# PERFORMANCE OF GRAFTING TECHNIQUES IN MANGO VARIETIES

**MOHAMMAD SOLAIMAN HOSSAIN**

**DEPARTMENT OF HORTICULTURE**

**SHER-E-BANGLA AGRICULTURAL UNIVERSITY**
**DHAKA-1207**

**DECEMBER, 2020**

**PERFORMANCE OF GRAFTING TECHNIQUES IN MANGO VARIETIES**

**MOHAMMAD SOLAIMAN HOSSAIN**

**Reg. No.: 18-09191**

A Thesis

*Submitted to the Department of Horticulture Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of*

**MASTER OF SCIENCE (MS)**
**IN**
**HORTICULTURE**

**SEMESTER: JULY-DECEMBER, 2020**

**APPROVED BY:**

______________________________
**Dr. Mohammad Humayun Kabir**
Professor
Department of Horticulture
SAU, Dhaka
**Supervisor**

______________________________
**Dr. Md. Ismail Hossain**
Professor
Department of Horticulture
SAU, Dhaka
**Co-Supervisor**

______________________________
**Prof. Dr. Md. Jahedur Rahman**
Chairman
Examination Committee

***DEDICATED TO***

***MY BELOVED PARENTS***

# DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University

**Sher-e-Bangla Nagar, Dhaka-1207**

Memo No: SAU/HORT/…………………………………………………………..

## CERTIFICATE

This is to certify that the thesis entitled **'Performance of grafting techniques in mango varieties'** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **Mohammad Solaiman Hossain**, Registration No. **18-09191** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

**Dated: December, 2020**

**Dhaka, Bangladesh**

______________________________

**Prof. Dr. Mohammad Humayun Kabir**

Department of Horticulture

Sher-e-Bangla Agricultural University

Dhaka-1207

**Supervisor**

# *ACKNOWLEDGEMENTS*

*All praises are due to the Omnipotent Allah, the Supreme Ruler of the universe who enables the author to complete this present piece of work.*

*The author feels proud to express his heartiest sense of gratitude, sincere appreciation and immense indebtedness to his supervisor Professor* ***Dr. Mohammad Humayun Kabir****, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his continuous scholastic and intellectual guidance, cooperation, constructive criticism and suggestions in carrying out the research work and preparation of thesis, without his intense co-operation this work would not have been possible.*

*The author feels proud to express his deepest respect, sincere appreciation and immense indebtedness to his co-supervisor* ***Dr. Md. Ismail Hossain****, Profesor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.*

*The author expresses his sincere respect and sense of gratitude to Professor and Chairman,* ***Dr. Md. Jahedur Rahman*** *, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for valuable suggestions and cooperation during the study period. The author also expresses her heartfelt thanks to all the teachers of the Department of Horticulture, SAU, for their valuable teaching and suggestions.*

*The author expresses his sincere appreciation to his colleagues, relatives, well-wishers and friends for their inspiration, help and encouragement throughout the study.*

***The Author***

# PERFORMANCE OF GRAFTING TECHNIQUES IN MANGO VARIETIES


## ABSTRACT

The study was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka during the period from June to December 2019 to assess the performance of different grafting techniques and scion from different mango varieties on young and adult mango tree. This experiment consisted of two factors: Factor A: Grafting techniques ($G_1$- Cleft grafting, $G_2$- Veneer grafting, $G_3$- Whip grafting) and Factor B: Scion from different mango varieties ($S_1$- Fazli, $S_2$- Langda, $S_3$- Himsagor, $S_4$- Namdokmai). The two factors experiment was laid out in Randomized Completely Block Design with three replications. Results exposed that different combinations of different grafting techniques and scion from different mango varieties had a significant effect on success of grafting, Significant effect were found in number of leaf production on scion part, circumference and height of scion part on both young and adult mango tree. In case of grafting on young mango plant $S_2$ and $G_1$ gave highest growth in scion and rootstock circumference, height of scion and number of leaves per scion which is reflected from the results of $S_2G_1$ combination. But the highest success rate was found from $S_1$ (73%) and $G_1$ (70%). Considering combined effect treatment combination $S_1G_1$ showed the best success result (80%). Regarding grafting on adult mango trees the highest grafting success rate was noted from $S_4$ (62.22%) and $G_2$(68%) while treatment combination $S_4G_2$ gave the best result (80%). On the other hand, $S_3$ (53.33%) and $G_1$ (48.13%) treatment combination gave the lowest success and it was only 53.33%.

# TABLE OF CONTENTS


| CHAPTER | TITLE | Page |
|---|---|---|
| | **ACKNOWLEDGEMENTS** | **iii** |
| | **ABSTRACT** | **iv** |
| | **TABLE OF CONTENTS** | **v** |
| | **LIST OF TABLES** | **viii** |
| | **LIST OF FIGURES** | **ix** |
| | **LIST OF PLATES** | **x** |
| | **LIST OF APPENDICES** | **xi** |
| **1.** | **INTRODUCTION** | **01-05** |
| **2.** | **REVIEW OF LITERATURE** | **06** |
| | 2.1 Review related to vegetative propagation | 06 |
| | 2.2. Review related to Grafting operation | 12-14 |
| **3.** | **MATERIALS AND METHODS** | **15** |
| | 3.1 Experimental site | 15 |
| | 3.2 Soil of the experimental field | 15 |
| | 3.3 Climate | 15 |
| | 3.4 Collection of planting materials | 16 |
| | 3.5 Treatments of the experiments | 16 |
| | 3.6 Design and layout of the experiment | 16 |
| | 3.7 Required tools and materials | 17 |

| | |
|---|---|
| 3.8 Collection of scion | 17 |
| 3.9 Rootstock selection | 18 |
| 3.10 Plants grafting principles | 18 |
| 3.11 Cleft grafting | 19 |
| 3.12 Veneer grafting | 22 |
| 3.13 Whip grafting | 23 |
| 3.14 Data collection procedures | 24 |
| 3.14.1 Circumference of rootstock (cm) | 24 |
| 3.14.2 Circumference of scion (cm) | 24 |
| 3.14.3 Height of scion (cm) | 25 |
| 3.14.4 Number of leaves on new graft | 25 |
| 3.14.5 Percentage of graft success (%) | 25 |
| **4. RESULTS AND DISCUSSION** | **26** |
| **4.1 Part -1 (Grafting on Young mango plant)** | 26 |
| 4.1.1 Effect of grafting techniques and scion from different mango varieties on circumference of rootstock after grafting | 26 |
| 4.1.2 Effect of grafting techniques and scion from different mango varieties on circumference of grafts | 28 |
| 4.1.3 Effect of grafting techniques and scion from different mango varieties on height of graft in young mango plant | 30 |
| 4.1.4 Effect of grafting techniques and scion from different mango varieties on the number of leaves per scion in young mango plant | 32 |

| | |
|---|---|
| 4.1.5 Effect of grafting techniques and scion from different mango varieties on the success rate of grafting in young mango plant | 34 |
| **4.2 Part -2 (Grafting on adult mango tree)** | 37 |
| 4.2.1 Effect of grafting techniques and scion from different mango varieties on the circumference of rootstock in adult mango tree. | 37 |
| 4.2.2 Effect of grafting techniques and scion from different mango varieties on the circumference of graft in adult mango tree | 39 |
| 4.2.3 Effect of grafting techniques and scion from different mango varieties on the graft height in adult mango tree. | 40 |
| 4.2.4 Effect of grafting techniques and scion from different mango varieties on the number of leaves per scion | 42 |
| 4.2.5 Effect of grafting techniques and scion from different mango varieties on the success rate of grafting in adult mango tree | 44 |
| **5. SUMMARY AND CONCLUSIONS** | **46** |
| **REFERENCES** | **48** |
| **APPENDICES** | **56** |

# LIST OF TABLES



| | Title | Page |
|---|---|---|
| **Table 1.** | Effect of scion from different mango variety on the circumference of rootstock in young mango plant | 27 |
| **Table 2.** | Effect of grafting techniques on the circumference of rootstock in young mango plant | 27 |
| **Table 3.** | Combined effect of grafting techniques and scion from different mango varieties on the circumference of rootstock in young mango plant | 28 |
| **Table 4.** | Effect of scion from different mango varieties on the circumference of scion part in young mango plant | 29 |
| **Table 5.** | Effect of different grafting method on the circumference of scion part in young mango plant | 29 |
| **Table 6.** | Combined effect of grafting techniques and scion from different mango varieties on the circumference of scion in young mango plant | 30 |
| **Table 7.** | Combined effect of grafting techniques and scion from different mango varieties on height of scion in young mango plant. | 32 |
| **Table 8.** | Effect of scion from different mango varieties on number of leaves per scion in young mango plant. | 33 |
| **Table 9.** | Effect of grafting techniques on number of leaves per scion in young mango plant. | 33 |
| **Table 10.** | Combined effect of grafting techniques and scion from different mango varieties on the number of leaves per scion in young mango plant. | 34 |
| **Table 11** | Combined effect of grafting techniques and scion from different mango varieties on grafting success in young mango plant. | 36 |
| **Table 12** | Effect of scion from different mango varieties on the circumference of rootstock in adult mango tree | 37 |
| **Table 13** | Effect of grafting techniques on the circumference of rootstock in adult mango tree | 38 |

| | | |
|---|---|---|
| **Table 14** | Combined effect of grafting techniques and scion from different mango varieties on the circumference of rootstock in adult mango tree | 38 |
| **Table 15** | Effect of scion from different mango varieties on the circumference of scion in adult mango tree | 39 |
| **Table 16** | Effect of grafting techniques on the circumference of scion in adult mango tree | 39 |
| **Table 17** | Combined effect of grafting techniques and scion from different mango varieties on the circumference of scion in adult mango tree | 40 |
| **Table 18** | Combined effect of grafting techniques and scion from different mango varieties on the height of scion in adult mango tree | 42 |
| **Table 19** | Effect of scion from different mango varieties on the leaves number per scion in adult mango tree | 43 |
| **Table 20** | Effect of different grafting techniques on the leaves number per scion in adult mango tree | 43 |
| **Table 21** | Combined effect of various grafting techniques and scion from different mango varieties on the leaves number per scion in adult mango tree | 44 |
| **Table 22** | Combined effect of grafting techniques and scion from different mango varieties on grafting success rate in adult mango tree. | 45 |

# LIST OF FIGURES


| | Title | Page |
|---|---|---|
| **Figure 1.** | Effect of scion from different mango varieties on graft height in young mango plant | 31 |
| **Figure 2.** | Effect of grafting techniques on graft height in young mango plant | 31 |
| **Figure 3.** | Effect of scion from different mango varieties on success of grafting in young mango plant | 34 |
| **Figure 4.** | Effect of grafting techniques on grafting success in young mango plant | 35 |
| **Figure 5.** | Effect of scion from different mango varieties on graft height in adult mango tree | 41 |
| **Figure 6.** | Effect of grafting techniques on graft height in adult mango tree | 41 |
| **Figure 7.** | Effect of scion from different mango varieties in grafting success on adult mango tree | 44 |

## LIST OF PLATES


| | Title | Page |
|---|---|---|
| **Plate 1** | Photograph of tools used during grafting. | 17 |
| **Plate 2** | Photograph of scions used for grafting | 18 |
| **Plate 3** | Photograph of rootstock preparation for cleft grafting | 19 |
| **Plate 4** | Photograph of prepared scion for cleft grafting | 20 |
| **Plate 5** | Scion insertion on rootstock and adjoining with plastic stripe during cleft grafting | 21 |
| **Plate 6** | Photograph of scion and rootstock preparation for veneer grafting ( a and b) | 22 |
| **Plate 7** | Contacting scion with rootstock during veneer grafting (c and d) . | 23 |

# LIST OF APPENDICES


| | Title | Page |
|---|---|---|
| **Appendix I.** | The map of the experimental site | 56 |
| **Appendix II.** | Characteristics of soil of experimental field | 57 |
| **Appendix III.** | Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2016 to April 2017 | 58 |
| **Appendix IV.** | Summary of analysis of variance for rootstock circumference and scion circumference changed at different intervals after grafting on young mango tree. | 58 |
| **Appendix V.** | Summary of analysis of variance for height of graft and leaves per plant changed at different intervals after grafting on young mango tree. | 59 |
| **Appendix VI.** | Summary of analysis of variance for Rootstock circumference and Scion circumference changed at different intervals after grafting on Adult Mango tree. | 59 |
| **Appendix VII.** | Summary of analysis of variance for Height of graft and Leaves per plant changed at different intervals after grafting on adult mango tree. | 59 |
| **Appendix VIII.** | Summary of analysis of variance for success rate of grafting on young and adult mango tree. | 60 |

# CHAPTER I

# 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, (Takele H, 2014). 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 (BBS, 2016).

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).

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).

Mango is a cross pollinated crop. Generally, mango is commercially propagated through vegetative means due to its heterozygous nature. Due to increasing trend of mango cultivation, time demand of mango graft required to be fulfilled. Traub and Autcher (1934) first reported the epicotyl grafting in mango is cost effective, easy to conduct, good success percentage with rapid multiplication of vigorous and healthy grafted seedlings (Patil *et al.*, 1991).

Recently the success of epicotyl grafting has been revealed by different authors (Jose and Velsalakumari, 1991 and Hossain, 1996). Kulwal and Tayde (1989a) reported that this technique requires less time for propagation proved to be cheaper. The success of epicotyl grafting depends on different factors such as temperature, relative humidity, light, soil moisture, variety of scion, pre-defoliation of scion, length of scion, age of rootstock, time and method of grafting and the skills of the grafter. Ram and Sirohi, (1989) reported that the success of grafting depends upon season, age of rootstock and scion and cultivar. Alam *et al.*, (2006) got better results from Langra scion grafted onto 15 days old seedlings using cleft methods on 5, 10, 15 and 20 days old BARI Aam-1. Maity and Biswas (1980) reported that defoliated scion shoots always produced higher percentage of successful grafts than the un-defoliated shoots.

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).

The practice of grafting plants for horticultural purposes has been commercially in use since the 1920s starting in Asia (King *et. al*,2010). The main advantage of joining two genotypes (sometimes two different species) is the tolerance to abiotic and/or biotic stresses of the genotype in the bottom (the rootstock) while preserving the characteristics of the genotype on top (the scion). Current solanaceous breeding programs are mostly targeting the development of material for cultivation under greenhouse conditions, since they promote vigorous growth of the plant which results in increased yields (King *et. al*,2010).

Vigorous plants require the uptake of higher amounts of all macronutrients including nitrogen (N). Depending on the combination of rootstock and scion, contrasting results have been reported with regards to the concentration of N in the biomass, resulting in similar (Albornoz *et. al*, 2018) or higher (Djidonou *et. al*, 2017) contents than in non-grafted plants. Once N is absorbed by the roots, it is loaded into the xylem where it is transported upwards by mass flow in the transpiration stream. Then, the unloading from the xylem vessels occurs following the concentration gradients generated in the growing tissues (Marschner, 2012). In fruit trees, it has been observed that rootstocks can supply higher quantities of mineral nutrients to the shoots by increasing the concentration of these elements in the xylem sap and/or enhancing the transpiration rate (Grassi *et. al*, 2002).

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, B1 and B2 and also contain many essential minerals such as calcium and iron (Mukherjee *et al*, 2009).

