaves per graft and graft success of grafted mango in 2015/2016 at Kalu fruit nursery site.

Source of variation	DF	Days required to bud break	Number of leaves per graft at		Graft success of mango at		
			60 DAG	90 DAG	30 DAG	60 DAG	90 DAG
Grafting time	11	872.23**	0.002**	0.01**	60.56**	24.10**	24.24**
Grafting technique	1	65.28**	0.03**	0.05**	8.26**	7.01**	7.09**
Grafting time x Grafting technique	11	15.76**	0.03**	0.02**	1.99**	1.64**	1.38**
Error	48	2.12	0.0005	0.0004	0.09	0.1	0.09

** = Highly significant; DF = Degree of Freedom

Table 4. Growth and development of grafted mango as affected by grafting time.

Grafting time (month)	Days required to bud	Rootstock diameter (mm) at		Scion diameter (mm) at		Rootstock length (cm) at		Scion length (cm) at		Number of leaves per graft at		Graft success at		
		60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	30 DAG	60 DAG	90 DAG
September	24.57	0.19	0.21	0.26	0.31	0.25	0.29	1.15	1.35	2.67	2.23	65.00	71.67	70.00
October	29.07	0.12	0.16	0.20	0.25	0.18	0.22	0.81	1.06	1.53	2.00	45.00	46.67	43.33
November	21.43	0.19	0.27	0.27	0.36	0.28	0.38	1.30	1.55	2.40	2.73	85.00	85.00	80.00
December	22.62	0.19	0.29	0.30	0.32	0.30	0.37	1.22	1.69	2.14	4.80	71.67	80.00	78.33
January	28.36	0.14	0.19	0.19	0.23	0.21	0.18	0.84	1.00	1.73	2.17	46.67	50.00	50.00
February	26.74	0.14	0.21	0.21	0.27	0.20	0.22	1.01	1.12	1.60	3.20	46.67	56.67	53.33
March	19.25	0.25	0.43	0.38	0.47	0.39	0.41	1.39	2.06	2.34	3.93	91.67	98.33	95.00
April	25.29	0.15	0.21	0.24	0.25	0.21	0.24	0.83	1.17	2.60	2.70	60.00	58.33	56.67
May	25.15	0.19	0.32	0.28	0.34	0.30	0.36	1.18	1.62	2.63	2.57	73.33	81.67	80.00
June	20.79	0.24	0.35	0.35	0.43	0.36	0.38	1.33	1.65	2.60	4.23	91.67	91.67	91.67
July	29.29	0.12	0.19	0.21	0.26	0.18	0.17	0.77	1.03	1.57	2.10	43.33	51.67	50.00
August	26.01	0.18	0.24	0.25	0.27	0.22	0.29	1.00	1.35	2.50	2.77	63.33	68.33	65.00
SE±	0.13	0.002	0.003	0.002	0.003	0.003	0.003	0.008	0.01	0.02	0.04	0.65	0.65	0.63
LSD (0.01)	1.69	0.02	0.02	0.02	0.02	0.02	0.02	0.09	0.08	0.19	0.22	5.80	5.96	5.30
CV (%)	5.85	8.71	6.62	6.56	6.12	6.65	6.55	7.16	4.89	7.45	6.55	7.66	7.34	6.73

DAG= Days after grafting; SE± = Standard error of a mean; LSD = Least significant difference and CV = Coefficient of variation.

Table 5. Growth and development of grafted mango as affected by grafting techniques.

Grafting technique	Days required to bud break	Rootstock diameter (mm) at		Scion diameter (mm) at		Rootstock length (cm) at		Scion length (cm) at		Number of leaves per graft at		Graft success at		
		60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	30 DAG	60 DAG	90 DAG
Cleft	21.40	0.21	0.31	0.31	0.39	0.27	0.31	1.1	1.62	2.16	3.14	78.89	78.89	76.67
Whip	28.36	0.14	0.20	0.22	0.24	0.24	0.27	1.03	1.15	2.23	2.76	51.67	61.11	58.89
SE±	0.89	0.01	0.02	0.02	0.02	0.02	0.02	0.06	0.08	0.14	0.26	4.51	4.46	4.36
LSD (0.01)	0.69	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.03	NS	0.09	2.37	2.43	2.16
CV (%)	5.85	6.56	6.12	6.56	6.12	6.65	6.55	7.16	4.89	7.45	6.55	7.66	7.34	6.73

DAG= Days after grafting; SE± = Standard error of a mean; LSD = Least significant difference; NS= Non-significant and CV = Coefficient of variation.

