Effect of Variety and Rootstock Age on the Success and Survivability of Epicotyl Grafting in Mango

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Received on: 21/03/2019 Accepted on: 26/03/2019 Published on: 29/03/2019

ABSTRACT

Aim: This experiment was conducted to study the effect of different varieties and rootstock age on the success and survivability of epicotyl grafting in Mango plant.

Method and Materials: The experiment consisted of three varieties viz., Kachametha, Mollika and Langra and four ages of rootstock viz., 10, 20, 30 and 40 days aged. The experiment was conducted in Randomized complete Block Design (RCBD).

Results: The time required to bud break and first flash, rootstock length, rootstock diameter, scion length, scion diameter, stionic height, number of new leaves per graft, percentage of graft success and survivability were significantly influenced by varieties and age of rootstock. In case of variety, Mollika took minimum time (16.32 days) for bud breaking and first flashing (25.40 days). In addition, Mollika variety showed best performace in respect of rootstock length (20.60 cm), scion length (19.05 cm), stionic height (39.24 cm) and number of new leaves per graft (17.34) at 150 DAG. The highest graft success (83.67%) and survivability (75.42%) was also observed in Mollika variety. On the other hand, 30 days aged rootstock took minimum time (15.78 days) to bud break and first flash (25.58 days). Moreover, the highest rootstock length (25.06 cm), scion length (20.47 cm), stionic height (44.98 cm), number of new leaves (19.62) per graft were noted from same aged rootstock. Rootstock of 30 days old aged gave the highest graft success (81.56%) and survivability (65.22%) at 150 DAG.

Conclusion: The present study concluded that the variety Mollika onto 30 days old rootstock was found to be the most suitable for best growth performace of graft, the highest graft success and survivability in epicotyl grafting of mango.

Keywords: Epicotyls, grafting, rootstock, scion, survivability.

Introduction

Mango (*Mangifera indica*) belongs to the family Anacardiaceae is one of the extensively cultured, traded and popular fruits in Bangladesh as well as in the world. It is originated in Southern part of Asia, particularly in Eastern India, Burma and the Andaman Islands [1]. In Bangladesh, mango is found to grow in all districts but commercially cultivated in Rajshahi, Rongpur, Dinajpur, Kustia and Jessore. Among the fruits grown in Bangladesh, mango ranked 5th and 3rd position in case of area and production, respectively. Mango occupied an area of 37846 ha with production of 1161685 metric tons which contribute 25.22% of the area and 24.38% production of total fruit crops in Bangladesh [2].

Citation as: Bose SK, Ghosh K and Howlader P (2019). Effect of variety and rootstock age on the success and survivability of epicotyl grafting in mango. J. Agri. Res. Adv. 01(01):13-25.

Currently, mango is considered to be the most valuable tropical fruit and has been thought as 'king of fruits' because of its attractive color and pleasant flavor, delicious taste and high dietetics value. The immature and unripe fruits are used for culinary purposes and also for the preparation of pickles, chutneys etc and ripe fruits are freshly consumed by people and also used for the preparation of squash, jam, custard powder, baby food and mango leather. Ripe mangoes contain medium level of vitamin C, fairly rich vitamin A, B_1 and B_2 and also contain many essential minerals such as calcium and iron [3,4].

Grafting is suggested as vegetative plant propagation method in respect of most of the fruit crops. It comprised the joining or combining scion and rootstock together and subsequently grows as one plant where the rootstock develops into the root system and the scion grow as upper fruiting part of the grafted plant. Rootstocks can be seedlings, rooted cuttings or layered plants.

Rootstocks may influence various physical and pomological traits of grafted plants such as size, growth habits of the tree, time of fruit maturity and yield [3]. Grafting facilitate us numerous advantages including early flowering, smaller size with bushy canopy and begin to bear fruit earlier compared to seedling trees [5]. Moreover, asexual propagation including grafting is a appropriate technique to maintain true-to-type of a given variety that enables to produce offspring with similar characteristics of mother plant [6].

On the other hand, most of the improved cultivars are mono-embryonic thus require grafting to produce true to type trees while some of them perform poorly due to unsuitability to tropical conditions. For this reason it is necessary to develop improved mango cultivars combining with traditional types through grafting. The success and survivality rate of grafting can be increased by use of proper rootstock and appropriate grafting time of the year based on the desirable growing conditions [7] and also by enhancing the skills and knowledge of gardener who involve in grafting operation [8]. Furthermore, the rate of graft success is also depending on grafting techniques that are used [9].

Various methods of grafting such as contact, veneer, cleft, saddle, splice, tongue etc have been developed and among them veneer and cleft graftings are mainly practiced in Bangladesh. But epicotyl grafting has been successfully used as an effective and quick method for the propagation of mango plant [10,11]. The benefits of epicotyl grafting are that the newly sprouted seedling is in juvenile stage and the cells have the capacity of quick differentiation and which play a crucial role in the success of graft. The variety and age of rootstock have been found to be important factors for the highest percentages of graft success and survivability and growth in case of epicotyl grafting in mango as reported by different authors [12]. In general, one year old seedlings are used as rootstocks for grafting. But in case of epicotyl grafting, it is not necessary to develop one year aged rootstocks because few weeks old very young seedlings can be used as rootstock.

A lot of study on the rootstock age and effect of variety on the success and survivality of grafting has been studied in different countries [13]. Very few research works has been conducted on epicotyl grafting in mango in Bangladesh. Considering the above facts in mind the present study was undertaken to investigate the most suitable aged rootstock and to find out the best mango varieties for epicotyls grafting resulting the maximum success rate which supporting the increase of mango production in the study area and other similar climatic area.

Materials and Methods

The experiment was conducted at the Germplasm Centre, Department of Horticulture, Patuakhali Science and Technology University (PSTU), Patuakhali, Bangladesh.

Experimental site

The experiment was conducted at the Germplasm Centre, Department of Horticulture, Patuakhali Science and Technology University (PSTU), Patuakhali, Bangladesh. The site of the experimental area is situated between $22^{0}37'$ N latitude and $89^{0}10'$ E longitudes at the elevation of at 0.9 to 2.1 meter above the sea level [14].

Soil and climate

The land selected for the experiment was medium high, fertile, well drained and slightly acidic with the pH range 5.5 to 6.8 [15]. The textrure of soil was silty loam belongs to the Gangas Flood Plain of AEZ-13 having non-calcareous dark grey flood plain soil. The experimental area was situated under the sub-tropical monsoon climate which is characterized by moderate temperature and heavy precipitation during the month of July to October.