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 (Griesbach J, 2003). Grafting facilitate us numerous advantages including early flowering, smaller size with bushy canopy and begin to bear fruit earlier compared to seedling trees (Janick *et al*, 2010). 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 (Nakasone *et al*, 1998).

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 (Simon *et al,* 2010) and also by enhancing the skills and knowledge of gardener who involve in grafting operation (Akinnifesi *et al*, 2008). Furthermore, the rate of graft success is also depending on grafting techniques that are used (Soleimani, A *et al*, 2010).

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 (Bhan, KC *et al*, 1969 and Amin, RS (1978). 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 (Jose *et al*, 1991). 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 different types of grafting on mango tree has been studied in different countries (Ghosh *et al*, 2015). Very few research works on the different types of grafting on mango tree has been conducted in Bangladesh. Considering the above facts in mind the present study was undertaken to investigate the most suitable grafting technique and to find out the best one which supporting the increase of mango production in the study area and other similar climatic area.

Objectives of the study:

- To find out the success rate of different grafting method on young and adult mango tree.
- To determine the performance of scion from different varieties on young and adult mango tree.
- To find out the efficiency of different grafting method and scion from various mango plant leading to the varietal improvement of adult mango tree.

# CHAPTER II

# REVIEW OF LITERATURE

The review of literature reveals that there is very limited research on some aspects of Mango Grafting particularly; Common grafting techniques of Mango, grafting conditions for Mango, grafting compatibility in Mango, Response of young and adult Mango Tree to Grafting. It highlights the need for research on these aspects for better utilization. Mango offers potential for new and traditional goods and convenience foods. The literature cited here under are on various aspects of value addition to fruits, not only of Mango but also of some other fruits and vegetables.

## 2.1 Review related to vegetative propagation

A mango is a stone fruit produced from numerous species of tropical trees belonging to the flowering plant genus *Mangifera*, cultivated mostly for their edible fruit. Most of these species are found in nature as wild mangoes. The genus belongs to the cashew family *Anacardiaceae*. Mangoes are native to South Asia, (Morton, Julia Frances,1987)from where the "common mango" or "Indian mango", *Mangifera indica*, has been distributed worldwide to become one of the most widely cultivated fruits in the tropics. Other *Mangifera* species (e.g. horse mango, *Mangifera foetida*) are grown on a more localized basis. Worldwide, there are several hundred cultivars of mango. Depending on the cultivar, mango fruit varies in size, shape, sweetness, skin color, and flesh color which may be pale yellow, gold, or orange (Morton, Julia Frances,1987) Mango is the national fruit of India and Pakistan, and the national tree of Bangladesh. It is the unofficial national fruit of the Philippines (Pangilinan, Jr., Leon,3 October 2014).

Epicotyl grafting has been successfully used as an effective and quick method for the propagation of mango plant (Ban *et al*. 1969). 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 (Jose *et al*. 1991).

Gosh (2015) reported that 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. Iftekhar (2004) showed that 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.

Dhakal and Huda (2000) 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. Hartmann *et al*. (1997) reported at least 10 mm as a desirable rootstock thickness for grafting fruit trees. Mhango *et al*. (2008), application of fertilizer to the growing medium improved the growth of *Uapaca kirkiana* seedlings with respect to root collar diameter, but not the heights.

Tyree et al. (2009) also reported that fertilization increased seedling foliage and roots. Growth increase is important, especially when nurserymen want to have rootstocks ready for grafting within a year. Mango rootstocks grafted at less than 5 mm thick did not promote the overall survival of grafted plants as well as plant height, especially for the early emerging seedlings.

Early emerging seedlings (nurse) had insignificant increase in plant height and root collar diameter after seedling thinning. The insignificant differences in plant height for the late emerging seedlings indicated uniformity in growth and this confirmed that nucellar seedlings could bring tree uniformity if used as rootstocks. Because of a long 'waiting period' before rootstocks are grafted, an improvement in growth rate to attain a desirable size, especially stem diameter within a year is important. This is because there is a cost incurred in keeping rootstocks in the nursery for a long time (Karim *et al.* 2004).

The success of the graft depends on the compatibility between the rootstock and scion. Studies have indicated that grafts in different genera of the same family are rarely compatible, but grafts of different species within the same genus can survive by forming an effective graft union (Goldschmidt, 2014). The majority of homografts are compatible, with the exception of monocots. Since the wound required for grafting disrupts the plant vascular system (Asahina & Satoh, 2015), reconnection of the vasculature is necessary to maintain normal water and nutrient transportation. Most monocots do not have vascular cambia, which may be a reason why grafting fails (Sachs, 1981; Melnyk & Meyerowitz, 2015). This further suggests that vascular differentiation during wound healing is a prerequisite for successful grafting.

When the cambium of the scion joins fully with that of the rootstock, intact cells divide and proliferate into calli, which eventually differentiate into vasculature and plasmodesmata forms (Melnyk & Meyerowitz, 2015). Although the detailed molecular mechanisms underlying this process require further research, some studies have found that hormones, such as auxin, cytokinin and GA, play a pivotal role in regulating stock–scion interactions (Aloni *et al*., 2010).

After cell walls fuse in the graft union, plasmodesmata stretch in small groups over the spaces of the inner cell wall, interconnecting the protoplasts of contiguous cells (Kollmann & Glockmann, 1985). Heterogeneous cells then interdigitate through the plasmodesmata (Melnyk & Meyerowitz, 2015). The plasmodesmata provide tunnels for small molecules and even selectively permit the movement of macromolecules, such as proteins and nucleic acids. Additionally, vascular reconstruction at the graft union enables macromolecules to be transported (Harada, 2010). In recent years, increasing effort has been made to determine how macromolecules are transferred between scions and rootstocks in grafting plants to reveal the mechanisms that control graft-induced changes in plant traits (Paultre *et al*., 2016).

Grafting commonly influences the phenotype of the grafted plants (Warschefsky *et al*., 2015), including changes in fruit quality, resistance to pests and pathogens, tolerance to adversity and stress, and other physiological disorders. The vegetative fruit quality of scions is commonly altered by the rootstocks after grafting. Taller *et al*. (1998) described a case in which two pepper scion cultivars acquired changes in fruit shape, color and pungency after grafting. The results also illustrated that several rootstock features were present in the progeny of the scion after self-pollination. Similarly, a graft of three watermelon cultivars and three hybrid squashes showed differences in shape, weight, yield, quality, rind thickness and pH among stocks (Turhan *et al*., 2012). Fruit trees, such as sweet cherry, apple and citrus, have also been shown to be influenced by grafting.

Grafting is widely used to improve resistance to pests and diseases. For instance, grafting can alleviate the development of post-harvest diseases in Hass avocado fruit (Willingham *et al*., 2001). Anthracnose, caused by the fungus *Colletotrichum gloeosporioides*, is the most severe post-harvest disease of avocado fruits. The rootstocks can significantly affect the post-harvest anthracnose resistance of scions, which is probably related to an increase in antifungal diene and improvement in mineral nutrients in the scions. Research on the resistance of pepper plants to both phytophthora blight and bacterial wilt also confirmed the effect of grafting. Five commercial stocks and nine breeding lines were used as rootstocks for the scion 'Nokkwang', three of which were selected for their greater resistance to phytophthora blight and bacterial wilt without reduction in productivity or fruit quality (Jang *et al*., 2012). Furthermore, a study using tomatoes revealed that cultivars grafted onto nematode-resistant rootstocks gained higher yields than did nongrafted ones (Lopez-Perez *et al*., 2006). Similar results have been found in eggplants (Ioannou, 2001), cucumbers (Gu *et al*., 2006) and peppers (Oka *et al*., 2004).

In addition to the cases mentioned above, related publications have indicated that physiological and morphological features can be altered by stock–scion interactions. The ability of rootstocks from certain fruit trees to dwarf their scions, which has been acknowledged for decades, is used in agriculture. A series of rootstocks used for dwarfing has been developed in apples, and genetic marker analysis linked to the dwarfing traits has been performed. In micro grafting experiments in *Arabidopsis*, Turnbull *et al*. (2002) found that the wild-type (WT) stocks can effectively inhibit rosette branching of the increased branching mutants *max*1 (more axillary growth) and *max*3. Notably, when two shoots from the *max*1 and WT seedlings were simultaneously grafted onto a *max*1 rootstock, the mutant shoot showed increasing branching while the WT shoot did not. When the *max*1 rootstock was replaced with a WT rootstock, neither of the shoots branched profusely. The results indicated that branch signaling can spread from root to shoot but not from shoot to shoot.

The majority of current research has been dedicated to using rootstocks to influence shoot phenotypes, but the root changes induced by scions have been seldom discussed, probably due to the important role that scions play in agricultural and horticultural practices and also the relative difficulty in observing root phenotype changes given that they are below ground. However, the effects of the scion on stock growth and carbohydrate storage seem to be indisputable (Dahniya *et al*., 1982), and root–shoot interactions remain to be explored further.

Graft-induced phenotypic changes have triggered research into the endogenous factors that control rootstock–scion interactions. Historically, botanists believed that plant hormones are responsible for these interactions due to their roles in regulating plant vegetative growth and reproduction. Hormones in plants are regulated by feedback loops and remain balanced in non graft plants. A study of peach grafts demonstrated that hormonal balance is disrupted after grafting (Sorce *et al*., 2002). Since many plant hormones are highly mobile, they can be translocated easily in the graft chimeras. According to existing evidence, hormonal signaling is involved in root–shoot interactions, including graft-union formation, scion–rootstock communication, and plant growth and development (Aloni *et al*., 2010).

The heritability of graft-induced phenotypic changes suggests that regulatory processes underlying the scion–rootstock communication also involve a genetic component (Taller et al., 1998; Tsaballa et al., 2013). In fact, the presence of heritability coincides with Lysenko's graft hybrid hypothesis, which suggests that graft hybridization has similar properties to those of sexual hybridization. This concept, which seems to be inconsistent with Mendelian genetics, was initially rejected by Western scientists, but research over recent decades has provided evidence for the existence of graft hybridization. Pandey (1976) proposed that fragments of chromatin produced by cells rupture after grafting and then can migrate into their neighboring cells via plasmodesmata. Later, Ohta (1991) provided evidence that chromatin can move via the vascular bundles from the lignifying stock, across the graft union, and into the growing point of the scion. In addition, a study by Taller et al. (1998) detected several random amplification of polymorphic DNA (RAPD) markers in the graft-induced variants and found the same bands in the rootstock cultivar but not in the scion. They suggested that the genetic changes caused by grafting were attributable to direct DNA uptake through the vascular bundles.

To demonstrate exchange of genetic materials between cells in grafted plants, Stegemann & Bock (2009) created two transgenic tobacco lines that harbor different marker and reporter genes in their nuclear and chloroplast genomes, respectively. These two lines were reciprocally grafted, with the grafted stem regions exposed to resistance selection. In subsequent reporter expression experiments, plastid genes were found to transfer short distances across the graft union, indicating an opportunity for grafting to pursue horizontal gene transfer (HGT). HGT is the asexual transfer of genetic materials from a donor organism to a recipient organism, playing an important part in eukaryotic genome evolution (Bock, 2010).

Plasmodesmata formation and re-establishment of vascular bundles provide transport channels for HGT during formation of the graft union. To investigate whether large DNA fragments or whole organelles are involved in gene transfer, Stegemann *et al*. (2012) generated three other tobacco lines (transplastomic *Nicotiana tabacum*, transgenic *N. glauca* and *N. benthamiana*) for graft experiments. After sequencing two polymorphic regions distant from the transgenic regions on the plastid differing substantially among the three lines, identical sequences from *N. tabacum* in *N. tabacum*/*N. glauca* and *N. tabacum*/*N. benthamiana* grafts were obtained. Since there is no genome recombination between scions and stocks, this finding indicates that the entire plastid genome travels through the graft union (Stegemann *et al*., 2012).

Despite horizontal transfer of DNA was confirmed to occur across the graft site, the authors stated that 'they do not lend support to the tenet of Lysenkoism that "graft hybridization" would be analogous to sexual hybridization' because of the restriction of gene transfer to short distances close to the graft site. Nevertheless, they offered a bolder suggestion that grafting could be an asexual path to speciation. In the experiments of grafting *Nicotiana* plants in which the graft unions were maintained in tissue culture after resistance selection, Fuentes *et al*. (2014) found that nuclear genome transfer between scion and stock has occurred, producing new fertile and stable allopolyploid species at a considerable rate. Thus, grafting could lead to a direct transfer of the entire nuclear and plastid genomes across the graft junction, which has widespread implications for understanding grafting mechanisms and plant evolution.

Epigenetic modifications may be other potential roles in creating heritable phenotypic variation via grafting. Epigenetics is the study of heritable variations in gene expression that are not caused by differences in DNA sequence as a result of modifications, such as DNA methylation or structural changes to chromatin. A study in interspecies Solanaceae grafting showed that locus-specific alterations in DNA methylation were produced in the grafting process and that these alterations in the grafted scions are partially heritable to their self-pollinated progenies (Wu *et al*., 2013). Moreover, small RNA (sRNA)-mediated graft-transmissible epigenetic modifications have been detected in *Arabidopsis thaliana* grafting experiments. Molnar *et al*. (2010) showed that 24 nt sRNAs that have transferred from shoots to roots can cause epigenetic changes by mediating DNA methylation at three sites in the rootstock cells. A follow-up study showed that the mobile sRNAs acted on RNA-directed DNA methylation at thousands of loci genome wide. A small number of genes characterized by transcriptomic analysis in recipient tissues were correlated with mobile small interfering RNAs (siRNAs) and DNA methylation (Lewsey *et al*.,2016).

The 24 nt sRNAs, as well as 21–23 nt sRNAs, are key components in gene silencing. These sRNAs are produced by the activities of DICER-LIKE proteins and then loaded onto ARGONAUTE proteins (AGOs) to target RNAs (Borges & Martienssen, 2015; Table 1). RNA gene silencing signals are distributed systemically in plants and are capable of transmitting across the graft union in grafting plants (Chitwood & Timmermans, 2010; Fragoso *et al*., 2011). All classes of both transgene-specific siRNAs and endogenous siRNAs showed mobility between graft partners in *A. thaliana* grafting studies (Molnar *et al*., 2010). The mobile siRNAs from the rootstock were reported to induce endogenous post-transcriptional gene silencing in the scion, and 24 nt siRNAs from the shoots have also been found to direct transcriptional gene silencing in the rootstock cells (Melnyk *et al*., 2011). In another report, Dunoyer *et al*. (2010) provided evidence that 21 nt siRNA duplexes function as mobile silencing signals among cells.

In terms of the transport through the stem, rootstocks can affect the delivery of nutrients to the shoots by altering the transpiration rate. The transpiration flux through the stem is controlled by gradients in the stem water potential (Yw). Due to the restrictions imposed by the graft union or at the root level, rootstocks can affect the stem water potential (Weibel *et. al*, 2003). To a lesser extent, the water potential in the stem can be modified by changes in the osmotic potential of the xylem sap through changes in the concentration of ions, mainly potassium and nitrate, thus altering the transport capacity in the xylem (Sellin *et. al*, 2010 and Ragel *et. al*, 2019).