Table 6. Days required to bud break, number of leaves per graft and grafting success of grafted mango as affected by interaction effect of time and grafting techniques.

Grafting time (month)	Grafting Technique	Days required to bud break	number of leaves per graft at		Graft success at		
			60 DAG	90 DAG	30 DAG	60 DAG	90 DAG
September	Cleft	20.63	2.27	2.33	80.00	76.67	73.33
	Whip	28.52	3.07	2.13	50.00	66.67	66.67
October	Cleft	23.78	1.40	1.87	70.00	63.33	56.67
	Whip	34.36	1.67	2.07	20.00	30.00	30.00
November	Cleft	19.04	1.93	2.40	86.67	83.33	80.00
	Whip	23.82	2.87	3.07	83.33	86.67	80.00
December	Cleft	20.30	1.67	6.80	86.67	93.33	90.00
	Whip	24.95	2.60	2.80	56.67	66.67	66.67
January	Cleft	22.17	2.53	2.40	73.33	73.33	73.33
	Whip	34.56	0.93	1.93	20.00	26.67	26.67
February	Cleft	23.03	1.33	3.47	63.33	66.67	60.00
	Whip	30.46	1.87	2.93	30.00	46.67	46.67
March	Cleft	17.37	2.67	4.27	100.00	100.00	100.00
	Whip	21.18	2.07	3.60	83.33	96.67	90.00
April	Cleft	20.65	2.67	3.20	73.33	73.33	73.33
	Whip	29.93	2.53	2.20	46.67	43.33	40.00
May	Cleft	19.70	2.20	2.13	86.67	86.67	86.67
	Whip	30.59	3.07	3.00	60.00	76.67	73.33
June	Cleft	18.87	3.07	4.60	100.00	100.00	100.00
	Whip	22.72	2.13	3.87	83.33	83.33	83.33
July	Cleft	27.98	1.13	1.60	53.33	53.33	53.33
	Whip	30.61	2.00	2.60	33.33	50.00	46.67

(Continued)

Table 6. (*Continued*)

Grafting time (month)	Grafting Technique	Days required to bud break	number of leaves per graft at		Graft success at		
			60 DAG	90 DAG	30 DAG	60 DAG	90 DAG
August	Cleft	23.30	3.07	2.67	73.33	76.67	73.33
	Whip	28.71	1.93	2.87	53.33	60.00	56.67
SE±		0.25	0.43	0.08	0.08	1.29	1.26
LSD (0.01)		2.39	0.27	0.32	0.32	8.43	7.94
CV (%)		5.85	7.45	6.55	6.55	7.34	6.73

DAG= Days after grafting; SE± = Standard error of a mean; LSD = Least significant difference and CV = Coefficient of variation.

3.2. Effects of grafting time and techniques on rootstock diameter of mango

The increase in rootstock diameter was highly significantly (P < 0.01) influenced by the main effect of grafting time at every date of data collection (Table 7). At 90 DAG, the maximum increment of rootstock diameter (0.43 mm) was recorded on grafting time of March while the minimum (0.12 mm) was from both July and October on the date of data collected at 60 DAG (Table 4).

Grafting techniques also affected the increment of rootstock diameter highly significantly (P < 0.01) at every date of data collection (Table 7). The results of increment of rootstock diameter influenced by different techniques of grafting have been presented in (Table 5). Accordingly, the highest increment of rootstock diameter (0.31 mm) was found in case of cleft grafting technique at 90 DAG. On the other hand, the lowest increment of rootstock diameter (0.14 mm) was recorded from grafted plants which received whip grafting technique at 60 DAG.

The interaction effect between the two factors on rootstock diameter was also found to be highly significant (P < 0.01) at every date of data collection (Table 7). The highest increment of rootstock diameter (0.51 mm) was observed on the grafted plants of March with that of cleft grafting technique followed by June grafting time using similar grafting technique (0.45 mm) on the data collected at 90 DAG. Whereas the lowest increment of rootstock diameter (0.08 mm) was recorded in case of whip grafting technique which was grafted in both January and October on the data collected at 60 DAG (Table 8).