Experimental Materials

Rootstock and scion of mango varieties were used as experimental materials. Local mango seeds were collected from home garden, local market and homestead area for producing rootstocks. The scion was collected from the mother plant of mango in Germplasm Centre of PSTU, Patuakhali, Bangladesh.

Treatments of the experiment

The two-factor experiment consisted of four different aged rootstock viz., 10, 20, 30 and 40 days aged and three different varieties of mango viz., Kachametha, Mollika and Langra.

Design and layout of the experiment

The experiment consisted of 12 treatment combinations with 3 replications having 10 grafts per replication. The experiment was conducted in

Randomized complete Block Design (RCBD). The treatment combinations were randomly assigned to each unit plot, so as to allot one treatment combination once only in each block.

Development and selection of rootstock for epicotyl grafting

From unknown cultivars of mango, healthy and weighty stones were collected and selected by deeping them in a bucket of water. The 400 selected stones were placed in polybag at about 2 cm depth of soil. The polybag contained a mixture of 50% well decomposed cowdung and 50% sandy loam soil. After germination of stones 360 healthy and straight rootstocks were selected for grafting.

Selection of mother plants for scion collection

Good quality stock plant with appropriate growing conditions assures higher percentage of graft success. Considering this fact, pest and disease free and healthy 4-5 years old uniform bearing scion mother plants were selected for the collection of scion shoots.

Collection of scion materials

The non-flowering shoots having dark green color leaves, about 12-20 cm long, straight, healthy, pest and disease free with swollen terminal bud with same thickness of scion were selected. The selected scion shoots were detached from the mother plants with the help of sharp secateurs and were defoliated leaving one- fourth of the petiole just after detachment from plants. The collected scion shoots were then carried in a polybag to the experimental plot and kept in shady place to avoid desiccation.

Grafting operations

About 2-3 cm long oblique cuts were performed both sides at the proximal end of the 15 cm long scion in such a way that the end portion cut became very thin as like a blade with the help of a sharp knife. Firstly, a horizontal cut was done on the rootstock at proper height above the ground level and then a vertical cut or cleft of near about 3 cm was made by a sharp grafting knife at the center of the horizontal cut of the rootstock. After that the scion was placed into the cleft of the rootstock through slight opening the vertical cut. The rootstock and scion were brought into intimate contact particularly cambium in face to face and tied with polythene strip and then the scion along with the union portion was covered with a polythene cap to protect the scion from direct sunlight and loss of water through transpiration. The grafting was done on the month of June because in this time we get suitable temperature and relative humidity for graft success.

Intercultural operation

Necessary measures were taken to make the experimental plots free from weed. To assure proper growth and development of grafted plants, weeding, mulching and watering were done whenever needed during the period of investigation. Proper shades were provided to protect the grafted plant from direct sunlight and sometimes the shade was removed for the exposure of grafts to the direct sunlight. Removal of off-shoots, polythene cap, polythene strip, watering, fertilizer application, disease and insect pest control were done whenever necessary.

Data collection and analysis

The data on different parameters were recorded at one month interval except the times required to bud break and first flash which were recorded at 5 days interval starting from the date of grafting.

Days required to bud break

Days required to first bud break were noted by counting the days elapsed from days to grafting until to the first bud break from the scion and the mean values were calculated and used for further analysis.

Days required to first flash

Days required to first flash were recorded by counting the days required for sprouting of leaf from the scion and the average values were computed and used for further analysis.

Number of new leaves

The number of new leaves per graft was counted at 30 days intervals which was started from the date of graft operation and continued 150 days. The number of leaves per graft was calculated by calculating the mean values and used for further analysis.

Percentage of graft success

Emergence of shoot from the terminal bud of scion was considered as the success of a graft. Number of successful grafts was counted up to 2 months from the date of grafting at 5 days interval and the results were expressed in percentage. The percent graft success was calculated by using the following formula:

$$\% \text{ of graft success} = \frac{\text{Number of successful graft}}{\text{Total number of grafted rootstocks}} \times 100$$

Rootstock length

The length of rootstock was measured from the ground level to the middle of the grafting place by using meter scale at 30 days interval. The rootstock length was computed by the following formula and expressed as centimeter.

Rootstock length= (Final length of rootstock) - (Initial length of rootstock at the time of grafting)

Scion length

The length of scion was counted from the middle of the grafting place to the tip of the terminal bud by meter scale at 30 days interval. The scion length was calculated by the following formula and expressed as centimeter.

Scion length = (Final length of scion) – (Initial length of scion at the time of grafting)

Stionic height

When the rootstock and scion were united and continued to grow as one plant, then the graft is also termed as stion. The stionic height was measured by meter scale at one month interval starting from the date of grafting and was continued up to 5 months. The stionic height was calculated by the following formula and expressed as centimeter.

Stionic height = (Height of tip of successful graft) – (Height of terminal end of scion at the time of grafting)

Scion diameter

Diameter of the scion was measured at 5 cm above the grafting place. The diameter was measured by 'Slide calipers' and was expressed as millimeter.

Rootstock diameter

The diameter of rootstock was measured by 'Slide calipers' at the middle portion of the rootstock and was expressed as millimeter.

Graft survivability

After initial success the growth of grafts were observed up to 5 months from the date of grafting success. The percentage of graft survival was calculated by using the following formula:

$$\% \text{ Graft survival} = \frac{\text{(Total number of successful grafts) – (Total number of dead scion after grafting success)}}{\text{Total number of successful grafts}} \times 100$$

Statistical analyses

The collected data on various parameters under this study were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done with the help of SPSS 22.0 (IBM, New York, USA) software. The differences between the treatment means were compared by Least Significance Difference (LSD) test [16].

Results

Effect of varieties and age of rootstock on the days required to bud break

The analysis of variance showed significant variation ($P<0.05$) in respect of bud breaking influenced by different varieties and age of rootstock of mango. The maximum time (18.78 days) required for bud breaking was recorded in the variety Kachametha followed by the variety Langra (17.62 days) whereas the minimum time (16.32 days) was recorded in Mollika variety for bud breaking (Fig. 1A). On the other hand, the minimum bud breaking time (15.78 days) was recorded when grafting was done onto 30 days old rootstock followed by 40 days old rootstock (17.13 days) whereas the maximum bud breaking time (19.17 days) was recorded at 10 days old rootstock (Fig. 1 B). The combined effect of varieties and ages of rootstock had no significant variation in case of days required to bud break. The lowest time (14.27 days) was recorded for bud breaking when graft was done onto the Mollika with 30 days old rootstock followed by the variety Langra (16.04 days) with same aged rootstock while the highest time (20.31 days) was noticed for bud break when grafting was made on the variety Kachametha with 10 days old rootstock (Table 1).