Vigorous plants require the uptake of higher amounts of all macronutrients including nitrogen (N). Depending on the combination of rootstock and scion, contrasting results have been reported with regards to the concentration of N in the biomass, resulting in similar (Albornoz *et. al*, 2018) or higher (Djidonou *et. al*, 2017) contents than in non-grafted plants. In fruit trees, it has been observed that rootstocks can supply higher quantities of mineral nutrients to the shoots by increasing the concentration of these elements in the xylem sap and/or enhancing the transpiration rate (Grassi *et. al*, 2002).

## 2.2 Review related to Grafting operation

### 2.2.1 Veneer grafting

For multiplication of nursery plants veneer grafting was first used in Florida (Lynch, 1941) and has since been standardized under Indian conditions (Mukherjee and Majumder, 1961). MUkherjee and Majumder, (1964) A study of the comparative performance of veneer grafts, inarched and budded plants showed that veneer grafts made comparable growth like the inarches in three months (Mukherjee and Majumder, 1962). Later, Mukherjee and Majumder (1962a) observed that the grafts prepared during March and April made excellent growth and were ready for planting in July in the same year. They tried veneer grafting in mango and found 80-90 per cent success in March to July. Jagirdar *et al.* (1968) reported that the age of rootstock (3 or 9 months) had no effect on graft success. The percentage of take, however, was increased by the use of mature scion wood compared with immature wood.

Majumder *et al*, (1972) found that the success of veneer grafting in mango was not affected by scion lengths (2.5 - 10 cm) but subsequent growth was greater with longer scions. Grafting with non-flowering scion shoots gave 90 per cent success compared with 70 per cent success with flowering shoots. Moistend scion material wrapped in plastic can be successfully stored at room temperature for 6-9 days during April and June and for shorter periods in May and July. Singh *et al,* (1979) obtained best results with 12-month-old stocks and 6-month-old scions, each 1.0 or 1.5 cm in diameter which were defoliated 10 days prior to grafting. Kahlon and Mishra (1979) in their experiment on the effect of leaf lamina as the success and scion vigor in veneer grafting of mango found highest percentage of success and most vigorous scion growth by excising the distal half of the lamina.

### 2.2.2 Side grafting

Bums and Prayag (1920), Bailey (1927) and Pope and Storey (1933) reported side tongue grafting being successful in mango in Hawaii. Veeraraghavan (1945) reported varying i degrees of success in different varieties, the maximum being 100 per cent with 'Khadar' as scion. Parsai (1963) obtained 80 per cent success in side grafting of mango. The technique has been further modified by Kashyap *et al*, (1972), who reported 70-80 percent success when fresh bud stick was used and up to 100 percent success in case of bud sticks being defoliated 10 days prior to the date of grafting. Bhambota *et al*, (1971) reported 82 per cent success with side grafting in mango. Scions, 7-5 cm long, were found most satisfactory and grafting in March/April and June-October gave the best results (Kanwar *et al'*, 1974).

### 2.2.3 Inarching

Inarching is one of the oldest methods used for mango propagation and in spite of its various drawbacks, it is still followed on commercial lines throughout the country. Bums and Prayag (1920) reported that in Philippines 3-week-old seedlings are used as rootstock and the grafts are usually removed from the parent tree within a month in Hawari the age of seedling stock is about 6 months. Sen (1939, 1941) secured best results by inarching current year's shoot, about the size of a lead pencil, into seedlings of about three months' age, using waxed tape. Naik (1941) succeeded with four-and-a-half month-old seedlings. Rangacharlu (1955) studied them further and found no significant differences among these trees 14 years later. Singh (1954 a) observed 80 per cent success with 4-weekold seedlings with their roots covered with sphagnum moss. Garg (1954a) suggested to wrap the seedling roots in plastic and to hang them on the tree for inarching, without any pot.

Taiukdar and Ahmed (1965) carried out inarching on 1-month-old seedling rootstocks using the varieties 'Langra', toashehari and 'Samar Behist'. The higher percentage of success with 'Samar Behist' (71 per cent compared with about 58 per cent for the others) was attributed to its wider camblal layer. Results of mid-August experiments were significantly superior to those of mid-September. Rao (1975) improved inarching in mango with a difference. Instead of using a scion shoot on a growing tree the scion shoot, excised under water, is kept in a water-filled polyethylene bag during Inarching to a seedling rootstock. Another polyethylene bag may be placed over the top o£ the scion shoot while union takes place. Inarching gave best result (84 per cent take) when scions of mango ' Dashehari' were grafted on seedling rootstocks using 'Bappakai' as interstock (Singh and Srivastava, 1980).

# CHAPTER III
# MATERIALS AND METHODS

The experiment was conducted during the period from June 2019 to December 2019 to study different grafting techniques on young and adult mango trees. This chapter presents a brief description about experimental period, site description, and climatic condition, planting materials, treatments, experimental design, data collection and statistical analysis.

## 3.1 Experimental site

The experiment was conducted at the Horticulture Research Farm of Sher-e- Bangla Agricultural University, Dhaka. It was located in 23°74′N latitude and 90°35′E longitudes. The altitude of the location was 8m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207, which have been shown in the Appendix I.

## 3.2 Soil of the experimental field

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with adequate irrigation facilities and remains fallow during previous growing season. The nutrient status of the farm soil under the experimental site was analyzed in the Soil Resource and Development Institute, Dhaka and result has been presented in Appendix II.

## 3.3 Climate

The experimental site was under the sub-tropical climate, which is characterized by high temperature, high humidity, heavy precipitation with occasional gusty winds and relatively long in kharif season (April-September) and scanty rainfall associated with moderately low temperature, low humidity and short day period during Rabi season (October-March). Weather information regarding the atmospheric temperature, relative humidity, rainfall, sunshine hours and soil temperature prevailed at the experimental site during the entire period of investigation as recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III. (DATA)

### 3.4 Collection of planting materials

The research work was operated with mango variety named Fazli, Langra, Himsagor and Namdokmai. Scions were collected from Horticulture farm of Sher-E-Bangla Agricultural University, Dhaka-1207. The scions were healthy, proper aged, and free from disease and pest. The young plant for rootstock was collected from near nursery at Agargaon area and it was a wild type variety.

### 3.5 Treatments of the experiments

The experiment consisted of two factors and carried out to study the field performance of Cleft, Veneer and Whip grafting techniques using scion from Fazli, Langra, Himsagor and Namdokmai variety. The following two factors were included in the experiment

Factor A: Different grafting techniques

i) $G_1$ –Cleft grafting

ii) $G_2$ –Veneer grafting

iii) $G_3$ –Whip grafting

Factor B: Scions from different varieties

i) $S_1$ -Fazli

ii) $S_2$ -Langra

iii) $S_3$ -Himsagor

iv) $S_4$ -Namdokmai

**Treatment Combination: 12**

S1G1, S1G2, S1G3, S2G1, S2G2, S2G3, S3G1, S3G2, S3G3, S4G1, S4G2, S4G3

**Replications:** 3

**Year**: 2019-2020

### 3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three types of grafting techniques and scion from four mango varieties. The total number of treatment combination was 12 and total number of young and adult root stock was 120. The experiment was placed in the Horticulture farm of Sher-e-Bangla Agricultural University.

### 3.7 Required tools and materials

Following materials were used during experimental work (Plate-01)

- Pruning scissor
- Scalpel
- Grafting knife.
- Grafting tape or soft clear polythene bag cut in tubes.
- Sterilizer such as spirit was used.
- Plastic bag was used to collect scion or wet newspaper or cooler box.


**Plate 01: Photograph of materials used during grafting.**

### 3.8 Collection of scion

Scions were collected from desired mother plant following scion's age and tenderness. Usually scions were collected during warm and humid weather, just before the production of new leaves. All scions were taken from the Horticulture farm of Sher-e-Bangla Agricultural University (Plate-02).

**To get quality scions following steps were followed**

A highly productive, healthy mother tree of the desired variety and quality was identified.

Scions were selected from the end of the branches which are as thick as a pencil and have an active, healthy terminal bud.


**Plate 02: Photograph of scions used for grafting**

### 3.9 Rootstock selection

A good rootstock is very important for future production of high quality mango fruits. Both young and adult mango trees were used as rootstock. The rootstock provides the rooting system and part of the stem of the future mango tree.

**The rootstocks were selected according to following criteria:**

- Suitable variety from a local mango tree that grows well was selected.
- Selected plants were healthy, strong and free of pests.
- In case of young rootstock, about 1-2 years old plant with a stem as thick as a pencil were used.
- In case of adult tree for rootstock, 10 years or above trees were used.

### 3.10 Plants grafting principles

Involves joining or uniting two separate woody parts of a living plant tissue from different trees or plants to form one plant.

Parts used in grafting: Scion; refers to the bud or piece of stem that is to be attached to the rootstock. Rootstock refers to the seedling or tree upon which a scion is to be attached. Materials selected as scions should be taken from terminals buds (end of a branch) of a tree or plant, at the 'tight bud stage' or before a new flush with buds which are swollen but have not opened.

There are several grafting methods which differ according to how the scion is attached to the rootstock. These grafting methods are top/wedge, whip/tongue and side/ veneer

### 3.11 Cleft grafting

**Preparation of rootstock**

- Ensured that pair scions to rootstock of the same thickness.
- The mango rootstock seedling was cut horizontally at a height of about 6 – 8 cm above soil level by using a pruning scissor or sharp knife.(Plate-03)
- At upper end of the rootstock a split cut was made to a depth of about 3 cm using a very sharp knife.

**Plate 03: Photograph of Rootstock preparation for Cleft grafting**

Preparing the scion for cleft grafting

- The scions were cut to a final length of about 10-15 cm with a pruning scissor or a sharp knife.
- The scalpel or razor blade was used to sharpen the cut lower end of the scion to a V-shape by removing the wood on both sides of the scion (Plate-04).

- The V-shape cut was made as deep as possible as this will increase the survival rate of grafted scion. About 2 – 3 cm long is suitable.


**Plate 04: Photograph of prepared scion for cleft grafting**

Joining of rootstock and scion (Plate-05, a)

- The sharpened end of the scion was slide into the slot that already cut on the rootstock.

- The scion was inserted as deep as possible into the cut of the rootstock and aligned the two parts.

**Enclosing the union**

Both the scion and rootstock were fixed in place by covering the point of union until it is healed. To do this (Plate-05, b);

- The union was carefully hold with one hand.

- The grafting was wrapped with the other hand using tape or the polythene tube tightly around the union and the two ends of the tape/tube was knotted or inter-looped.

- It was made sure that the wrapping was tight enough and that the scion did not move out of the union while wrapping.

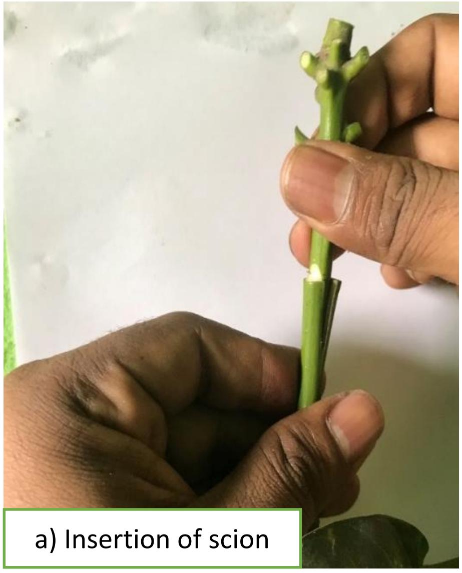




**Plate 05: Scion insertion on rootstock and adjoining with plastic tube during cleft grafting**

**Covering of the scion**

This was done in order to increase the temperature and humidity around the graft hence improving the chances of a successful graft union.

- Another grafting tape or polythene tube was wrapped around the scion, but a bit more loosely than the one bandaging the union.

- The two ends of the tape/tube were knotted or inter-looped.

- The upper part of the scion must not be covered which was the terminal bud so that it could grow and produce new leaves.

**Wound healing and removing of the bandage**

- The grafted seedling with the name of the scion from different variety was labeled.

- The grafted seedlings were kept in the shade and watered them well.

- After about 14-21 days the scions developed new leaves and the wound should have healed.
- The grafting tape or polythene tube was removed when the wound was fully healed.

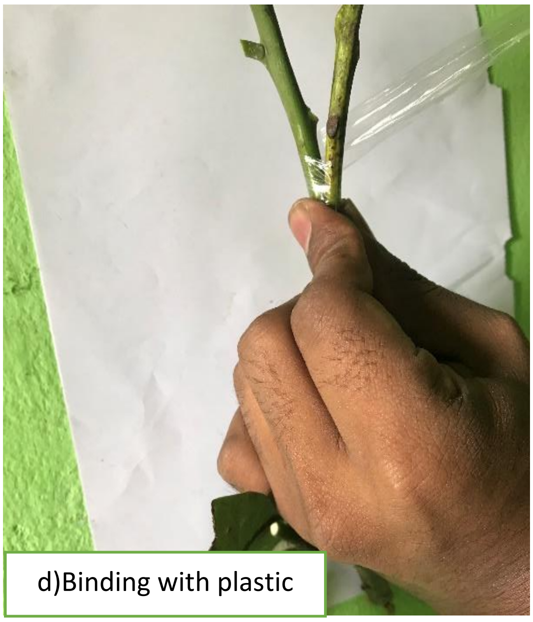
### 3.12 Veneer grafting (Plate-06 and 07)

- For conducting this grafting operation, a downward and inward 30-40 mm long cut was made in the smooth area of the stock at a height of about 20 cm (Plate-06, b).
- At the base of cut, a small shorter cut was given to intersect the first so as to remove the piece of wood and bark.
- The scion stick was given a long slanting cut on one side and a small short cut on the other so as to match the cuts of the stock (Plate-06, a).
- The scion was inserted in the stock so that the cambium layers comes on the longer side.
- The graft union was then tied with polythene tube as recommended for inarching
- After the scion remains green for more than 10 days, the rootstock was clipped in stages.



**Plate 06: Photograph of Scion and Rootstock preparation for Veneer grafting**

c)grafting



d)Binding with plastic

**Plate 07: Contacting scion with rootstock during Veneer grafting**

### 3.13 Whip grafting

- The knife was Pulled upward with the blade angled about 45 degrees, making a smooth & the straight diagonal cut. This slanting straight-plane cut was made 2 to 3 inches long. Tried to create this cut with one stroke of the knife.
- The leaves were removed from the scion with a clean sharp knife or secateurs.
- The knife was Place at a spot on the slant cut approximately one-third of the distance from the tip to the bottom of the cut. A "tongue" cut was created by working the knife blade downward for a distance of 1 to 1 1/2 inches.
- The "tongue" cut was created on the scion by placing the knife blade at a point about one-third of the distance down from the tip. The blade was pulled downward at an angle that was about halfway between the grain of the scion & plane of the slant cut.
- The plane slice surface of the scion down to the slant cut of the stock was slipped until the two "tongue" cuts mesh together. The cambium layers of the stock & scion made aligned to obtain accurate union. The two cuts were made properly; the stock & scion will appear to be one.

### 3.14 Data collection procedures

Data were recorded on the following parameters from the sample plants during the course of experiment. The plant response to the treatment application under the present investigation was evaluated on the basis of joining of scion during 30, 60 and 90 days after joining of graft. The grafts were kept under observation for 90 days. After that 5 grafts for each mango variety on both young and adult were selected randomly for data collection. Measuring tape and scalpel were used for growth status measurement. Then data were collected for the following parameters-

i. Diameter of rootstock
ii. Diameter of scion
iii. Length of graft
iv. Number of leaves per plant
v. Success rate of grafting

#### 3.14.1 Circumference of rootstock

The initial Circumference of all rootstock were around 2cm and then five randomly selected rootstocks from each treatment were measured at the middle height using measuring tape 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.