The current results are in agreement with the previous research result of Razzaque (2005). He reported that the highest increment of stock diameter (0.26 cm) was found from grafting operation with Amrapali cultivar as a scion conducted in June using a cleft technique. On the other hand, the same author indicated that the lowest increment of stock diameter (0.16 cm) was recorded on plants grafted in December with a similar technique.

3.3. Effects of grafting time and techniques on scion diameter of mango

The increase in scion diameter due to the main effect of grafting time was highly significant (P < 0.01) at every date of data collection (Table 7). At 90 DAG, the maximum increment of scion diameter (0.47 mm) was recorded on grafting time of March followed by plants grafted in June (0.43 mm). Whereas the lowest increment of rootstock diameter (0.19 mm) was recorded on grafted plants in January at 60 DAG (Table 4).

Table 7. Mean square of analysis of variance for rootstock and scion growth of grafted mango in 2015/2016 at Kalu fruit nursery site.

Source of variation	DF	Rootstock diameter (mm) at		Scion diameter (mm) at		Rootstock length (cm) at		Scion length (cm) at	
		60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG
Grafting time	11	0.09**	0.21**	0.14**	0.41**	0.02**	0.04**	0.09**	3.91**
Grafting technique	1	0.01**	0.04**	0.02**	0.03**	0.03**	0.04**	0.30**	0.65**
Grafting time x Grafting technique	11	0.001**	0.01**	0.01**	0.01**	0.01**	0.005**	0.05**	0.08**
Error	48	0.0002	0.0003	0.0003	0.0004	0.0003	0.0004	0.01	0.005

** = Highly significant; DF = Degree of Freedom

Table 8. Rootstock and scion growth of grafted mango as affected by the interaction effect of time and grafting techniques.

Grafting time (month)	Grafting technique	Rootstock diameter (mm) at		Scion diameter (mm) at		Rootstock length(cm) at		Scion length (cm) at	
		60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG
September	Cleft	0.22	0.24	0.28	0.37	0.23	0.29	1.20	1.49
	Whip	0.17	0.18	0.25	0.24	0.28	0.29	1.09	1.21
October	Cleft	0.16	0.19	0.25	0.33	0.24	0.27	0.96	1.36
	Whip	0.08	0.12	0.15	0.13	0.11	0.17	0.65	0.77
November	Cleft	0.23	0.28	0.28	0.41	0.23	0.39	1.18	1.65
	Whip	0.16	0.25	0.26	0.31	0.33	0.37	1.43	1.45
December	Cleft	0.24	0.39	0.35	0.43	0.33	0.44	1.34	2.01
	Whip	0.14	0.19	0.25	0.21	0.27	0.30	1.10	1.37
January	Cleft	0.19	0.25	0.27	0.31	0.29	0.22	1.03	1.37
	Whip	0.08	0.13	0.12	0.14	0.13	0.13	0.65	0.63
February	Cleft	0.17	0.23	0.23	0.23	0.22	0.22	1.02	1.35
	Whip	0.11	0.18	0.19	0.18	0.17	0.23	0.99	0.89
March	Cleft	0.32	0.51	0.47	0.61	0.40	0.42	1.28	2.51
	Whip	0.18	0.36	0.28	0.33	0.38	0.39	1.50	1.61
April	Cleft	0.17	0.27	0.27	0.29	0.27	0.27	0.87	1.46
	Whip	0.13	0.14	0.20	0.2	0.15	0.21	0.79	0.88
May	Cleft	0.21	0.37	0.31	0.4	0.29	0.40	1.19	1.78
	Whip	0.17	0.27	0.24	0.28	0.31	0.31	1.17	1.46

(Continued)

Table 8. (*Continued*)