Effect of varieties and age of rootstock on the days required to first flash

The effect of varieties and ages of rootstock had significant ($P<0.05$) effect on the days required to first flash.The lowest time (25.40 days) was recorded in Mollika and the highest time (30.07 days) was noted in Kachametha for first flash (Fig. 1C).

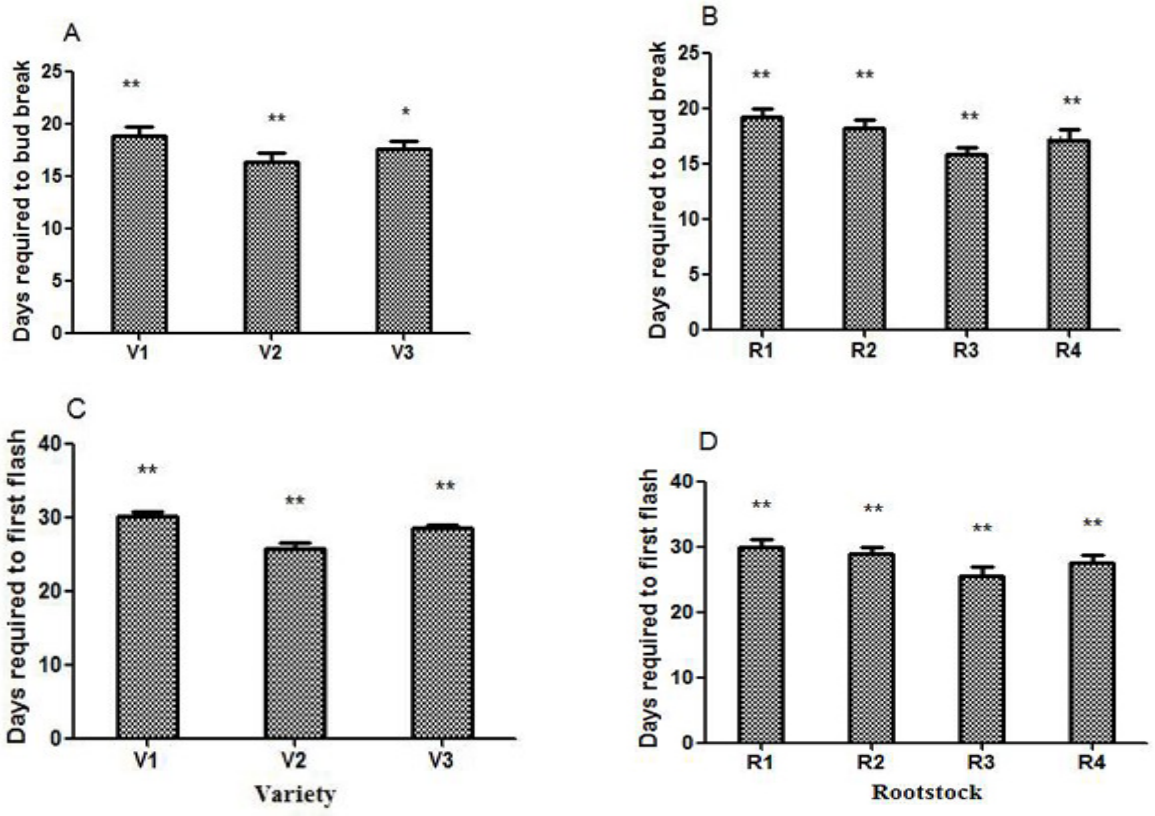

Fig. 1 Effect of variety and rootstock age on days required to bud break (A & B) and days required to first flash (C & D) of epicotyl grafting in mango. ** = Significant at 1% level of probability

Table 1. Combined effect of variety and rootstock age on days required to bud break and days required to first flash of epicotyl grafting in mango

Variety x Rootstock	Days required to bud breaking	Days required to first flashing
V_1R_1	20.31	32.09
V_1R_2	19.46	30.92
V_1R_3	17.04	27.79
V_1R_4	18.32	29.48
V_2R_1	17.95	28.07
V_2R_2	17.07	26.42
V_2R_3	14.27	22.26
V_2R_4	16.00	24.85
V_3R_1	19.24	29.82
V_3R_2	18.13	29.26
V_3R_3	16.04	26.69
V_3R_4	17.07	28.08
Level of significance	NS	*
$LSD_{0.05}$	1.56	1.02
CV (%)	5.25	2.16

* = Significant at 5% level of probability, NS = Not significant

The minimum time (25.58 days) required for first flash was noticed in the grafts produced by 30 days old rootstock whereas, the maximum time (29.99 days) was recorded for the first flash onto the rootstock of 10 days old (Fig. 1D). The minimum time (22.26 days) required for first flash was noticed in the grafts produced by 30 days old rootstock with Mollika variety whereas, the maximum time (32.09 days) was recorded for the first flash onto the rootstock of 10 days old with Kachametha variety (Table 1). The length of rootstock as influenced by all treatments was recorded periodically during the entire period of investigation starting from the date of grafting operation and was continued up to 150 DAG at 30 days interval.

Effect of varieties and age of rootstock on the length of rootstock

Rootstock length was significantly ($P<0.05$) influenced by the different varieties and ages rootstock of mango. The rootstock length was always higher in Mollika variety followed by Langra during the studied period. The highest rootstock length (20.60 cm) was noted from Mollika variety while the lowest was recorded from Kachametha (15.36 cm) after 150 days of grafting (Table 2). On the other hand, the highest length of rootstock (25.06 cm) was noted in the

grafts produced by 30 days old rootstock whereas, the lowest length of rootstock (11.85 cm) was recorded onto the rootstock of 10 days old (Table 2). The periodical data showed that there was more increase in length of rootstock as recorded at 150 DAG. The highest length of rootstock (27.85 cm) was recorded when grafting was done with the variety Mollica onto the 30 days old rootstock followed by the same stage of rootstock (23.91 cm) with Langra whereas the lowest length of rootstock (9.41 cm) was recorded when the grafts were made with the variety Kachametha onto the 10 days old rootstock (Table 2).