#### 3.14.2 Circumference of scion

The Circumference of initial scion were around 2cm and five randomly selected scions from each treatment were measured about 5 cm above the graft union using measuring tape 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.

#### 3.14.3 Height of scion

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.

#### 3.14.4 Number of leaves on new growth

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.

### 3.14.5 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).

Percentage of graft success = (Number of successful grafts /Total number of grafted rootstocks) X 100

# CHAPTER IV

# RESULTS AND DISCUSSION

The experiment was conducted to determine the grafting success rate both on mature and young mango tree using scion from various mother plant including Fazli, Langra, Himsagor and Namdokmai. Data on success rate of grafting contact, scion growth, scion and rootstock circumference change and leaves per scion at several intervals were recorded. A summary of the analysis of variance (ANOVA) of the data have been presented in Appendix IV-V. The result has been discussed with the help of table, graph and possible interpretations are given under the following sub-heading.

The interpretation on result from analyzed data were done in two separate part including young and mature plant's result.

## 4.1 Part -1 (Grafting on young mango plant)

### 4.1.1 Effect of grafting techniques and scion from different varieties on circumference of rootstock after grafting

The table-01 reflects that circumference of rootstock at 30, 60 and 90 days after grafting in young mango plant shows a significant variance. We see from that the grafting technique and scion from different variety has impact on rootstock circumference change. $S_2$ showed the highest change at rootstock circumference at 30, 60 and 90 days after grafting (DAG) and it was 2.86cm, 2.89cm and 3.17cm respectively.

**Table 01: Effect of scion from different variety on the circumference of rootstock after grafting in young mango plant**

| Treatments | Circumference of rootstock at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1$ | 2.10 | 2.86a | 2.86a | 2.94b |
| $S_2$ | 2.04 | 2.29b | 2.89b | 3.17a |
| $S_3$ | 2.02 | 2.02a | 2.12a | 2.24c |
| $S_4$ | 2.07 | 2.38ab | 2.28ab | 2.41ab |
| LSD(.05) | 0.652 | 0.509 | 0.509 | 0.4379 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai

**Table 02: Effect of different grafting techniques on the circumference of rootstock after grafting in young mango plant**

| Treatments | Circumference of rootstock at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $G_1$ | 2.05 | 2.63 | 2.65b | 2.95b |
| $G_2$ | 2.00 | 2.56 | 2.40c | 2.52c |
| $G_3$ | 1.96 | 2.08 | 2.13a | 2.46a |
| LSD (.05) | 0.645 | 0.4414 | 0.4202 | 0.3792 |

**Note:** $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The circumference of rootstock in young mango plant was highest at $G_1$ and it was 2.63cm, 2.65 cm and 2.95 cm at 30, 60 and 90 DAG respectively. The circumference change of rootstock was the lowest impact at $G_3$ and it was 2.08cm, 2.13cm and 2.46 cm at 30, 60 and 90 DAG respectively.

**Table 03: Combined effect of grafting techniques and scion from different varieties in the circumference of rootstock after grafting on young mango plant**

| Treatments | Circumference of rootstock at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1G_1$ | 2.05 | 2.44c-e | 2.67a | 2.93a-d |
| $S_1G_2$ | 2.10 | 2.36ab | 2.63abc | 2.84ab |
| $S_1G_3$ | 2.00 | 1.99de | 2.46cd | 2.67cde |
| $S_2G_1$ | 2.04 | 2.92ab | 2.96a | 3.03a |
| $S_2G_2$ | 2.00 | 2.40e | 2.42bcd | 2.96b-e |
| $S_2G_3$ | 2.12 | 2.23bcd | 2.32ab | 2.48a |
| $S_3G_1$ | 2.07 | 2.68a-d | 2.73abc | 2.95cde |
| $S_3G_2$ | 2.02 | 2.38cde | 2.76bcd | 2.94abc |
| $S_3G_3$ | 2.11 | 2.11a-d | 2.12.bc | 2.14f |
| $S_4G_1$ | 2.07 | 2.23cde | 2.71d | 2.89de |
| $S_4G_2$ | 2.00 | 2.61bcd | 2.73bcd | 2.97ab |
| $S_4G_3$ | 2.03 | 2.78cde | 2.87abc | 2.95e |
| LSD(0.05) | .927 | 0.882 | 0.840 | 0.758 |
| CV | 1.88 | 2.38 | 2.63 | 3.16 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 03 represents the combined effect of grafting techniques and scion from different varieties on rootstock circumference change after grafting. In case of combined effect at 30, 60 and 90 DAG the highest value of rootstock circumference change was 2.92cm, 2.96cm and 3.03cm respectively in $S_2G_1$ combination. In case of combined effect in $S_3G_3$ combination at 30, 60 and 90 DAG the lowest value of rootstock circumference change was 2.11cm, 2.12cm and 2.14cm respectively.

### 4.1.2 Effect of grafting techniques and scion from different varieties on circumference of grafts

Circumference change of scion at 30, 60 and 90 days after grafting shows a significant change. We see from the table-04 that scion from different varieties have impact on scion circumference change. At 30, 60 and 90 DAG the circumference change was highest in $S_2$ and it was 2.78cm, 2.94cm and 3.32cm respectively.

**Table 04: Effect of scion from different varieties in the circumference of scion part on young mango plant**

| Treatment | Circumference of scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1$ | 2.10 | 2.36ab | 2.47cd | 2.56c |
| $S_2$ | 2.02 | 2.78a | 2.94a | 3.32a |
| $S_3$ | 2.05 | 2.17cd | 2.19d | 2.35d |
| $S_4$ | 2.12 | 2.73bc | 2.86bc | 2.93ab |
| LSD(.05) | 0.620 | 0.515 | 0.401 | 0.525 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai

We also see from the table 04 that the scion from different varieties have the lowest impact in scion circumference change in $S_3$ variety at 30, 60 and 90 DAG and it was 2.17cm, 2.19cm and 2.35cm respectively.

**Table 05: Effect of different grafting method in the circumference of scion part on young mango plant**

| Treatment | Circumference of scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $G_1$ | 2.00 | 2.53 | 2.81b | 3.21a |
| $G_2$ | 2.08 | 2.33 | 2.26b | 2.62a |
| $G_3$ | 2.05 | 2.03 | 2.28a | 2.31b |
| LSD(.05) | 0.552 | 0.446 | 0.347 | 0.454 |

**Note:** $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The circumference of scion was highest at $G_1$ and it was 2.53cm, 2.81cm and 3.21cm at 30, 60 and 90 DAG respectively. The circumference of scion faced the lowest change at $G_3$ and it was 2.03cm, 2.28cm and 2.31cm at 30, 60 and 90 DAG respectively (Table-05).

**Table 06: Combined effect of grafting techniques and scion from different varieties in the circumference of scion after grafting on young mango plant**

| Treatment | Circumference of scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | **0 Day** | **30 DAG** | **60 DAG** | **90 DAG** |
| $S_1G_1$ | 2.05 | 2.67a-e | 2.66bc | 2.75a-c |
| $S_1G_2$ | 2.10 | 2.07 | 2.27ab | 2.43ab |
| $S_1G_3$ | 2.08 | 2.13ab | 2.13ab | 2.35ab |
| $S_2G_1$ | 2.00 | 2.61a | 2.94a | 3.13a |
| $S_2G_2$ | 2.06 | 2.33abc | 2.31 | 2.89b |
| $S_2G_3$ | 2.00 | 1.94a-d | 2.13a | 2.34f |
| $S_3G_1$ | 2.00 | 2.15de | 2.28ab | 2.53ab |
| $S_3G_2$ | 2.11 | 2.24a-e | 2.33d | 2.83bc |
| $S_3G_3$ | 2.04 | 2.13e | 2.21ef | 2.22g |
| $S_4G_1$ | 2.09 | 2.27b-e | 2.43ab | 2.52c |
| $S_4G_2$ | 2.05 | 2.13ab | 2.23ab | 2.33b |
| $S_4G_3$ | 2.04 | 2.11e | 2.26cd | 2.28e |
| LSD(0.05) | 0.921 | 0.892 | 0.695 | 0.909 |
| CV (%) | 1.93 | 2.64 | 2.92 | 3.49 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 06 shows the combined effect of grafting techniques and scion from different varieties on the circumference of scion in young mango plant. In case of combined effect at 30, 60 and 90 DAG the highest value of scion part circumference changes and it was 2.61cm, 2.94cm and 3.13cm respectively in $S_2G_1$ combination. On the other hand, at 30, 60 and 90 DAG the lowest value of scion circumference change was 2.13cm, 2.21cm and 2.22cm respectively in $S_3G_3$ combination.

### 4.1.3 Effect of grafting techniques and scion from different varieties in height of scion on young mango plant

The figure 01 and 02 and the table 03 shows that grafting techniques and scion from different varieties has significant effect on the growth of scion in mango tree.

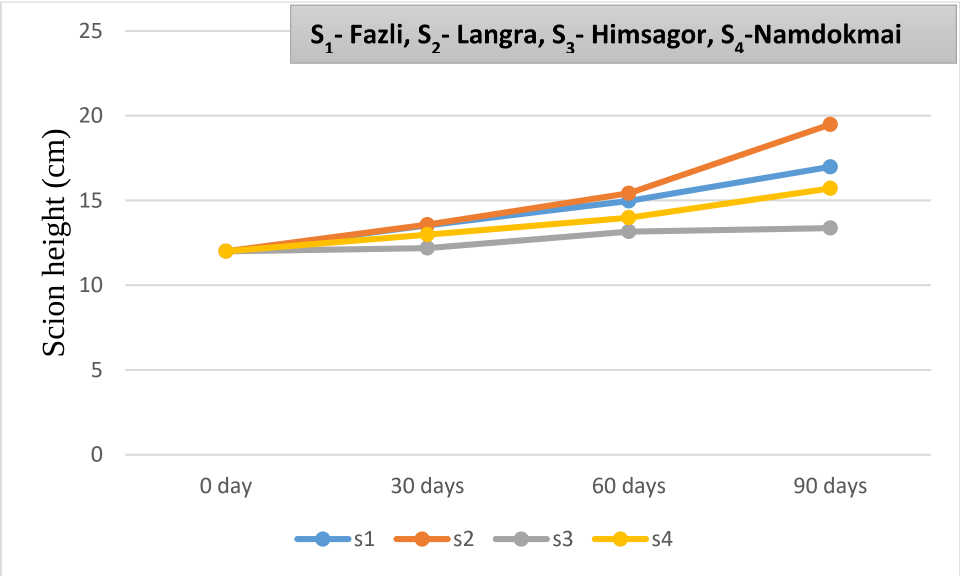



**Figure 01: Effect of scion from different varieties in scion part height after grafting on young mango plant**

We see from the figure-01 that scion from different varieties have impact on scion height change in mango tree. At 30, 60 and 90 DAG the height of scion was the highest in $S_2$ variety and the lowest height of scion found in $S_3$ variety.

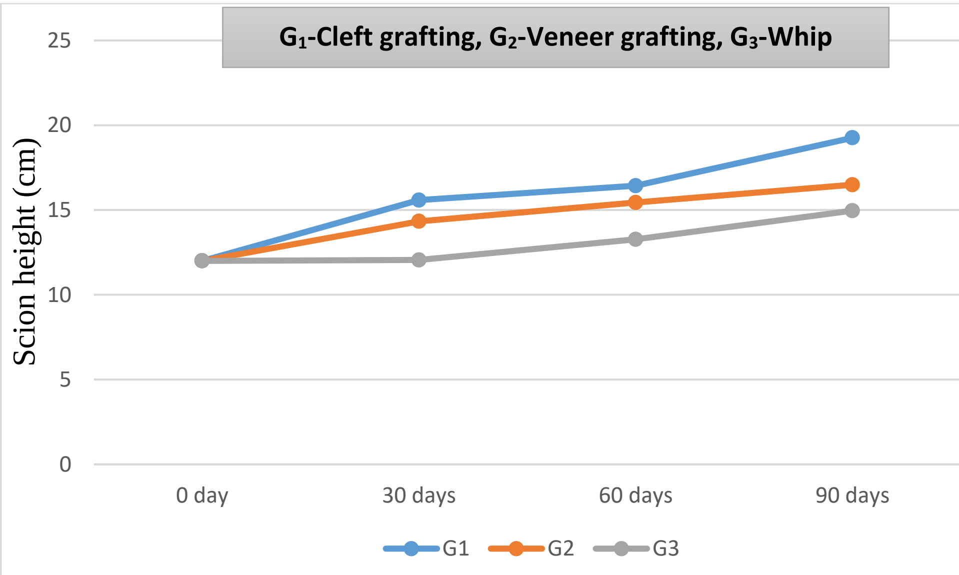



**Figure 02: Effect of grafting techniques in scion height on young mango plant after grafting**

The figure 02 reflects the effect of grafting techniques on the growth of scion height at different days after grafting. From 30 to 90 days after grafting the $G_1$ gave maximum height to the scion part. The line diagram also shows that the scion part height was the lowest at $G_3$ technique.

**Table 07: Combined effect of grafting techniques and scion from different varieties in height of scion after grafting on young mango plant.**

| Treatments | Height of scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1G_1$ | 12 | 13.77ab | 14.05abc | 16.43ab |
| $S_1G_2$ | 12 | 12.03a | 16.73a-c | 18.13a-d |
| $S_1G_3$ | 12 | 13.27bc | 14.87e | 15.87cde |
| $S_2G_1$ | 12 | 14.44a | 17.16a | 19.09a |
| $S_2G_2$ | 12 | 12.27abc | 14.67bcd | 17.83de |
| $S_2G_3$ | 12 | 12.74ab | 15.13ab | 17.51ab |
| $S_3G_1$ | 12 | 13.78ab | 14.09abc | 16.97a-d |
| $S_3G_2$ | 12 | 14.02abc | 15.63cd | 17.43b-e |
| $S_3G_3$ | 12 | 12.85e | 13.27f | 15.68h |
| $S_4G_1$ | 12 | 13.12a | 14.51abc | 16.51b-e |
| $S_4G_2$ | 12 | 12.15c | 14.073d | 17.87f |
| $S_4G_3$ | 12 | 13.12ab | 15.33abc | 18.87b-e |
| LSD(0.05) | 2.263 | 2.5426 | 2.2653 | 2.232 |
| CV (%) | 11.327 | 10.27 | 8.06 | 6.67 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 07 shows the combined effect of grafting techniques and scion from different varieties on the growth of scion height. All scions were taken at length of 12cm initially. Here we see that the highest scion height was in $S_2G_1$ combination and height were 14.44cm, 17.16cm and 19.09cm at 30, 60 and 90 DAG respectively. On the other hand, the lowest growth rate was in $S_3G_3$ combination and these were 12.08cm, 13.27cm and 15.68cm at 30, 60 and 90 DAG.

### 4.1.4 Effect of grafting techniques and scion from different varieties in the number of leaves per scion after grafting on young mango plant

From the table-08 we see that the leaf number per scion on young mango plant was the highest when $S_2$ scion was used and leaf number per scion were 2.28, 4.08 and 8.56 at 30, 60 and 90 DAG. On the other hand, the lowest number of leaves per scion were 2.76, 2.89 and 3.69 at 30, 60 and 90 DAG when $S_3$ variety was used as scion.