Grafting time (month)	Grafting technique	Rootstock diameter (mm) at		Scion diameter (mm) at		Rootstock length(cm) at		Scion length (cm) at	
		60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG	60 DAG	90 DAG
June	Cleft	0.27	0.45	0.44	0.56	0.37	0.35	1.31	1.88
	Whip	0.22	0.25	0.27	0.29	0.35	0.41	1.35	1.41
July	Cleft	0.14	0.21	0.21	0.3	0.19	0.17	0.78	1.09
	Whip	0.10	0.18	0.20	0.21	0.17	0.16	0.76	0.96
August	Cleft	0.21	0.31	0.30	0.31	0.21	0.32	1.08	1.50
	Whip	0.15	0.16	0.21	0.14	0.23	0.25	0.92	1.21
SE±		0.003	0.006	0.005	0.006	0.005	0.006	0.02	0.02
LSD (0.01)		0.03	0.03	0.03	0.03	0.03	0.03	0.13	0.11
CV (%)		8.71	6.62	6.56	6.12	6.65	6.55	7.16	4.89

DAG= Days after grafting; SE± = Standard error of a mean; LSD = Least significant difference and CV = Coefficient of variation.

The main effect of grafting techniques has affected highly significantly (P < 0.01) the increment of scion diameter (Table 7). At every date of data collection, a significant variation in increased scion was obtained. The highest increment (0.39 mm) of the aforementioned parameter was obtained from the date of data collection at 90 DAG in case of cleft grafting technique while the lowest record (0.22 mm) was found to be that of whip grafting from the date of data collection at 60 DAG (Table 5).

The interaction effects among the factors employed were also found to be highly significant (P < 0.01) at every date of data collection (Table 7). At 90 DAG, the increment of scion diameter was maximum (0.61 mm) in March grafted plants with cleft grafting technique followed by June grafted plants of the same technique (0.56 mm). On the other hand, the minimum increment of scion diameter (0.12 mm) was found to be in graft receiving the treatment combination of January grafting time with whip grafting technique. Moreover, the second minimum increment of scion diameter (0.15 mm) was recorded on grafted plants in October using whip grafting technique (Table 8).

These results are in agreement with the previous finding of Razzaque (2005). He reported that grafting operation with Amrapali cultivar as a scion conducted in June using cleft grafting technique gave the highest increment of scion diameter (0.88 cm) which was compatible with that of May (0.38 cm) and July (0.36 cm) using similar grafting technique. He also reported that grafting operation conducted in December gave the lowest increment of scion diameter (0.27 cm), which was statistically similar with November (0.28 cm) and October (0.29 cm) grafting operation with cleft technique.

3.4. Effects of grafting time and techniques on rootstock length of mango

The increase in rootstock length was highly significantly (P < 0.01) influenced by the main effect of grafting time at every date of data collection (Table 7). At 90 DAG, the maximum increment of rootstock diameter (0.41 cm) was recorded on grafting time of March while the minimum (0.17 cm) was on grafting time of July (Table 4). The increase in rootstock length was highly significantly (P < 0.01) influenced by the main effect of grafting technique at every date of data collection (Table 7). At 90 DAG, the maximum increment of rootstock length (0.31 cm) was recorded on cleft grafted plants. The minimum increment of rootstock length (0.24 cm) was observed on the whip grafting technique on the date of data collected at 60 DAG (Table 5).

The results of the analysis of variance also revealed that the interaction effect of grafting time and techniques highly significantly (P < 0.01) influenced the rootstock length at every date of data collection (Table 7). At 90 DAG, the maximum increment of root sock length was recorded at grafting time of December with cleft technique (0.44 cm), March with cleft technique (0.42 cm) and June with whip technique (0.41 cm), respectively, in which no significant differences appeared between the means of the aforementioned treatments. On the contrary, the minimum increment of rootstock length was observed in case January (0.13 cm) and October (0.11 cm) grafting time with whip technique insignificantly on the date of data collection at 60 DAG (Table 8).

3.5. Effects of grafting time and techniques on scion length of mango

The increase in scion length was highly significantly (P < 0.01) influenced due to the main effect of grafting time at every date of data collection (Table 7). At 90 DAG, the maximum increment of scion length (2.06 cm) was recorded on grafting time of March. While the minimum increment of scion length (0.77 cm) was observed in case of grafts receiving a grafting time of July on the date of data collection at 60 DAG (Table 4).

The analysis of variance for the increment of scion length was highly significant (P < 0.01) due to the main effect of grafting technique at every date of data collection (Table 7). Accordingly, the maximum increment of scion length (1.62 cm) was recorded from cleft grafting on the date of data collection at 60 DAG. While the minimum increment of scion length (1.03 cm) was observed in case of grafts receiving a grafting technique of whip on the date of data collection at 60 DAG (Table 5).