Table.2: Effect of variety and rootstock age on rootstocklength of epicotyl grafting in mango.

Variety	Length of rootstock (cm) Days after grafting				
	30	60	90	120	150
V_1	13.35	13.64	14.19	14.71	15.36
V_2	18.21	18.59	19.13	19.91	20.60
V_3	15.90	16.27	16.75	17.18	17.81
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.691	0.685	0.655	0.803	0.601
Rootstock					
R_1	9.78	10.07	10.61	11.10	11.85
R_2	12.67	12.97	13.50	14.11	14.78
R_3	23.05	23.41	23.94	24.51	25.06
R_4	17.78	18.21	18.73	19.35	19.99
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.803	0.791	0.756	0.927	0.693
Variety x Rootstock					
V_1R_1	7.18	7.49	7.84	8.30	9.41
V_1R_2	9.41	9.68	10.30	10.73	11.29
V_1R_3	21.42	21.74	22.31	23.01	23.44
V_1R_4	15.38	15.63	16.32	16.79	17.29
V_2R_1	11.48	11.79	12.20	13.01	13.55
V_2R_2	15.58	15.95	16.47	17.34	18.16
V_2R_3	25.37	25.77	26.45	27.01	27.85
V_2R_4	20.41	20.83	21.40	22.27	22.83
V_3R_1	10.69	10.93	11.77	11.97	12.60
V_3R_2	13.02	13.27	13.73	14.27	14.89
V_3R_3	22.35	22.70	23.04	23.50	23.91
V_3R_4	17.55	18.18	18.46	18.99	19.85
Level of significance	*	*	**	*	**
$LSD_{0.05}$	1.39	1.37	1.31	1.61	1.20
CV (%)	5.19	5.00	4.63	5.49	3.96

**= Significant at 1% level of probability, *= Significant at 5% level of probability

Effect of varieties and age of rootstock on the diameter of rootstock

Rootstock diameter was significantly (P<0.05) influenced by the different varieties and ages of rootstocks of mango. Rootstock diameter was always higher in Mollika variety and the highest rootstock diameter (9.95 mm) was obtained from Mollika variety while the lowest was found in Kachametha (6.16 mm) variety at 150 DAG (Table 3). At 150 DAG, the rootstock diameter (9.53 mm) was recorded in the graft produced by 30 days old rootstock followed by 40 days old rootstock while the lowest rootstock diameter (4 6.44 mm) was noted in the grafts produced by 10 days old rootstock (Table 3). The highest diameter of rootstock (11.35 mm) was recorded when grafting was done with the variety Mollica onto the 30 days old rootstock followed by the same stage of rootstock (9.250 mm) with Langra whereas the lowest diameter of rootstock (4.363 mm) was recorded when the grafts were made with the variety Kachametha onto the 10 days old rootstock (Table 3).

Table.3: Effect of variety and rootstock age on rootstock diameter of epicotyl grafting in mango

Variety	Rootstock diameter (mm) Days after grafting				
	30	60	90	120	150
V_1	4.44	4.94	5.22	5.51	6.16
V_2	5.95	7.27	8.20	8.86	9.95
V_3	5.58	6.10	6.59	7.32	7.95
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.173	0.29	0.332	0.397	0.325
Rootstock					
R_1	4.32	4.78	5.23	5.76	6.44
R_2	4.86	5.43	6.06	6.56	7.53
R_3	6.337	7.71	8.19	8.69	9.53
R_4	5.78	6.48	7.20	7.91	8.57
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.200	0.341	0.384	0.458	0.375
Variety x Rootstock					
V_1R_1	2.72	3.30	3.56	3.80	4.36
V_1R_2	3.73	3.95	4.11	4.35	5.23
V_1R_3	6.08	6.76	7.07	7.30	8.00
V_1R_4	5.25	5.74	6.17	6.59	7.06
V_2R_1	5.20	5.91	6.48	7.17	8.29
V_2R_2	5.64	6.69	7.90	8.57	9.74
V_2R_3	6.59	9.14	9.99	10.26	11.35
V_2R_4	6.36	7.35	8.42	9.46	10.43
V_3R_1	5.03	5.14	5.65	6.32	6.68
V_3R_2	5.21	5.65	6.18	6.77	7.63
V_3R_3	6.33	7.24	7.51	8.51	9.25
V_3R_4	5.74	6.36	7.03	7.69	8.23
Level of significance	**	**	**	*	*
$LSD_{0.05}$	0.347	0.591	0.665	0.794	0.649
CV (%)	3.84	5.71	5.87	6.48	4.78

**= Significant at 1% level of probability, *= Significant at 5% level of probability

Effect of varieties and age of rootstock on the length of Scion

The length of scion of the graft produced by epicotyl grafting was significantly (P<0.05)

influenced by the different varieties and ages of rootstock at different days after grafting. The highest length of scion (19.05 cm) was recorded in Mollika and the lowest length of scion (15.42 cm) was noted in Kachametha (Table 4). The highest scion length (20.47cm) was noticed in the grafts produced by 30 days old rootstock followed by 40 days old rootstock whereas the lowest scion length (13.90 cm) was found onto the 10 days old rootstock (Table 4). The highest scion length (22.19 cm) was observed when grafting was done with the variety Mollica onto the 30 days old rootstock followed by the same stage of rootstock (20.09 cm) with Langra whereas the lowest length of scion (11.81 cm) was recorded when the grafts were made with the variety Kachametha onto the 10 days old rootstock (Table 4).

Table. 4: Effect of variety and rootstock age on scionlength of epicotyl grafting in mango

Variety	Length of scion (cm)				
	Days after grafting				
	30	60	90	120	150
V_1	6.76	7.81	10.35	13.59	15.42
V_2	8.17	11.65	14.01	16.85	19.05
V_3	7.36	9.27	11.80	14.83	16.70
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.167	0.587	0.539	0.499	0.401
Rootstock					
R_1	5.93	7.37	10.02	12.34	13.90
R_2	7.00	8.43	11.32	13.83	15.89
R_3	8.98	11.96	14.19	17.99	20.47
R_4	7.81	10.54	12.68	16.22	17.97
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.193	0.677	0.622	0.577	0.463
Variety x Rootstock					
V_1R_1	5.45	5.08	7.97	10.59	11.81
V_1R_2	6.37	6.81	9.453	12.69	14.60
V_1R_3	8.27	11.15	13.17	16.80	19.14
V_1R_4	6.97	8.20	10.80	14.28	16.12
V_2R_1	6.44	10.59	12.53	14.59	16.52
V_2R_2	7.75	11.09	13.72	15.85	17.78
V_2R_3	9.67	12.68	15.35	19.12	22.19
V_2R_4	8.82	12.23	14.42	17.85	19.73
V_3R_1	5.90	6.46	9.540	11.85	13.37
V_3R_2	6.90	7.39	10.80	12.93	15.28
V_3R_3	9.00	12.06	14.05	18.04	20.09
V_3R_4	7.64	11.18	12.83	16.51	18.07
Level of significance	*	**	*	*	*
$LSD_{0.05}$	0.334	1.17	1.08	0.999	0.801
CV (%)	2.67	7.23	5.28	3.91	2.77