**Table 08: Effect of scion from different varieties in number of leaves per scion after grafting on young mango plant.**

| Treatments | Number of leaves per scion at different DAG | | |
|---|---|---|---|
| | 30 DAG | 60 DAG | 90 DAG |
| $S_1$ | 2.61cd | 3.54b | 6.74a |
| $S_2$ | 2.82a | 4.08ab | 8.56b |
| $S_3$ | 2.76c | 2.89a | 3.69ab |
| $S_4$ | 2.79ab | 3.11ab | 6.617ab |
| LSD | 0.385 | 0.4828 | 0.272 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai.

The table 09 reflects the effects of grafting techniques on number of leaves per scion after grafting. From the table we see that $G_1$ caused the highest number of leaves per scion and $G_3$ produced the lowest number of leaves per scion in young mango plant.

**Table 09: Effect of different grafting techniques in number of leaves per scion after grafting on young mango plant.**

| Treatments | Number of leaves per scion at different DAG | | |
|---|---|---|---|
| | 30 DAG | 60 DAG | 90 DAG |
| $G_1$ | 2.92a | 4.17a | 7.63a |
| $G_2$ | 2.85ab | 3.85b | 5.68b |
| $G_3$ | 2.42c | 3.75ab | 4.75c |
| LSD | 0.333 | 0.418 | 0.249 |

**Note:** $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 10 shows the combined effect of grafting techniques and scion from different variety on number of leaves per plant in young mango plant. The combined effect of grafting techniques and scion from different variety shows highest number of leaves per scion in $S_2G_1$ combination. But the lowest number of leaves per scion were in $S_3G_3$ combination.

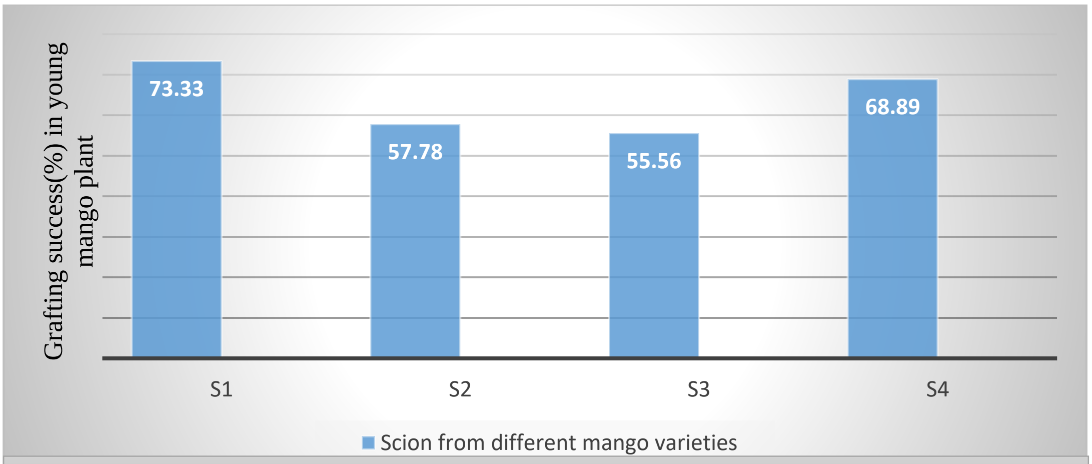
**Table 10: Combined effect of grafting techniques and scion from different varieties in number of leaves per scion after grafting on young mango plant.**

| Treatments | Number of leaves per scion at different DAG | | |
|---|---|---|---|
| | 30 DAG | 60 DAG | 90 DAG |
| $S_1G_1$ | 2.67bcd | 3.24d | 5.66abc |
| $S_1G_2$ | 2.43e | 3.47d | 5.44cd |
| $S_1G_3$ | 2.93ab | 3.03a-d | 4.91a |
| $S_2G_1$ | 2.70bcd | 4.93bcd | 8.52cd |
| $S_2G_2$ | 3.11a | 4.54ab | 6.07ab |
| $S_2G_3$ | 2.51e | 3.71cd | 5.51cd |
| $S_3G_1$ | 2.88ab | 4.87a | 6.02ab |
| $S_3G_2$ | 2.83abc | 3.61cd | 5.18d |
| $S_3G_3$ | 2.66cd | 3.82bcd | 4.59abc |
| $S_4G_1$ | 2.78bcd | 4.04a-d | 7.56bcd |
| $S_4G_2$ | 2.94ab | 4.31abc | 5.83abc |
| $S_4G_3$ | 2.55cd | 3.49cd | 6.45cd |
| LSD(0.05) | 0.667 | 0.836 | 0.469 |
| CV (%) | 2.33 | 4.59 | 5.88 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

### 4.1.5 Effect of grafting techniques and scion from different varieties in the success of grafting on young mango plant

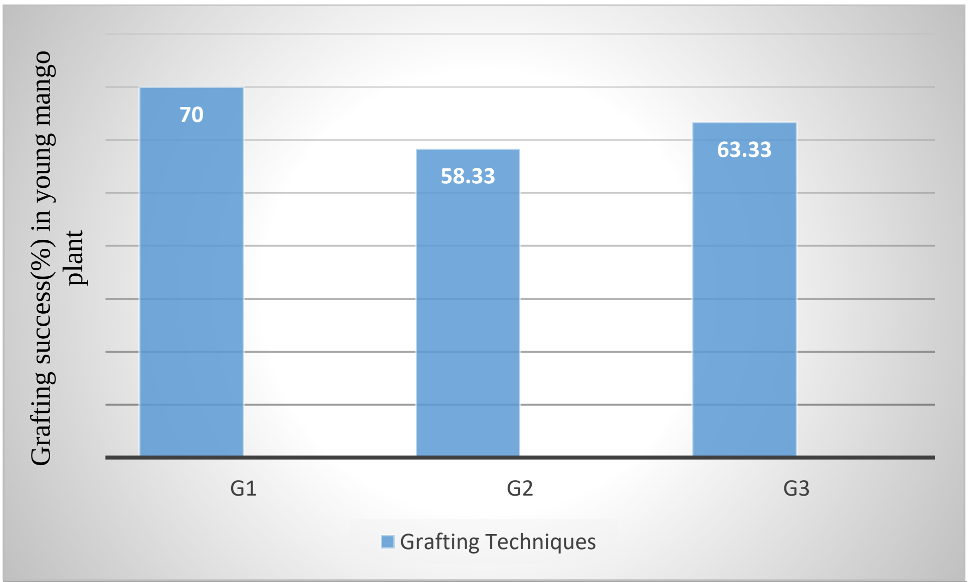
From the result of statistical analysis, we easily see that, the grafting technique and scion from different varieties and their combined interaction has a significant variance in grafting success rate which we see from figure 03, 04 and table 11.




**$S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai**

**Figure 03: Effect of scion from different varieties in success of grafting on young mango plant**

The figure-03 reflects the grafting success due to impact of scion from different variety. Here we see $S_1$ scion gave highest success of grafting in young mango plant and it was 73.33%. But the lowest grafting success gained from all grafting method when $S_3$ variety was used as scion and it was 55.56%.




**$G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting**

**Figure 04: Effect of grafting techniques in grafting success on young mango plant**

The figure-04 reflects the grafting success due to impact of grafting technique. Here we see $G_1$ gave highest success of grafting in young mango plant and it was 70%. But the lowest grafting success gained from all scion when $G_3$ method was used and it was 58.33%.

**Table 11: Combined effect of grafting techniques and scion from different varieties in grafting success on young mango plant.**

| Treatments | Grafting success (%) |
|---|---|
| $S_1G_1$ | 80.00 |
| $S_1G_2$ | 60.00 |
| $S_1G_3$ | 53.33 |
| $S_2G_1$ | 60.00 |
| $S_2G_2$ | 60.00 |
| $S_2G_3$ | 53.33 |
| $S_3G_1$ | 66.67 |
| $S_3G_2$ | 40.00 |
| $S_3G_3$ | 60.00 |
| $S_4G_1$ | 73.33 |
| $S_4G_2$ | 73.33 |
| $S_4G_3$ | 60.00 |
| LSD(0.05) | 18.565 |
| CV (%) | 17.16 |

**Note:** $S_1$- Fazli, $S_2$- La ngda, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 11 reflects the combined effect of grafting techniques and scion from different varieties on grafting success. We see from the result that, the highest grafting success was found from $S_1G_1$ combination and it was 80%. On the other hand, the lowest success rate was in $S_3G_2$ combination and it was only 40%.

## 4.2 Part -2 (Grafting on adult mango tree)

### 4.2.1 Effect of grafting techniques and scion from different varieties in the circumference change of rootstock on adult mango tree.

The table-12 reflects that the circumference changes of rootstock at 30, 60 and 90 days after grafting on adult mango tree shows a significant variance. We see from the table that the scion from different varieties have impact on rootstock circumference change. At 30, 60 and 90 DAG the circumference change was highest in $S_1$ variety and it was 2.72cm, 2.83cm and 3.12cm respectively.

**Table 12: Effect of scion from different varieties in the circumference of rootstock after grafting on adult mango tree**

| Treatments | Rootstock circumference at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1$ | 2.04 | 2.72a | 2.83a | 3.12a |
| $S_2$ | 2.10 | 2.14ab | 2.64ab | 2.72a |
| $S_3$ | 2.11 | 2.08b | 2.44b | 2.56a |
| $S_4$ | 2.12 | 1.98c | 2.20cd | 2.23d |
| LSD(0.05) | 0.576 | 0.490 | 0.310 | 0.407 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai.

We also see from the table-12 that scion from different varieties have the lowest impact in rootstock circumference change in $S_4$ variety at 30, 60 and 90 DAG and it was 1.98cm, 2.20cm and 2.23cm respectively.

**Table 13: Effect of grafting techniques in the circumference of rootstock on adult mango tree**

| Treatments | Rootstock circumference at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $G_1$ | 2.04 | 2.53ab | 2.65b | 2.82b |
| $G_2$ | 2.14 | 2.55a | 2.83a | 3.18a |
| $G_3$ | 2.08 | 2.23b | 2.25c | 2.29c |
| LSD(0.05) | 0.541 | 0.424 | 0.268 | 0.353 |

**Note:** $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 13 shows the circumference change of rootstock on adult mango tree was highest at $G_2$ technique and it was 2.55cm, 2.83cm and 3.18 cm at 30, 60 and 90 DAG respectively. The rootstock circumference change was the lowest in $G_3$ technique and it was 2.23cm, 2.25cm and 2.29cm at 30, 60 and 90 DAG respectively.

The table 14 reflects the combined effect of grafting techniques and scion from different varieties on the rootstock circumference change on adult mango tree. In case of combined effect at 30, 60 and 90 DAG the highest value of rootstock circumference change was 2.93cm, 3.13cm and 3.24cm respectively in $S_1G_2$ combination.

**Table 14: Combined effect of grafting techniques and scion from different varieties in the circumference of rootstock after grating on adult mango tree**

| Treatments | Rootstock circumference at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1G_1$ | 2.06 | 2.17a | 2.23ab | 2.63ab |
| $S_1G_2$ | 2.00 | 2.93bc | 3.13a | 3.24a |
| $S_1G_3$ | 2.10 | 2.53cde | 2.92abc | 2.98bcd |
| $S_2G_1$ | 2.13 | 1.98abc | 2.02ab | 2.72bcd |
| $S_2G_2$ | 2.12 | 2.03ab | 2.17de | 2.67cd |
| $S_2G_3$ | 2.06 | 2.23bcd | 2.63abc | 2.65abc |
| $S_3G_1$ | 2.16 | 2.39de | 2.69e | 2.93ef |
| $S_3G_2$ | 2.11 | 2.67abc | 2.73ab | 2.83ab |
| $S_3G_3$ | 2.15 | 2.83cde | 2.83cd | 2.97c-f |
| $S_4G_1$ | 2.05 | 1.83ab | 2.17ab | 2.27abc |
| $S_4G_2$ | 2.01 | 2.65abc | 2.67bc | 2.69bcd |
| $S_4G_3$ | 2.14 | 1.93e | 2.06f | 2.19f |
| LSD (0.05) | 0.945 | 0.8498 | 0.5371 | 0.706 |
| CV (%) | 1.92 | 2.15 | 2.96 | 3.14 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 14 also shows the combined effect of grafting techniques and scion from different varieties at 30, 60 and 90 DAG had the lowest value of rootstock circumference change and it was 1.93cm, 2.06cm and 2.19cm respectively in $S_4G_3$ combination.

### 4.2.2 Effect of grafting techniques and scion from different varieties in the circumference of scion after grafting on adult mango tree

The table-15 shows the effect of scion from different varieties have a significant variance on circumference change of scion. At 30, 60 and 90 DAG the circumference of scion was highest in $S_1$ variety and it was 2.57cm, 2.76cm and 3.13cm respectively.

**Table 15: Effect of scion from different varieties in the circumference of scion after grafting on adult mango tree**

| Treatments | Circumference of scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1$ | 2.11 | 2.57a | 2.76a | 3.13a |
| $S_2$ | 2.05 | 2.18c | 2.47b | 2.56ab |
| $S_3$ | 2.08 | 2.26b | 2.44ab | 2.58b |
| $S_4$ | 2.00 | 2.05d | 2.12c | 2.17c |
| LSD(0.05) | 0.603 | 0.504 | 0.321 | 0.305 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai.

We also see from the table 15 that the scion from different varieties has the lowest impact in scion circumference change in $S_4$ variety at 30, 60 and 90 DAG and it was 2.05cm, 2.12cm and 2.17cm respectively.

The table 16 shows effect of grafting techniques on the circumference change of scion on adult mango tree. The circumference change of scion was highest at $G_2$ grafting technique and it was 2.26cm, 2.77cm and 3.28cm at 30, 60 and 90 DAG respectively.

**Table 16: Effect of different grafting techniques in the circumference of scion after grafting on adult mango tree**

| Treatments | Circumference of scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $G_1$ | 2.13 | 2.13b | 2.13ab | 2.43b |
| $G_2$ | 2.12 | 2.26a | 2.77a | 3.28a |
| $G_3$ | 2.15 | 1.95c | 2.03c | 2.14c |
| LSD(0.05) | 0.518 | 0.428 | 0.278 | 0.2645 |

**Note:** $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The circumference of scion faced the lowest development at $G_3$ technique and it was 1.95cm, 2.03cm and 2.14cm at 30, 60 and 90 DAG respectively.

The table 17 shows the Combined effect of grafting techniques and scion from different varieties on the circumference of scion on adult mango tree. In case of combined effect at 30, 60 and 90 DAG the highest value of scion circumference was 2.35cm, 2.63cm and 3.05cm respectively in $S_1G_2$ combination.