The result of the analysis of variance also revealed that the increase of scion length was found to be highly significantly (P < 0.01) affected by the interaction effect of grafting time and techniques (Table 7). The mean values of the increment of the scion length were observed to be in the ranges of 0.65–1.50 cm and 0.63–2.51 cm and on the dates of data collection at 60 DAG and 90 DAG, respectively. At 90 DAG, the highest scion height increment (2.51 cm) was recorded in case of grafts receiving treatment combinations of March grafting time with cleft technique whereas the lowest scion height increment (0.63 cm) was recorded in treatment combinations of January grafting time with that of whip technique (Table 8).

The current results are not in agreement with Rahim, Choudhury, and Ali (1984) who reported that the highest lengths of scion were found in June grafted plants using Langra mango cultivar as a scion. Moreover, the research findings of Razzaque (2005) also contradict with the current results. He reported that grafting operation using mango rootstocks of unknown variety and scion of Amrapali in June showed the maximum growth of scion (24.84 cm) which was closely followed by May (23.58 cm) and July (23.58 cm) graft operations, respectively, with cleft grafting technique. He also reported that grafted plants in October with similar grafting technique showed the lowest increase in scion length (18.25 cm). The findings of Sanjay, Singh, and Sengupta (1996) are also not in agreement with the current results where the longest scion height was achieved from July grafting (27.34 cm) using Amrapali cultivar as a scion.

3.6. Effects of grafting time and techniques on number of leaves per graft of mango

The number of leaves of new growth was found to be statistically highly significant (P < 0.01) at every date of data recording due to the main effect of grafting time as presented in (Table 3). After 90 days of grafting, the maximum number of leaves (4.8) was recorded in December grafting whereas the minimum (1.53) was in October on the date of data collection at 60 DAG (Table 4).

The number of leaves of new growth was found to be statistically highly significant (P < 0.01) at every date of data recording due to the main effect of grafting technique (Table 3). As presented in (Table 5), after 90 days of grafting, the maximum (3.14) and minimum (2.76) number of leaves were recorded at cleft and whip grafting techniques, respectively. On the contrary, the maximum (2.23) and minimum (2.16) number of leaves recorded from whip and cleft grafting techniques, respectively, on the date of data recorded at 60 DAG.

The result of the analysis of variance also revealed that the number of leaves of new growth was found to be highly significantly (P < 0.01) affected by the interaction effect of grafting time and techniques (Table 3). The mean values of the number of leaves of new growth were observed to be in the ranges of (0.93–3.07) and 1.60–6.80) on the dates of data collection at 60 DAG and 90 DAG, respectively (Table 8).

The highest value for the number of leaves of new growth 0.89 (6.80) was recorded from December grafting with cleft technique followed by June grafting time with similar grafting technique 0.75 (4.60). On the contrary, the lowest value 0.29 (0.93) was recorded in treatment combinations of January grafting time with that of whip technique (Table 6).

The current results are in agreement with the findings of Razzaque (2005) who reported that the higher number of leaves (34.69) was observed from June grafting of Amrapali mango cultivar as a scion using cleft grafting techniques at 150 DAG. The present results are also in accordance with Rahim et al. (1984) who reported that the highest number of leaves (29.20) and growth of scion shoot were recorded during the June grafting. On the other hand, the current results contradict with the previous finding of Sivudu, Reddy, Dorajeerao, and Hussain (2014). They found that grafting on 15 July using Banganpalli variety as a scion gave the highest number of leaves (19.55) per graft.

3.7. Effects of grafting time and techniques on graft success of mango

Highly significant (P < 0.01) variation was observed on the graft success of mango at every date of data collection due to the main effect of grafting time (Table 3). The highest percentage of graft success (98.33%) was achieved from March grafted plants on the date of data collected at 60 DAG followed by the same month of grafting (95.00%) on the data taken at 90 DAG. On the other hand, the minimum percentage of graft success (43.33%) was recorded in both July grafting time on the date of data collection at 30 DAG and October grafting time of 90 DAG, respectively (Table 4).