**= Significant at 1% level of probability, *= Significant at 5% level of probability

Effect of varieties and age of rootstock on the diameter of Scion

Varietal effect and ages of rootstock showed significant ($P<0.05$) variation in respect of scion diameter at different days after graftage. The variety Mollika showed the highest scion diameter (7.45 mm) followed the variety Langra (6.47 mm) whereas the variety kachametha showed the lowest scion diameter (5.62 mm) at 150 DAG (Table 5). At 150 DAG, the maximum diameter of scion (8.24 mm) was recorded from 30 days old rootstock followed by 40 days aged rootstock (6.90 mm) while the minimum scion diameter (4.85 mm) was noted from 10 days aged rootstock (Table 5). The variety Mollika produced (9.32 mm) maximum diameter of scion when grafting was done with 30 days aged rootstock followed by the same aged rootstock (8.15 mm) with the variety Langra whereas the minimum diameter of scion (1 3.54 mm) was noted when the variety Kachametha was grafted with 10 days aged rootstock at 150 DAG, (Table 5).

Table 5: Effect of variety and rootstock age on scion diameter of epicotyl grafting in mango

Variety	Scion diameter (mm)				
	Days after grafting				
	30	60	90	120	150
V_1	3.57	3.97	4.42	5.05	5.62
V_2	4.53	5.72	6.01	6.97	7.45
V_3	4.17	4.69	5.51	5.83	6.47
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.248	0.365	0.358	0.224	0.221
Rootstock					
R_1	3.09	3.76	4.32	4.76	4.85
R_2	4.00	4.42	4.97	5.68	6.05
R_3	4.88	5.97	6.43	7.18	8.24
R_4	4.40	5.02	5.52	6.17	6.90
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.287	0.389	0.414	0.259	0.255
Variety x Rootstock					
V_1R_1	1.86	2.41	2.90	3.35	3.54
V_1R_2	3.50	3.83	4.28	4.87	5.29
V_1R_3	4.75	5.20	5.56	6.43	7.26
V_1R_4	4.19	4.45	4.94	5.54	6.38
V_2R_1	4.11	4.93	5.07	5.92	6.09
V_2R_2	4.36	5.10	5.367	6.67	6.81
V_2R_3	5.08	7.13	7.51	8.37	9.32
V_2R_4	4.56	5.66	6.10	6.93	7.57
V_3R_1	3.30	3.87	5.00	5.03	4.94
V_3R_2	4.13	4.34	5.27	5.49	6.06
V_3R_3	4.80	5.59	6.24	6.75	8.15
V_3R_4	4.45	4.95	5.52	6.05	6.75
Level of significance	**	*	*	**	**
$LSD_{0.05}$	0.497	0.673	0.716	0.448	0.442
CV (%)	7.15	8.28	7.97	4.45	4.00

**= Significant at 1% level of probability, *= Significant at 5% level of probability

Effect of varieties and age of rootstock on the stionic height

A highly significant variation (P<0.05) was observed due to the effect of mango varieties and ages of rootstocks in respect of stionic height at different days after grafting (Table 6). Among the varieties, Mollika gave the maximum stionic height (39.24 cm) followed by the variety Langra (34.53 cm) whereas the minimum stionic height was recorded from the variety Kachametha (30.78 cm) at 150 DAG (Table 6).

Table 6: Effect of variety and rootstock age on stionic height of epicotyl grafting in mango

Variety	Stionic height (cm)				
	Days after grafting				
	30	60	90	120	150
V_1	20.1	21.45	24.54	28.22	30.78
V_2	26.33	30.23	33.17	36.76	39.24
V_3	23.26	25.38	28.56	32.01	34.53
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.682	1.16	0.912	0.876	0.908
Rootstock					
R_1	15.72	17.45	20.67	23.33	25.76
R_2	19.68	21.40	24.82	27.94	30.69
R_3	31.96	35.15	38.13	42.49	44.98
R_4	25.59	28.75	31.41	35.57	37.97
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.787	1.34	1.05	1.01	1.05
Variety x Rootstock					
V_1R_1	12.63	12.57	15.82	18.56	21.23
V_1R_2	15.79	16.49	19.75	23.42	25.88
V_1R_3	29.69	32.89	35.49	39.81	42.58
V_1R_4	22.36	23.84	27.12	31.07	33.41
V_2R_1	17.92	22.38	24.87	27.60	30.07
V_2R_2	23.33	27.04	30.18	33.19	35.94
V_2R_3	34.84	38.46	41.80	46.13	48.37
V_2R_4	29.23	33.05	35.82	40.13	42.57
V_3R_1	16.59	17.39	21.31	23.82	25.97
V_3R_2	19.92	20.66	24.53	27.20	30.25
V_3R_3	31.35	34.09	37.09	41.54	44.00
V_3R_4	25.18	29.37	31.29	35.50	37.92
Level of significance	*	*	*	*	*
$LSD_{0.05}$	1.36	2.32	1.82	1.75	1.82
CV (%)	3.46	5.34	3.75	3.19	3.08

**= Significant at 1% level of probability, *= Significant at 5% level of probability

The 30 days aged rootstock produced the highest stionic height (44.98 cm) followed by the rootstock of 40 days aged (37.97 cm) whereas the lowest stionic height(25.76 cm) was counted from 10 days old rootstock at 150 DAG (Table 6). At 150 DAG, the highest stionic height (34.84, 38.46, 41.80, 46.13 and 48.37 cm) was recorded from the variety Mollika when grafted with 30 days aged rootstock followed the variety Langra with same aged rootstock (31.35, 34.09, 37.09, 41.54 and 44 cm) where the lowest stionic height (12.63, 13.57, 15.82, 18.56 and 21.23 cm) was counted from the variety Kachametha when grafting was done with 10 days old rootstock (Table 6).