**Table 17: Combined effect of grafting techniques and scion from different varieties in the circumference of scion after grafting on adult mango tree**

| Treatments | Circumference of scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | 0 Day | 30 DAG | 60 DAG | 90 DAG |
| $S_1G_1$ | 2.13 | 2.01ab | 2.21a | 2.67ab |
| $S_1G_2$ | 2.06 | 2.35a | 2.63a | 3.05a |
| $S_1G_3$ | 2.06 | 2.21d | 2.33ab | 2.53cd |
| $S_2G_1$ | 2.14 | 1.94cd | 2.13c | 2.75e |
| $S_2G_2$ | 2.15 | 2.33a | 2.38c | 2.57ef |
| $S_2G_3$ | 2.11 | 1.97e | 2.14ab | 2.46cd |
| $S_3G_1$ | 2.12 | 2.26abc | 2.34b | 2.76bc |
| $S_3G_2$ | 2.15 | 2.46d | 2.73ab | 2.84cd |
| $S_3G_3$ | 2.17 | 2.47a-d | 2.64ab | 2.93a |
| $S_4G_1$ | 2.13 | 2.14a | 2.33ab | 2.41cd |
| $S_4G_2$ | 2.12 | 2.06d | 2.21c | 2.35e |
| $S_4G_3$ | 2.06 | 1.93g | 2.13f | 2.17e |
| LSD(0.05) | 0.943 | 0.8568 | 0.556 | 0.529 |
| CV (%) | 1.67 | 2.17 | 3.21 | 3.96 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

On the other hand, in case of combined effect the lowest value of scion circumference was 1.93cm, 2.13cm and 2.17cm at 30, 60 and 90 DAG respectively in $S_4G_3$ combination.

### 4.2.3 Effect of grafting techniques and scion from different varieties in the scion height after grafting on adult mango tree.

The figure 05 and 06 and the table 18 show that grafting techniques and scion from different varieties have significant effect on the growth of scion in mango tree.

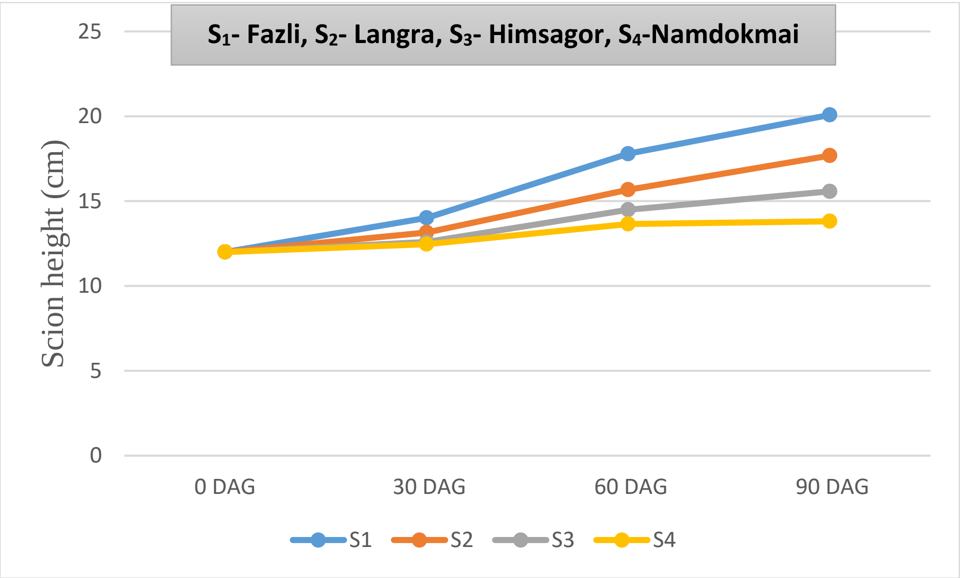



**Figure 05: Effect of scion from different varieties in scion height after grafting on adult mango tree**

We see from the figure 05 that scion from different varieties have significant impact on scion height change on adult mango tree. At 30, 60 and 90 DAG the height of scion was highest in $S_1$ variety and the lowest height of scion was found in $S_4$ variety.

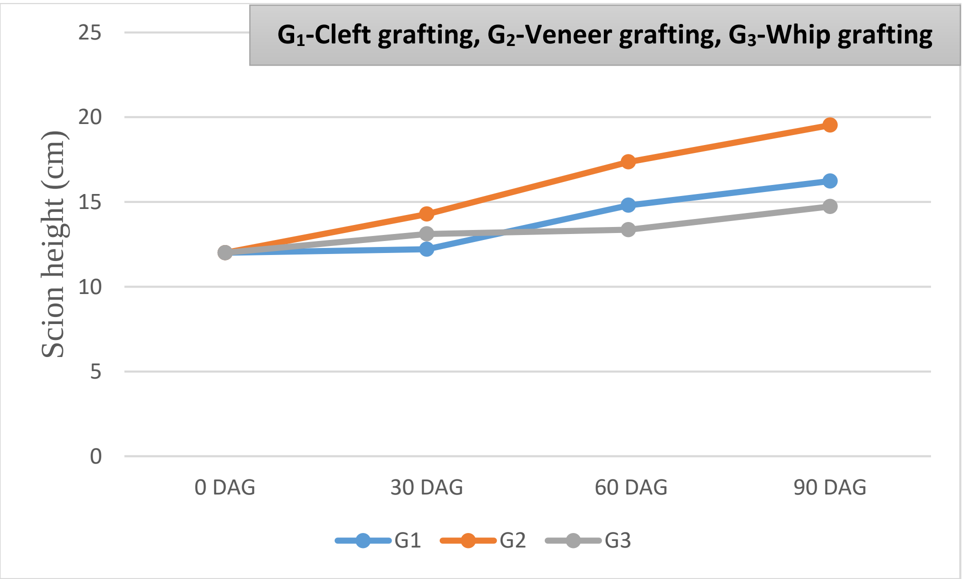



**Figure 06: Effect of different grafting techniques in scion height on adult mango tree**

The figure 06 reflects the effect of grafting techniques on the growth of scion height at different days after grafting. From 30 to 90 DAG the $G_2$ technique gave maximum height to the scions. The line graph also shows that the scion height was the lowest at $G_3$ method of grafting.

**Table 18: Combined effect of grafting techniques and scion from different varieties in the height of scion after grafting on adult mango tree**

| Treatments | Height of the scion at different DAG (cm) | | | |
|---|---|---|---|---|
| | Scion Length | 30 DAG | 60 DAG | 90 DAG |
| $S_1G_1$ | 12 | 13.28a | 13.92a | 15.44ab |
| $S_1G_2$ | 12 | 14.81a | 17.48a | 19.70a |
| $S_1G_3$ | 12 | 13.08bcd | 14.56def | 16.21abc |
| $S_2G_1$ | 12 | 13.44a | 14.56ab | 15.28bc |
| $S_2G_2$ | 12 | 12.94cde | 14.81efg | 17.87ab |
| $S_2G_3$ | 12 | 12.83abc | 13.03c-f | 15.31c |
| $S_3G_1$ | 12 | 12.69abc | 13.84a-d | 14.95ab |
| $S_3G_2$ | 12 | 12.21abc | 13.23b-e | 16.73a |
| $S_3G_3$ | 12 | 13.07ab | 14.40abc | 15.03ab |
| $S_4G_1$ | 12 | 12.77de | 14.53fg | 16.26ab |
| $S_4G_2$ | 12 | 12.17de | 13.79gh | 15.46ab |
| $S_4G_3$ | 12 | 12.10e | 12.58h | 13.35f |
| LSD(0.05) | 1.434 | 1.884 | 1.623 | 3.304 |
| CV (%) | 6.343 | 8.200 | 6.051 | 8.542 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 18 shows the combined effect of grafting techniques and scion from different varieties on the growth of scion height. All scions were taken at length of 12cm initially. Here we see the highest scion height was in $S_1G_2$ combination and height were 14.81cm, 17.48cm and 19.70cm at 30, 60 and 90 DAG respectively. On the other hand, the lowest growth rate was in $S_4G_3$ combination and these were 12.10cm, 12.58cm and 13.35cm at 30, 60 and 90 DAG respectively.

**4.2.4 Effect of grafting techniques and scion from different varieties in the number of leaves per scion after grafting on adult mango tree.**

From the table 19 we see that leaf number per scion on adult mango tree was highest when $S_1$ variety was used and leaf number per scion were 2.47, 5.77 and 7.76 at 30, 60 and 90 DAG respectively. On the other hand, the lowest number leaf per scion was 2.16, 3.12 and 4.94 at 30, 60 and 90 DAG respectively when $S_4$ variety was used as scion.

**Table 19: Effect of scion from different varieties on the leaves number per scion after grafting on adult mango tree**

| Treatments | Number of leaves per scion at different DAG | | |
|---|---|---|---|
| | 30 DAG | 60 DAG | 90 DAG |
| $S_1$ | 2.47a | 5.77a | 7.76a |
| $S_2$ | 2.29b | 3.73c | 6.88b |
| $S_3$ | 2.48ab | 3.99b | 6.06bc |
| $S_4$ | 2.16c | 3.12d | 4.94c |
| LSD(0.05) | 0.510 | 0.819 | 0.452 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai.

The table 20 reflects the effect of different grafting techniques on the leaves number per scion on adult mango tree. From the table we can see that $G_2$ caused highest number of leaves per scion and it was 2.35, 4.58 and 6.92 after 30, 60 and 90 DAG respectively. $G_3$ technique produced the lowest number of leaves per scion on adult mango plant.

**Table 20: Effect of different grafting techniques in the leaves number per scion after grafting on adult mango tree**

| Treatments | Number of leaves per scion at different DAG | | |
|---|---|---|---|
| | 30 DAG | 60 DAG | 90 DAG |
| $G_1$ | 2.25 | 3.68 | 5.95a |
| $G_2$ | 2.35 | 4.58a | 6.92a |
| $G_3$ | 2.40 | 3.75a | 4.17a |
| LSD(0.05) | 0.441 | 0.707 | 0.3916 |

**Note:** $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 21 shows that the combined effect of grafting techniques and scion from different varieties on the number of leaves per scion. Here we see that the highest number of leaves per scion was in $S_1G_2$ combination and the leaf number were 2.77, 5.97 and 7.43 at 30, 60 and 90 DAG respectively. But the lowest number of leaves per scion was in $S_4G_3$ combination.

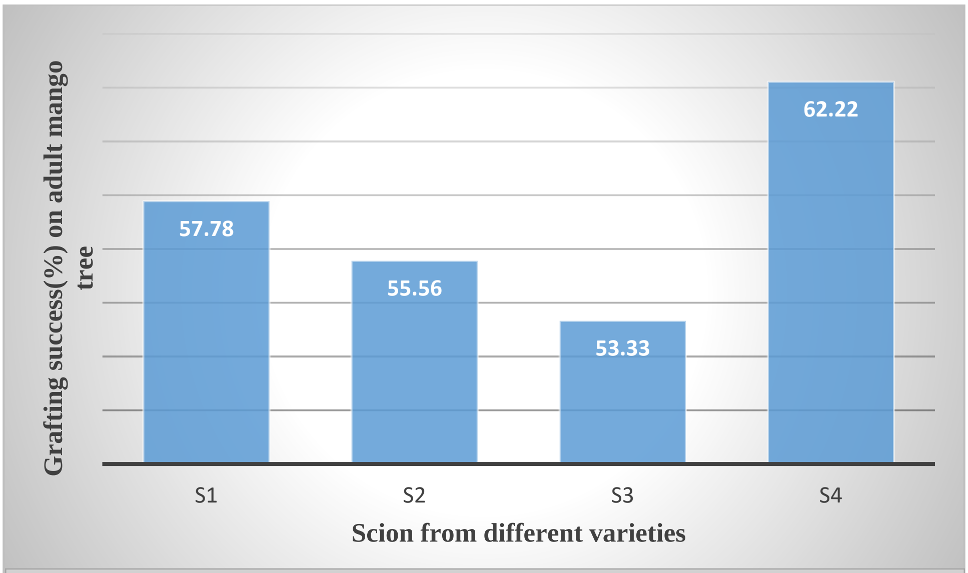
**Table 21: Combined effect of various grafting techniques and scion from different varieties in the leaf number per scion after grafting on adult mango tree**

| Treatments | Number of leaves per scion at different DAG | | |
|---|---|---|---|
| | 30 DAG | 60 DAG | 90 DAG |
| $S_1G_1$ | 1.94bc | 3.24b | 5.67ab |
| $S_1G_2$ | 2.77a | 5.97a | 7.43a |
| $S_1G_3$ | 2.47abc | 4.17ab | 6.23ab |
| $S_2G_1$ | 2.14de | 3.97ab | 5.00ab |
| $S_2G_2$ | 2.09e | 3.35cd | 6.13ab |
| $S_2G_3$ | 2.37abc | 3.86ab | 6.23ab |
| $S_3G_1$ | 2.46d | 4.17ab | 6.33ab |
| $S_3G_2$ | 2.15abc | 2.95b | 5.67d |
| $S_3G_3$ | 2.84ab | 4.64ab | 6.67ab |
| $S_4G_1$ | 2.19abc | 3.33c | 5.98ab |
| $S_4G_2$ | 2.42bc | 3.93ab | 5.67ab |
| $S_4G_3$ | 1.89f | 2.87ef | 4.67e |
| LSD(0.05) | 0.883 | 1.419 | 0.783 |
| CV | 22.33 | 22.12 | 7.73 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

### 4.2.5 Effect of grafting techniques and scion from different varieties in the success of grafting on adult mango tree

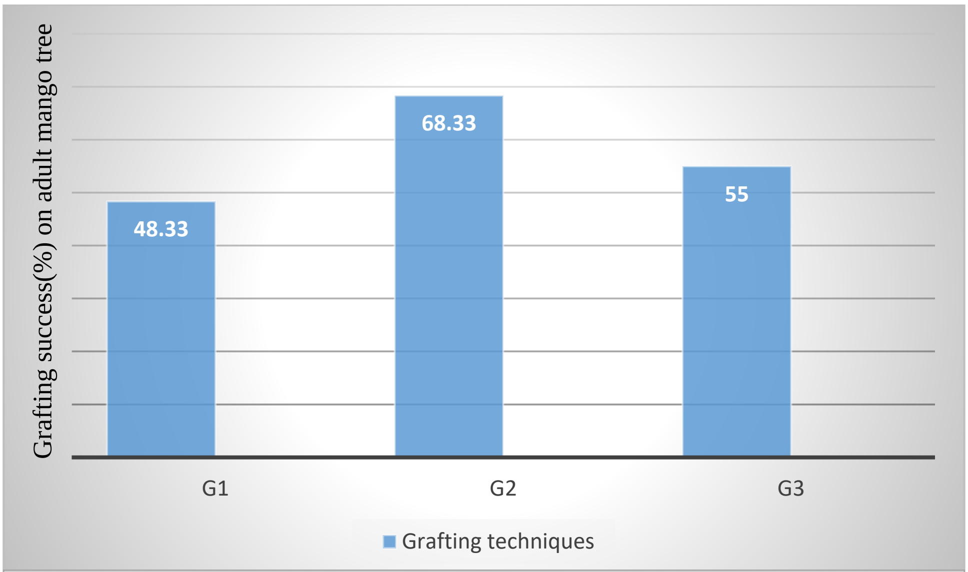
From the result of statistical analysis, we easily see that, the grafting technique and scion from different varieties and their combined interaction has a significant variance in grafting success which we see from figure 07, 08 and table 22.