Highly significant (P < 0.01) variation was observed on the graft success of mango at every date of data collection due to the main effect of grafting technique (Table 8). The highest percentage of graft success (78.89%) was achieved from cleft grafted plants on the date of data collected at both 30 and 60 DAG. On the other hand, the minimum percentage of graft success (51.67%) was recorded on whip grafted plants on the date of data collection at 30 DAG (Table 5).

The graft success of mango responded highly significantly (P < 0.01) due to the interaction effect of grafting time and techniques (Table 8). The mean values of percentage of graft were observed to be in the ranges (20–100%). The maximum percentage of graft success (100%) was obtained from treatment combination of both June and March grafting time with a cleft technique in the cases of all data recorded dates. On the contrary, grafted plants receiving January and October grafting time with whip technique gave the minimum percentage of graft success (20%) on the date of data recorded at 30 DAG (Table 6).

The maximum rates of success in March and June grafted mango may be probably associated with relatively high temperature (31°C) and lower relative humidity (42.70% in March and 51.87% in June) prevailed during the time of the experiment in the study area that is suitable for growth and development of grafted mango compared to other months of the year as indicated in (Table 1). The current results are in harmony with the previous findings of Razzaque (2005) who has reported that grafting operation of Amrapali scion cultivar of mango with unknown rootstock variety in June using cleft grafting technique recorded the maximum percentage of graft success (78.33%). Rahim et al. (1984) also reported that grafting on the 13th of June gave the highest percentage (76.80%) of success in case of Langra cultivar when used as a scion. Moreover, Ram (1997) also reported that cleft grafting was easier to implement and recorded the maximum success rate (97%) compared to veneer grafting in the propagation of mango. Similarly, Rafikul (2013) also reported (100%) success rate when softwoods of mango were grafted using BAU Aam-14 (Mahlisa) variety as a scion and the leaves below the graft union were retained. He also evaluated the technique as simple and effective in dry hot weather or in areas with low precipitation.

The present results are in agreement with the findings of Cholid et al. (2014) who conduct an experiment on the effect of grafting time and grafting methods used on the scion and rootstock compatibility of Physic Nut. According to their study, the average of grafting success rate reached up to 78.57%, in which the higher graft success rate was reached by grafting combination between 3 as well as 2 months rootstock old and top cleft grafting method (93.80% and 89.50% respectively). The lowest grafting success rates occurred in grafted plant combination between 1-month rootstock old and whip grafting method (66.70%). The current findings are not in agreement with the findings of Sivudu et al. (2014) who have reported that graft success was the highest (80.91%) when grafting was conducted on the 15th of July using Banganpalli variety as a scion. Similarly, the research finding of Ullah, Malik, Prakash, and Singh (2017) contradict with the current results. They reported that grafting operation on August 10th with Amrapali mango cultivar as a scion showed the maximum percentage (76.80%) of success. The research findings of Braahmachari, Kumar, and Kumar (1997) are also not in agreed with the current results. They reported that the maximum sprouting of scion (91.13%) was observed in July under Bhagalpur condition using Amrapali mango cultivar as a scion.

4. Conclusions and recommendations

4.1. Conclusions

The present study clearly indicated that both the main and interaction effects of grafting time and technique had significantly influenced days required to bud break, rootstock diameter, scion diameter, scion length, rootstock length, number of leaves per graft and graft success of mango. The plants grafted using cleft grafting technique in March and June required the minimum time to break buds of the scion and thus scored the highest success rate of grafting and maximum growth of grafted mango.

4.2. Recommendations

Based on the results of the present study, propagation of Apple mango variety on local polyembryonic rootstock using cleft grafting technique during the month of March can be recommended for the study area and areas with similar agro-ecologies, since this combination recorded the highest graft success of mango and fits to the transplanting time of grafted seedlings on the set of rainfall after three or four months of grafting which assures the survivability of the transplanted grafts to permanent orchards.

This finding was based on the one-year data, so it is necessary to repeat the experiment to come up with a confidential result. Furthermore, as the nation has diverse agro-ecologies, it is advised to do such researches on wider temporal and spatial scale to find best-fit mango propagation techniques and time for the particular agro-ecologies in order to improve the production and productivity of mango in the Amhara region in particular and in Ethiopia in general.

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Competing Interests
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