Effect of varieties and age of rootstock number of new leaves

The analysis of variance on the number of leaves due to the effect of different varieties and ages of rootstocks differed significantly (P<0.05). The variety Mollika showed the highest number of leaves per graft (5.20, 6.87, 9.72, 13.95 and 17.34) followed the variety Langra (3.78, 6.26, 9.46, 12.34 and 15.31) whereas the variety kachametha showed the lowest number of leaves (3.22, 5.55, 8.24, 11.08 and 13.26) at 30, 60, 90, 120 and 150 DAG (Table 7).

Table 7: Effect of variety and rootstock age on number ofnew leaves of epicotyl grafting in mango

Variety	Number of new leaves				
	Days after grafting				
	30	60	90	120	150
V_1	3.227	5.557	8.244	11.08	13.26
V_2	5.202	6.874	9.720	13.95	17.34
V_3	3.783	6.263	9.468	12.34	15.31
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.283	0.202	0.408	0.239	0.617
Rootstock					
R_1	3.04	4.16	5.53	8.874	11.10
R_2	3.64	5.53	7.60	10.85	14.10
R_3	5.37	8.46	13.22	16.84	19.62
R_4	4.21	6.76	10.22	13.26	16.39
Level of significance	**	**	**	**	**
$LSD_{0.05}$	0.327	0.233	0.471	0.277	0.712
Variety x Rootstock					
V_1R_1	2.59	3.72	5.00	7.68	9.91
V_1R_2	2.933	4.97	7.00	9.38	11.67
V_1R_3	4.09	7.56	12.01	15.29	17.04
V_1R_4	3.28	5.97	8.96	11.97	14.42
V_2R_1	3.70	4.67	5.84	9.99	11.29
V_2R_2	4.65	5.92	7.49	12.49	16.68
V_2R_3	6.83	9.41	14.17	18.34	23.04
V_2R_4	5.61	7.48	11.38	14.99	18.38
V_3R_1	2.82	4.09	5.76	8.95	12.11
V_3R_2	3.33	5.70	8.33	10.69	13.96
V_3R_3	5.21	8.42	13.48	16.89	18.78
V_3R_4	3.75	6.83	10.31	12.82	16.37
Level of significance	**	*	**	*	**
$LSD_{0.05}$	0.567	0.404	0.816	0.478	1.23
CV (%)	8.23	3.84	5.27	2.27	4.76

**= Significant at 1% level of probability, *= Significant at 5% level of probability

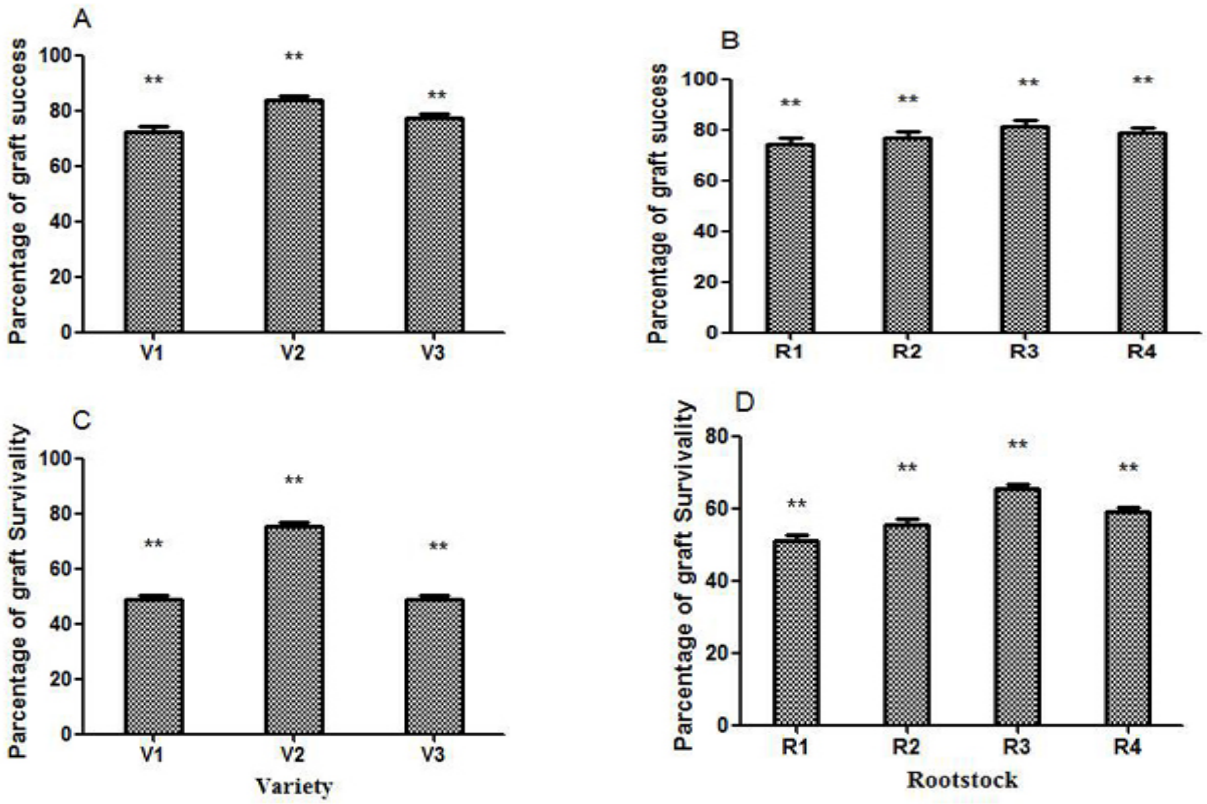

Fig. 2 Effect of variety and rootstock age on percentage of graft success (A & B) and survivability (C & D) of epicotyl grafting in mango

At 30, 60, 90, 120 and 150 DAG the highest number of leaves (5.37, 8.46, 13.22, 16.84 and 19.62) was noted from 30 days old rootstock followed by 40 days aged rootstock (4.21, 6.76, 10.22, 13.26 and 16.39) whereas the lowest number of leaves (3.04, 4.16, 5.53, 8.87 and 11.10) was found from 10 days aged rootstock (Table 7). At 30, 60, 90, 120 and 150 DAG, the highest number of leaves (6.83, 9.41, 14.17, 18.34 and 23.04) was recorded from the variety Mollika when grafted with 30 days aged rootstock followed the variety Langra with same aged rootstock (5.21, 8.42, 13.48, 16.89 and 18.78) where the lowest number of leaves (2.59, 3.72, 5.00, 7.68 and 9.91) was counted from the variety Kachametha when grafting was done with 10 days old rootstock (Table 7).