$S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai

**Figure 07: Effect of scion from different varieties in grafting success on adult mango tree**

Figure 07 shows the effect of scion from different varieties in grafting success on adult mango trees. From the result we see that $S_4$ variety gave the highest success in grafting and it was 62.22%. On the other hand, the lowest grafting success was found from $S_3$ scion and success rate was only 53.33%




. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

**Figure 08: Effect of different grafting techniques in grafting success on adult mango tree**

The figure-08 reflects the grafting success due to impact of grafting technique. Here we see that the $G_2$ gave highest success rate of grafting on adult mango plant and it was

68.33%. But the lowest grafting success rate gained from all scion when $G_1$ method was used and it was 48.33%.

**Table 22: Combined effect of grafting techniques and scion from different varieties in grafting success on adult mango tree.**

| Treatments | Grafting success (%) |
|---|---|
| $S_1G_1$ | 55.33 |
| $S_1G_2$ | 60.00 |
| $S_1G_3$ | 60.00 |
| $S_2G_1$ | 55.00 |
| $S_2G_2$ | 66.67 |
| $S_2G_3$ | 60.00 |
| $S_3G_1$ | 57.33 |
| $S_3G_2$ | 66.67 |
| $S_3G_3$ | 53.33 |
| $S_4G_1$ | 58.67 |
| $S_4G_2$ | 80.00 |
| $S_4G_3$ | 60.00 |
| LSD(0.05) | 16.055 |
| CV | 16.57 |

**Note:** $S_1$- Fazli, $S_2$- Langra, $S_3$- Himsagor, $S_4$-Namdokmai. $G_1$-Cleft grafting, $G_2$-Veneer grafting, $G_3$-Whip grafting

The table 22 reflects the combined effect of grafting techniques and scion from different varieties on grafting success on adult mango tree. We see from the result that, the highest grafting success was found from $S_4G_2$ combination and it was 80%. On the other hand, the lowest success rate of grafting was both in $S_2G_1$ and in $S_3G_1$ combination and it was only 53.33%.

# CHAPTER-V

## SUMMARY AND CONCLUSION

An investigation entitled "Performance of grafting techniques mango varieties" was conducted at the Horticulture Germplasm Center, Sher-e-Bangla Agricultural University, Dhaka during the period from June 2019 to December 2019 .The experiment was laid out in Randomized Complete Block Design with twelve treatment combinations , comprising with two factors A (Grafting techniques including Cleft grafting, Veneer grafting and Whip grafting) and factor B comprising various scion (Scion from Fazli Langra, Himsagor and Namdokmai). The treatments were replicated thrice. The effect of these treatments on rootstock and scion circumference, height of scion developed, number of leaves emerged from each scion and success of grafting percentage were studied. The salient features of the experimental findings are summarized and concluded in this chapter.

Same type of practice was done on young and adult mango tree. All the data were collected separately for both young and adult mango tree. Results exposed that the different combinations of different grafting techniques and scion from different varieties had a significant effect on most of grafting success, number of leaf production on scion, circumference and height of scion on both young and adult mango tree. In case of young mango plant $S_2$ variety scion and $G_1$ method gave highest growth in scion and rootstock circumference, height of scion and number of leaves per scion. But $S_1$ scion produced higher success of grafting with $G_1$ method and success rate was 70%. $S_4$ scion with $G_3$ method produced lowest development in scion circumference, scion eight and number of leaves per scion. And the lowest grafting success rate was found when $S_3$ scion were used with $G_2$ and it was 58.33%. On the other hand, on adult mango tree $S_1G_2$ combination produced highest result and the $S_4G_3$ combination gave the lowest output for in growth and development factor.

## Conclusion

On the basis of results of present investigation, it can be concluded that all scion and all types of grafting techniques do not perform same performance. In case of grafting on young mango plant $S_2$ and $G_1$ gave highest growth in scion and rootstock circumference, height of scion and number of leaves per scion which is reflected from the results of $S_2G_1$ combination. But grafting success showed the different scenario, where we see $S_1G_1$ combination resulted the highest success. In case of grafting on adult mango tree, we can follow $G_2$ grafting technique $S_4$ scion variety highly, as we got success using this method and scion from $S_4$ variety was more effective. In the same way Cleft grafting is more suitable for grafting on young mango tree. Among studied scion from different varieties, Langra scion performed better than others on young mango plant. But Fazli scion was better when grafting was done on adult mango tree.

# REFERENCES


Akinnifesi, F. K., Leakey, R., Ajayi, O. C., Gudeta, S., Tchoundjeu, Z., Matakala, P., & Kwesiga, F. R. (2008). *Trees in the tropics: Domestication, utilization and commercialization*. Wallingford, UK: CABI Publishing.

Alam, M. A., M. Z. Islam, J. C. Uddin and A. K. Quamruzzaman. (2006). Effect of age of seedling and variety of scion in stone grafting of mango. International Journal of Sustainability Crop Production **2**: 27-32.

Albornoz, F.; Gebauer, M.; Ponce, C.; Cabeza, **(**2018) R. LeNRT1.1 improves nitrate uptake in grafted tomato plants under high nitrogen demand. Int. J. Mol. Sci., **19**, 3921.

Aloni B, Cohen R, Karni L, Aktas H, Edelstein M. (2010). Hormonal signaling in rootstock–scion interactions. Scientia Horticulturae **127**: 119–126.

Amin, RS (1978). In-situ softwood grafting in mango. Indian Hort., **23**(3): 9-10.

Asahina M, Satoh S. (2015). Molecular and physiological mechanisms regulating tissue reunion in incised plant tissues. Journal of Plant Research **128**: 381–388.

BBS (2016). Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of People's Republic of Bangladesh, 28th series. 204.

Bhambota J.R, Rajput, M.S. and Sandhu K.S. (1971). Veneer grafting successful method of mango propagation, Punjab Hort. J. 1 (1/2) i 40-3.

Bhan, KC; Samadar, HN and Yadav, PC (1969). Chip-budding and stone grafting of mango in India. Tropical Agri., **46**: 147-253.

Bhuyan MAJ and Guha D (1995). Performance of some exotic mango germplasm under Mymensingh conditions. *Bangladesh Hort.* **23** 17-22.

Bhuyan MAJ and Islam. MH (1989): Physio-chemical studies of some varieties of mango grown at Nawabgonj. *Bangladesh Hort.* **14** 42-44.

Bock R. (2010). The give-and-take of DNA: horizontal gene transfers in plants. Trends in Plant Science **15**: 11–22.

Borges F, Martienssen RA. (2015). The expanding world of small RNAs in plants. Nature Reviews Molecular Cell Biology **16**: 727–741.

Bums, W, -and Prayag, S.H (1920) The book of the mango'Bull' Bombay Dept. Acpric 103

Chitwood DH, Timmermans MC. 2010. Small RNAs are on the move. Nature **467**: 415–419.

Dahniya M, Oputa C, Hahn S. (1982). Investigating source-sink relations in cassava by reciprocal grafts. Experimental Agriculture **18**: 399–402.

Dhakal, BR and Huda, MN (2000). Effect of defoliation period and storage of scion shoots on success of veneer grafting in mango. Propagation Horticulture., **19** (3&4): 167-170.

Djidonou, D.; Zhao, X.; Brecht, J.K.; Cordasco, K.M, (2017**.** Influence of interspecific hybrid rootstocks on tomato growth, nutrient accumulation, yield, and fruit composition under greenhouse conditions. Hort Techonology, **27**, 868–877.

Dunoyer P, Schott G, Himber C, Meyer D, Takeda A, Carrington JC, Voinnet O. (2010). Small RNA duplexes function as mobile silencing signals between plant cells. Science **328**: 912–916.

Fragoso V, Goddard H, Baldwin IT, Kim S-G. (2011). A simple and efficient micrografting method for stably transformed Nicotiana attenuata plants to examine shoot-root signaling. Plant Methods **7**: 1–8.

Fuentes I, Stegemann S, Golczyk H, Karcher D, Bock R. (2014). Horizontal genome transfer as an asexual path to the formation of new species. Nature **511**: 232–235.

Garg, M.L, (1954). 'Mango propagation by means of marcotting or airlayering' Indian J. Hort. ljL. 147-48.

Ghosh, SN and Bera, B (2015). Studies on standardization of propagation methods of some minor fruit crops in India. Int. J. of Minor Fruits, Medicinal and Aromatic Plants., **1**(**1**), 31–36.

Goldschmidt EE. (2014). Plant grafting: new mechanisms, evolutionary implications. Frontiers in Plant Science **5**: 1–9.

Graft-transformation, the mechanism for graft-induced genetic changes in higher plants. Euphytica **55**: 91–99.Applied Genetics **47**: 299–302.

Grassi, G.; Millard, P.; Wendler, R.; Minotta, G.; Tagliavini, M, **(**2002). Measurements of xylem sap amino acid concentrations in conjunction with whole tree transpiration estimates spring N remobilization by cherry (Prunus avium L.) trees. Plant Cell Environ, **25**, 1689–1699.

Griesbach, J (2003). Mango growing in Kenya. Nairobi, Kenya: World Agro forestry Centre (ICRAF).

Gu X, Zhang S, Zhang S. (2006). The screening of cucumber rootstocks resistant to southern root-knot nematode. China Vegetables **2**: 4–8.

Harada T. (2010). Grafting and RNA transport via phloem tissue in horticultural plants. Scientia Horticulturae **125**: 545–550

Honja, T. (2014). Review of mango value chain in Ethiopia. *Journal of Biology, Agriculture and Health Care*, 4(**25**), 230–240.

Iftekhar, MS and Islam, MR (2004). Managing mangroves in Bangladesh: A strategy analysis, J. Coast. Conserv., **10**: 139–146.

Ioannou N. (2001). Integrating soil solarization with grafting on resistant rootstocks for management of soil-borne pathogens of eggplant. The Journal of Horticultural Science and Biotechnology **76**: 396–401.

Jang Y, Yang E, Cho M, Um Y, Ko K, Chun C. (2012). Effect of grafting on growth and incidence of phytophthora blight and bacterial wilt of pepper (Capsicum annuum L.). Horticulture, Environment, and Biotechnology **53**: 9–19.

Janick, J; Scofied, S and Goldschmit, EE (2010). Principles of Grafting and Budding. In Vegetative Propagation, 415–463.

Jose, M and Velsalkumari, PK (1991). Standardization of epicotyl and softwood grafting in mango. South Indian Hort., **39**(5): 264- 267.

Jose, M. and P. K. Velsalakimari. (1991). Standardization of epicotyl and softwood grafting in jackgruit. South Indian Horticulture **39**: 264-267.

Kahlon, P.S and Mishra, M.L, (1979). Effect of leaf lamina on the success and scion vigour in veneer grafting of mango, Punjab Hort. J. lg (l/2) t 56-8.

Kanwar, J.S. and Bajwa, M.S. (1974). Propagation of mango by side grafting, Indian jT. Agric. Sci. (**5**) s 270-72.

Karim, MR (2004). Effect of leaf and node retention in rootstock on epicotyl grafting in mango. M.Sc. (Ag). Thesis, Hort. Dept. BAU, Mymensingh. 30-53.

King, Angela R. Davis, Xingping Zhang, Kevin Crosbya. (2010) Genetics, breeding and selection of rootstocks for Solanaceae and Cucurbitaceae. Vegetable and Fruit Improvement Center, Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843, USA

Kollmann R, Glockmann C. (1985). Studies on graft unions. I. Plasmodesmata between cells of plants belonging to different unrelated taxa. Protoplasma **124**: 224–235

Kostermans, AJHG; Bompard, JM (1993). The Mangoes: Their Botany, Nomenclature, Horticulture and Utilization. Academic Press. ISBN 978-0-12-421920-5.

Kulwal, L. V. and G. S. Tayde. (1989). Studies on propagation of mango by stone grafting-Extent of mortality. Acta Horticulturae **231**: 249-251

Lewsey MG, Hardcastle TJ, Melnyk CW, Molnar A, Valli A, Urich MA, Nery JR, Baulcombe DC, Ecker JR. (2016). Mobile small RNAs regulate genome-wide DNA methylation. Proceedings of the National Academy of Sciences, USA **113**: 801–810.

Lopez-Perez J-A, Le Strange M, Kaloshian I, Ploeg AT. (2006). Differential response of Mi gene-resistant tomato rootstocks to root-knot nematodes (Meloidogyne incognita). Crop Protection **25**: 382–388.

Maiti, S. C. and P. Biswas. (1980). Effect of scion variety and type of scion shoot on success of epicotyl grafting of mango. Punjab Horticulture Journal **20**: 152-155.

Majumder, P.K, Mukherjee, sK. and Rathore, D.S, (1972). Further researches on propagation techniques in mango, Acta Horticulture. 72-6.

Marschner, P. Marschner’s (2012) Mineral Nutrition of Higher Plants, 3rd ed.; Academic Press: San Diego, CA, USA; pp. 49–70.

Melnyk CW, Meyerowitz EM. (2015). Plant grafting. Current Biology **25**: R183–R188.

Melnyk CW, Molnar A, Bassett A, Baulcombe DC. (2011). Mobile 24 nt small RNAs direct transcriptional gene silencing in the root meristems of Arabidopsis thaliana. Current Biology **21**: 1678–1683.

Molnar A, Melnyk CW, Bassett A, Hardcastle TJ, Dunn R, Baulcombe DC. (2010). Small silencing RNAs in plants are mobile and direct epigenetic modification in recipient cells. Science **328**: 872–875.

Morton, Julia Frances (1987). Mango. In: Fruits of Warm Climates. New CROP, New Crop Resource Online Program, Center for New Crops & Plant Products, Purdue University. pp. 221–239. ISBN 978-0-9610184-1-2.

Mukherjee, S. K., & Litz, R. E. (2009). The mango: Botany, production and uses. (Richard E. Litz, Ed.) (2nd ed.). CAB International.

Mukherjee, S.K, and Majumder, P.K (1962). Performance of veneer grafting in comparison to other methods of propagation in mango, Curr. Sci..**31**: 174-75.

Naik, K.C (1941), Studies on the propagation of the mango (Man gif era indlca li.), Indian J, aqric.Sci. ^**3**, 736-68.

Nakasone, H. Y., & Paull, R. E. (1998). *Tropical fruits*. University of Hawaii, Honolulu, USA: CABI.

Oka Y, Offenbach R, Pivonia S. (2004). Pepper rootstock graft compatibility and response to Meloidogyne javanica and M. incognita. Journal of Nematology **36**: 137–141.

Pandey K. (1976). Genetic transformation and “graft-hybridization” in flowering plants. Theoretical and Ohta Y. 1991.

Pangilinan, Jr., Leon (2014). "In Focus: 9 Facts You May Not Know About Philippine National Symbols". National Commission for Culture and the Arts. Retrieved 8 January 2019.

Parsai, P’s, (1963). Propagation of mangoes by side grafting and shield budding, Punjab Hort. J7. J .180-4.

Patil, A. A., B. G. Vadigeri and U. G. Nalawadi. (1991). Response of mango varieties to stone grafting. Current Research **20**(7): 135-136.

Paultre DSG, Gustin M-P, Molnar A, Oparka KJ. (2016). Lost in transit: long-distance trafficking and phloem unloading of protein signals in Arabidopsis homografts. The Plant Cell **28**: 2016–2025.

Ragel, P.; Raddatz, N.; Leidi, E.O.; Quintero, F.J.; Pardo, J.M. **(**2019**).** Regulation of K+ nutrition in plants. Front. Plant Sci. 10.

Ram, S. (1997). The mango: Botany, production and uses. (R. E. Litz, Ed.). UK: CAB International. Wallingford.