Effect of varieties and age of rootstock on the percentage of graft success

The different varieties and ages of rootstock had significant ($P<0.05$) effect on the percentage of graft success. Mollika variety showed the highest percentage of graft success (83.67%) followed by Langra (77.50%) and the lowest success (72.50%) was recorded in Kachametha (Fig. 2 A).

Table 8: Effect of variety and rootstock age on percentage of graft success and survivability of epicotyl grafting in mango

Variety x rootstock	Percentage of graft success	Percentage of graft survivability
V_1R_1	68.67	41.67
V_1R_2	71.00	47.00
V_1R_3	76.67	57.00
V_1R_4	73.67	50.67
V_2R_1	81.00	70.00
V_2R_2	82.33	73.67
V_2R_3	87.33	81.67
V_2R_4	84.00	76.33
V_3R_1	74.00	41.67
V_3R_2	77.00	46.33
V_3R_3	80.67	57.00
V_3R_4	78.33	50.33
Level of significance	*	*
$LSD_{0.05}$	1.10	1.68
CV (%)	0.84	1.72

**= Significant at 1% level of probability, *= Significant at 5% level of probability

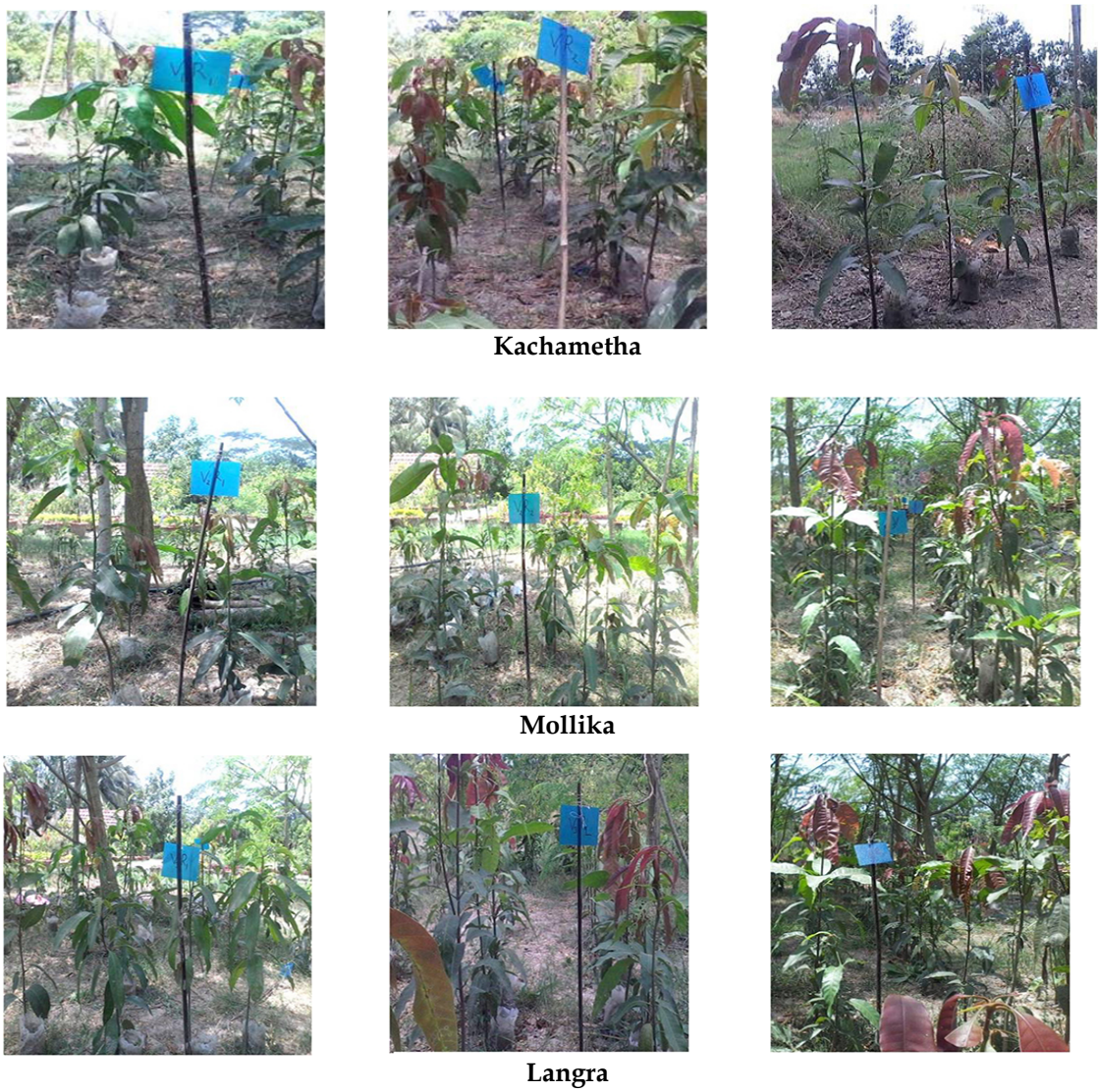

Fig.3: The success and survivality of grafted mango plants.

The highest percentage of graft success (81.56%) was noticed in the grafts produced by 30 days old rootstock followed by 40 days old rootstock (78.67%) and the lowest percentage of graft success (74.56%) was found onto the 10 days old rootstock (Fig. 2 B). The highest percentage of graft success (87.33%) was recorded when grafting was done with the variety Mollika onto the 30 days old rootstock followed by the same stage of rootstock (80.67%) with Langra and the lowest percentage of graft success (68.67%) was recorded when the grafts were made with the variety Kachametha onto the 10 days old rootstock (Table 8).