Rangacharulu, V.S. (1955) Mango rootstock investigations at the fruit research station, Kodur, Andhra agrlc, J. J i 182-6.

Rao, K -M. (1975) ‘Inarching in mango with a difference - a possible common method for both propagation and rejuvenation’ Lai –Bauah, Jg (3/2). 9-12.

Sachs T. (1981). The control of the patterned differentiation of vascular tissues. Advances in Botanical Research **9**: 151–262.

Sellin, A.; Ounapuu, E.; Karusion, A.; Oren, R. **(**2010). Experimental evidence supporting the concept of light-mediated modulation of stem hydraulic conductance. Tree Physiol. **30,** 1528–1535.

Sen, P.K. (1939, 1941) Annual Reports of the Fruit Research Station, Sabour, Bihar, for 1938-39, 1939-40 and 1940-41. Supdt, Govt. Printing, Bihar, Patna.

Simon, A. M., Akinnifesi, F. K., Sileshi, G., & Ajayi, O. C. (2010). Rootstock growth and development for increased graft success of mango (Mangifera indica) in the nursery. **9**(**9**), 1317–1324. doi:10.5897/AJB10.668

Singh RN, Majumdar PK, Sharma DK, Mukherjee SK (1972): Some promising mango hybrids. Acta *Hort*. **24** 175-184.

Singh, N-P. and Srivastava, R.P, (1979). Studies on the different aspects involved in veneer grafting in mango, Progressive Hort. 1(1) s 67-74.

Soleimani, A; Hassani, V and Rabiei, D (2010). Effect of different techniques on walnut grafting. J. Food, Agri. & Environ., **8**(**29**): 544–546.

Sorce C, Massai R, Picciarelli P, Lorenzi R. (2002). Hormonal relationships in xylem sap of grafted and ungrafted Prunus rootstocks. Scientia Horticulturae **93**: 333–342.

Stegemann S, Bock R. (2009). Exchange of genetic material between cells in plant tissue grafts. Science **324**: 649–651.

Stegemann S, Keuthe M, Greiner S, Bock R. (2012). Horizontal transfer of chloroplast genomes between plant species. Proceedings of the National Academy of Sciences, USA **109**: 2434–2438.

Takele H (2014). Review of Mango Value Chain in Ethiopia. J. Biol., Accepted Manuscript, Agriculture and Health Care., 4(**25**): 230–240.

Taller J, Hirata Y, Yagishita N, Kita M, Ogata S. (1998). Graft-induced genetic changes and the inheritance of several characteristics in pepper (Capsicum annuum L.). Theoretical and Applied Genetics **97**: 705–713.

Talukder, M.R, and Ahmed, S. (1965) ‘Success of inarching done on young stocks at Layallpur’ Pakist. J. Sci. 17 s 72-4

Traub, H. P. and B. C. Auchter. (1934). Propagation experiments with avocado, mango and papaya. Proceed. Amer. Soc. Hort. Sci. **30**: 382-385.

Tsaballa A, Athanasiadis C, Pasentsis K, Ganopoulos I, Nianiou-Obeidat I, Tsaftaris A. (2013). Molecular studies of inheritable grafting induced changes in pepper (Capsicum annuum) fruit shape. Scientia Horticulturae **149**: 2–8.

Turhan A, Ozmen N, Kuscu H, Serbeci MS, Seniz V. (2012). Influence of rootstocks on yield and fruit characteristics and quality of watermelon. Horticulture, Environment, and Biotechnology **53**: 336–341.

Turnbull CG, Booker JP, Leyser H. (2002). Micrografting techniques for testing long-distance signalling in Arabidopsis. Plant Journal **32**: 255–262.

Warschefsky EJ, Klein LL, Frank MH, Chitwood DH, Londo JP, von Wettberg EJ, Miller AJ. (2015). Rootstocks: diversity, domestication, and impacts on shoot phenotypes. Trends in Plant Science 21: 418–437.

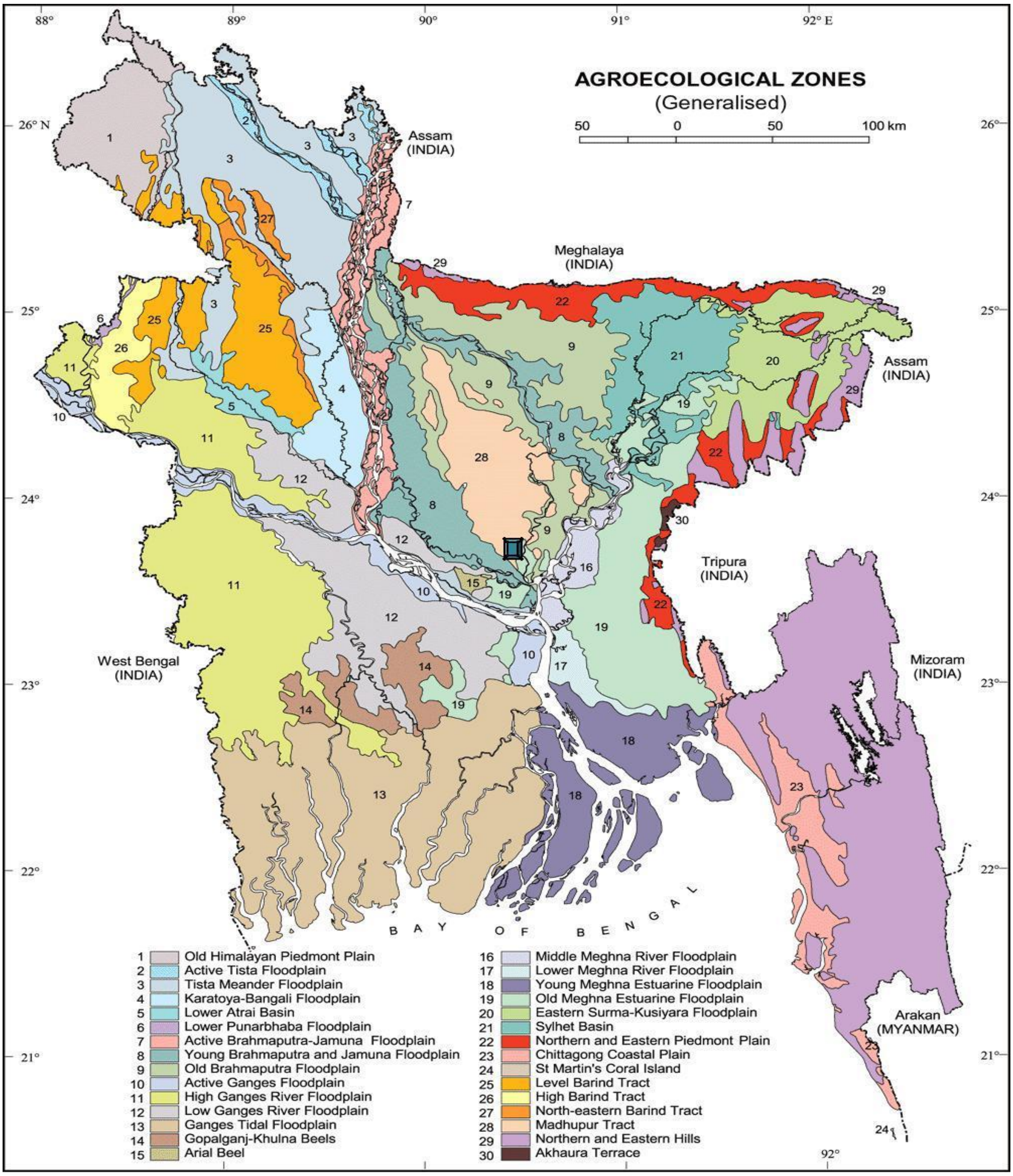
Weibel, A.; Johnson, R.S.; DeJong, T.M. **(**2003). Comparative vegetative growth responses of two peach cultivars grown on size-controlling versus standard rootstocks. J. Am. Soc. Hortic. Sci. **128**, 463–471.

Willingham S, Pegg K, Cooke A, Coates L, Langdon P, Dean J. (2001). Rootstock influences postharvest anthracnose development in ‘Hass’ avocado. Crop and Pasture Science **52**: 1017–1022.

Wu R, Wang X, Lin Y, Ma Y, Liu G, Yu X, Zhong S, Liu B. (2013). Inter-species grafting caused extensive and heritable alterations of DNA methylation in Solanaceae plants. PLoS ONE 8: e61995.

# Appendices

## Appendix I. Map showing the experimental site under the study



**Appendix II. Characteristics of soil of experimental field**

**A. Morphological characteristics of the experimental field**

| Morphological features | Characteristics |
|---|---|
| Location | Horticulture Research Farm, SAU, Dhaka |
| AEZ | Madhupur Tract (28) |
| General Soil Type | Shallow red brown terrace soil |
| Land type | High land |
| Soil series | Tejgaon |
| Topography | Fairly leveled |

**B. Physical and chemical properties of the initial soil**

| Characteristics | Value |
|---|---|
| % Sand | 26 |
| % Silt | 43 |
| % Clay | 30 |
| Textural class | Silty-clay |
| pH | 6.20 |
| Organic matter (%) | 1.14 |
| Total N (%) | 0.05 |

Source: Soil Resources Development Institute, (SRDI), Khamarbari, Farmgate, Dhaka

**Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from August 2019 to January 2020**

| Month | *Air temperature (ºc) | | *Relative humidity (%) | *Rainfall (mm) | *Sunshine (hr) |
|---|---|---|---|---|---|
| | Maximum | Minimum | | | |
| August, 2019 | 25.35 | 14.22 | 78 | 14 | 8.2 |
| September,2019 | 24.32 | 17.22 | 75 | 13 | 7.2 |
| October, 2019 | 25.82 | 16.04 | 78 | 00 | 6.8 |
| November, 2019 | 22.40 | 13.50 | 74 | 00 | 6.3 |
| December, 2019 | 24.50 | 12.40 | 68 | 00 | 5.7 |
| January, 2020 | 27.10 | 16.70 | 67 | 30 | 6.7 |

## Appendix: IV

**Summary of analysis of variance for Rootstock circumference and Scion circumference changed at different intervals after grafting on young mango tree.**

| Source of variance | DF | Values of mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | RC 30 DAG | RC 60 DAG | RC 90 DAG | SC 30 DAG | SC 60 DAG | SC 90DAG |
| Replication | 2 | 0.12048 | 0.35003 | 0.72694 | 0.24467 | 0.18452 | 0.027 |
| Variety | 3 | 0.46189** | 0.63417* | 0.30117** | 0.65141* | 0.12254** | 0.38331** |
| Grafting | 2 | 0.07379** | 0.25292** | 1.29202$^{NS}$ | 2.3796$^{NS}$ | 1.29642* | 2.3715$^{NS}$ |
| variety*Grafting | 6 | 1.35673* | 1.05955* | 1.01962* | 0.31716** | 0.90609** | 0.8981** |
| Error | 22 | 0.27182 | 0.35003 | 0.20061 | 0.27747 | 0.16886 | 0.28873 |

**Note:** RC-Rootstock Circumference, SC- Scion Circumference, DAG- Days After Grafting

**Significant at 1 % Level, *Significant at 5% Level, $^{NS}$ Non-Significant

**Appendix V**

**Summary of analysis of variance for Height of graft and Leaves per plant changed at different intervals after grafting on young mango tree.**

| Source of variance | DF | Values of mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | HG 30 DAG | HG 60 DAG | HG 90 DAG | LP 30 DAG | LP 60 DAG | LP 90DAG |
| Replication | 2 | 1.28379 | 3.17485 | 21.2979 | 0.00354 | 0.7193 | 0.03809 |
| Variety | 3 | 2.27114** | 5.44061** | 6.8488* | 0.02214** | 0.49167* | 0.02319** |
| Grafting | 2 | 7.70369$^{NS}$ | 6.88687* | 2.2659$^{NS}$ | 0.08548** | 0.23604$^{NS}$ | 0.0409** |
| variety*Grafting | 6 | 9.10628$^{NS}$ | 7.19784** | 6.7029$^{NS}$ | 0.17872** | 0.87416** | 0.43068** |
| Error | 22 | 2.2547 | 1.78969 | 1.7375 | 0.1555 | 0.24391 | 0.07695 |

HG-Height of the graft, LP- Leaves per Plant, DAG- Days After Grafting

**Significant at 1 % Level, *Significant at 5% Level, $^{NS}$ Non-Significant

## Appendix: VI

**Summary of analysis of variance for Rootstock circumference and Scion circumference changed at different intervals after grafting on Adult Mango tree.**

| Source of variance | DF | Values of mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | RC 30 DAG | RC 60 DAG | RC 90 DAG | SC 30 DAG | SC 60 DAG | SC 90DAG |
| Replication | 2 | 0.14595 | 0.22241 | 0.25551 | 0.03569 | 0.06507 | 0.24234 |
| Variety | 3 | 0.89767** | 0.52976** | 0.35616** | 0.07044** | 0.82894** | 1.52227$^{NS}$ |
| Grafting | 2 | 2.20187$^{NS}$ | 0.29347** | 0.13936** | 1.49753* | 1.22405* | 1.85129** |
| variety*Grafting | 6 | 0.90648** | 1.03414* | 1.27809* | 1.04889* | 0.49579** | 0.94961** |
| Error | 22 | 0.25189 | 0.1006 | 0.17385 | 0.24289 | 0.10781 | 0.09759 |

RC-Rootstock Circumference, SC- Scion Circumference, DAG- Days After Grafting

**Significant at 1 % Level, *Significant at 5% Level, $^{NS}$ Non Significant

**Appendix: VII**

**Summary of analysis of variance for Height of graft and Leaves per plant changed at different intervals after grafting on adult mango tree.**

| Source of variance | DF | Values of mean square | | | | | |
|---|---|---|---|---|---|---|---|
| | | HG 30 DAG | HG 60 DAG | HG 90 DAG | LP 30 DAG | LP 60 DAG | LP 90DAG |
| Replication | 2 | 2.1899 | 2.847 | 7.0094 | 0.51359 | 7.86613 | 0.26748 |
| Variety | 3 | 18.205** | 20.1678* | 6.6552$^{NS}$ | 0.18042** | 0.07127$^{NS}$ | 0.26223** |
| Grafting | 2 | 4.8912** | 8.3452** | 11.516* | 0.07235** | 1.01223* | 0.10992$^{NS}$ |
| variety*Grafting | 6 | 1.4109* | 2.1691** | 6.7555** | 0.37248* | 0.82563** | 0.20379$^{NS}$ |
| Error | 22 | 1.239 | 0.9193 | 3.8078 | 0.2724 | 0.70265 | 0.21391 |

HG-Height of the graft, LP- Leaves per Plant, DAG- Days After Grafting

**Significant at 1 % Level, *Significant at 5% Level, $^{NS}$ Non Significant

**Appendix: VIII**

**Summary of analysis of variance for success rate of grafting on young and adult mango tree.**

| Source of variance | DF | Values of mean square | |
|---|---|---|---|
| | | Success on young plant | Success on Adult plant |
| Replication | 2 | 11.111 | 77.78 |
| Variety | 3 | 662.963** | 129.63* |
| Grafting | 2 | 411.111** | 1244.44** |
| variety*Grafting | 6 | 262.963** | 251.85** |
| Error | 22 | 120.202 | 89.90 |

**Significant at 1 % Level, *Significant at 5% Level