Effect of varieties and age of rootstock on the percentage of graft survivability

A highly significant variation ($P<0.05$) was observed due to the effect of mango varieties and ages of rootstocks in respect of graft survivability at different days after grafting. Mollika variety showed the highest percentage of graft survivability (75.42%) followed by Langra (48.83%) and the lowest survivability (47.08%) was recorded in Kachametha (Fig. 2 C). Alam (2008) was recorded that the highest percentage of graft survivability was recorded in the variety Mollika (70.13%) followed by variety Langra (54.17%). The highest percentage of graft survivability (65.22%) was noticed in the grafts produced by 30 days old rootstock followed by

40 days old rootstock and the lowest percentage of graft survivability (51.11%) was found onto the 10 days old rootstock (Fig. 2 D). The highest graft survivability (81.67%) was recorded when grafting was done with the variety Mollika onto the 30 days old rootstock followed by the same stage of rootstock (57%) with Langra and the lowest graft survivability (41.67%) was recorded when the grafts were made with the variety Kachametha onto the 10 days old rootstock (Table 8). Great variation exhibited in the response of different cultivars to this method of grafting (Fig.3). In all tables and figures indicators are:

R1 = Rootstock of 10 days old containing opened red coloured leaves with single internode,
R2 = Rootstock of 20 days old containing opened radish green coloured leaves with single Internode,
R3 = Rootstock of 30 days old containing opened green coloured leaves with single internode,
R4 = Rootstock of 40 days old containing opened green coloured leaves with double internode.
V1 = Kachametha, V2 = Mollika, V3 = Langra

Discussion

Grafting is suggested as most crucial vegetative plant propagation method in respect of most of the fruit crops. Grafting facilitate us numerous advantages including early flowering, smaller size with bushy canopy and begin to bear fruit earlier compared to seedling trees [5]. Moreover, asexual propagation including grafting is a appropriate technique to maintain true-to-type of a given variety that enables to produce offspring with similar characteristics of mother plant [6]. Epicotyl grafting has been successfully used as an effective and quick method for the propagation of mango plant [10, 11]. The benefits of epicotyl grafting are that the newly sprouted seedling is in juvenile stage and the cells have the capacity of quick differentiation and which play a crucial role in the success of graft. The variety and age of rootstock have been found to be important factors for the highest percentages of graft success and survivability and growth in case of epicotyl grafting in mango as reported by different authors [12].

Bud breaking is the primary indication of grafting success.The variation in the varieties and ages of rootstock for the bud breaking might be due to the differences in the translocation of food reserves and changes in cambial activity due to different treatments. The rootstock containing opened green coloured leaves with single internode (30 days old) was physiologically mature; the leaves supplied more food materials and juvenility having the capacity of rapid cell elongation and cell division, which are important for rapid wound healing process. So, it possibly attributed to rapid callus formation and union of graft that led to earlier bud break. Our results validated the results of Dhakal and Hoda [17] who stated that sprouting of scion buds started from second weeks of grafting and number of days required for sprouting varied from minimum of 15.23 days to maximum of 22.88 days. The variations in the days required to first flash might be due to the genetical factors of the respective variety. The earlier leaf flash onto the 30 days old rootstock might be due to the quick graft union process that enhanced the translocation of food materials from leaves of the rootstock through union which also enhanced excellent flashing of new leaves. This result is supported by BARI [18] and they reported that the maximum time (17.38 days) required for bud breaking was noted in BARI mango-9 (Kachametha) and the minimum time (15.54 days) was required in BARI mango-10.

The rootstock length was always higher in Mollika variety followed by Langra during the studied period. This result in agreement with the results reported by Alam [19] who found that the increase in height of the rootstock over initial height in Mollika was 0.96 cm while in Langra it was 0.82 cm at 6 months after grafting. The probable cause behind this might be climatic factor and juvenility of rootstock. The highest increase in rootstock length after grafting might be due to the getting maximum time by the stock for manufacturing of more food through its leaves and excellent physiological condition. From the above results, it was found that the rate of increase in length of rootstock follow a sequential pattern among the interaction with the variety and ages of rootstock under investigation.

The highest rootstock diameter was achieved in Mollika variety followed by Langra during the studied period. This result in line with the result of Karim [20] who recorded that rootstock diameter of Mollika was 0.89 cm and Langra was 0.73 cm. The highest result might be due to the active growth of the rootstock of 30 days after seed germination. This rootstock was possibly strong enough to withstand the grafting shock with an excellent sap flow and continued food supply from the stored food that enhanced the graft union process resulting higher growth. It

was reported that 30-35 days old seedling gave better diameter than 20 or 40 days old seedling [21].

Scion length was always higher in case of Mollika variety throughout the study period. Our results are in line with the results of Gurudutta et al. [22] who conducted an experiment with the mango cultivars Langra, Dashehari, Amrapali and mallika at Raipur, Chhattisgarh, India and reported that Mollika gave highest scion length the 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. The highest increase in scion diameter after grafting might be due to the getting maximum time by the stock for producing of more food through its leaves and excellent physiological condition. This rootstock was possibly strong enough to withstand the grafting shock with an excellent sap flow and continued food supply from the stored food that enhanced the graft union process resulting higher growth in diameter of scion.

Among the varieties, Mollika variety gave the maximum stionic height. This observation is also an agreement with the findings of Karim [20] and he noted that the stionic height of Mollika was 46.24 cm and in Langra was 40.23 cm. The rootstock got maximum time for 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.

A significant variation was also observed in the production of leaves at every date of counting due to the interaction effect of the varieties and ages of rootstock. Islam et al. [23] 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.

Findings of this study also validated the results of Madalgeri et al. [24] who carried out an experiment on the response of mango varieties to epicotyl grafting method of propagation and they observed the grafting success ranged from 66.1% in the Mallika and 64.6% in the cultivar dashehari. Radha and Aravindakshan [25] evaluated the response of 14 mango cultivars to the epicotyl grafting method of propagation and they reported that an average survival of 62.98% was noticed 6 month after grafting. Alam [19] reported that the highest percentage of graft survivability was recorded in the variety Mollika (66.24%) followed by variety Langra (63.17%). Sultana *et al*. (2014) noted that 30-35 days old seedling gave better result than 20 or 40 days old seedling.

Conclusion

The results of the present study suggest that the different variety and different aged rootstocks exhibited great variation. The success and survivability of grafts also depend on variety and age of rootstocks. From these findings it can be concluded that the variety Mollika and Rootstock containing opened green coloured leaves with single internode (30 days old) is the best for higher percentage of graft success and survivability followed by Langra and Kachametha with the same stage of rootstock for the large scale propagation of epicotyl grafting in mango

Acknowledgements

The authors deeply acknowledges there gratefulness to Chairman and all the teachers of the Department of Horticulture, PSTU, Patuakhali, Bangladesh for there valuable suggestions, encouragement and for providing all the facilities to conduct the experiment.

Conflict of interest:

Authors declared no conflict of interest.

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