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Ascertaining wedge grafting time of wild mango seedling under subtropical conditions of Himachal Pradesh

Shiv Kumar Shivandu[1*], Sanjeev Kumar Banyal[2], Uday Raj Patial[3] and Nischala[2]

[1] Division of Fruits and Horticultural Technology, ICAR- Indian Agriculture Research Institute, New Delhi- 110012, India.

ABSTRACT

This study was conducted at the College of Horticulture and Forestry in Neri, Himachal Pradesh, addresses the challenge of meeting the high demand of premium planting material. Focusing on wedge grafting, the research aimed to standardize grafting time under sub-tropical conditions. Randomized block design with seven treatments, T_1 (First fortnight of August) emerged as the best time, exhibiting the shortest bud break duration (16.43 days), highest graft success rate (68.19%), and maximum graft survival (72.00%). T_1 also resulted in maximum height (32.11 cm), number of leaves (15.02), branches (1.80), and scion diameter (7.60 mm). While T_2 (Second fortnight of August) showed maximum rootstock diameter, T_3 (Second fortnight of September). In conclusion, August, particularly the first fortnight (T_1), was identified as the key month for achieving optimal wedge grafting outcomes in Himachal Pradesh, addressing the demand for high-quality planting material in the region.

Key words: Wedge grafting, root stock, graft success, survival percentage, subtropical.

INTRODUCTION

Mango (*Mangifera indica*, Anacardiaceae) is the most popular tropical fruit and is known as the "King of Fruits" due to its appealing look and delectable flavor. It is well-known for being rich provider of nutritional elements. It is cultivated in practically around the globe and has a special position among Indian fruit crops. India is the largest producer of mango in the world, with an estimated area of 2.32 million hectares under cultivation and an annual production of about 20.39 million metric tonnes (NHB, 14). Mango is preferred by people around the globe for its excellent flavours, aroma colour and taste (Karna *et al.,* 5). Mango has wide diversity of uses like unripe mangoes are commonly used in cooking and for making pickles and chutneys, while ripe mangoes are sold at premium prices, exported or processed into products like juice, squash, and mango leather. Mango is propagated using sexual as well as asexual (vegetative) methods but vegetative methods are highly preferable in order to retain similarity to mother plant (Nakasone and Paull, 12). Grafting is an old horticultural method essential for contemporary gardening and it mainly depends on environmental conditions and age of scion and rootstock. The graft success and survivability of mango grafts also depends on variety time and type of grafting, defoliation period of scion leaf and node retention on stock. Since, it allows us to reap the benefits of grafted plants. The benefits include early blooming compared to seedling trees, and the trees are often smaller in size than seedling trees since they yield earlier fruit bearing (Janick *et al.,* 5). Grafting is defined as joining rootstock on to scion or scion onto the rootstock so the plant grows as one entity as grafted plant (Mukherjee and Litz, 11). There are several disadvantages of utilizing a wild seedling tree. The majority of seedling trees are strong and have a long juvenile phase, they bear their first fruit roughly 6-8 years after planting; however, adopting vegetative techniques promotes dwarfness and induce precociousness in mango trees (Honja, 3).

Side veneer grafting has been used since time immemorial, but poor graft union leads to poor growth of the mango plant due to the low area in contact of stock and scion. Wedge grafting being the modern method has been reported to be successfully practiced because of its ease and it also has lower chance of mismatching of scion and stock width, which provides a strong hold for union development. Wedge grafting has been observed to be extremely favorable in comparison to other procedures since it is highly effective, quick as the area in contact is greater than in any other form of grafting. Wedge grafting has enormous promise and may be used to rapidly increase mango plants for year-round output. The appropriateness of time of wedge grafting varies according to climatic conditions of the location. Available information regarding the influence of time of wedge grafting on the success of grafting is inconclusive, hence this study was conducted with objective of standardize the time of wedge grafting.

*Corresponding author email: marginshiv05@gmail.com

[2]Dept. of Fruit Science, College of Horticulture and Forestry, Dr. Y S Parmar University of Horticulture and Forestry, Neri, Hamirpur, H.P. 177 001, India

[3]Dept. of Fruit Science, PAU Ludhiana, Punjab 141 004, India

MATERIALS AND METHODS

The present experiment was laid out in Randomized block design (RBD) having 7 treatment and 3 replications at fruit nursery of College of Horticulture and Forestry Neri, Hamirpur, Himachal Pradesh, India *w.e.f* August 2019 to September 2021. The experimental site falls under subtropical low hill zone of Himachal Pradesh which is characterized by harsh summers and receives heavy rainfall from July to September. The region received an average rainfall of 1600 mm and average humidity of 66-70% during experimental period. The wedge grafting was performed on rootstock raised from local wild mango seeds in polythene bags of (13 × 10 cm) under greenhouse conditions. A total of 1070 plants were used for the experiment.

The wedge grafting was performed at seven different times during the year, which were designated as treatments. These included: T_1 – first fortnight of August, T_2 – second fortnight of August, T_3 – first fortnight of September, T_4 – second fortnight of February, T_5 – first fortnight of March, T_6 – second fortnight of March, and T_7 – first fortnight of April. Robust, three to four months old shoots having 3-4 buds were selected from mother plants of D-51 as scions, leaves of selected shoots were partially defoliated to ¾ of actual leaf length 7-10 days prior to the grafting process. The selected scions were of same or slightly smaller shoot diameter as that of the rootstock. Wedge grafting, one of the simplest grafting methods, was performed by heading back seedling rootstocks at 15–18 cm above the soil with a sterilized knife. A vertical slit of 3.5–4.0 cm was made at the top of each stock, and scion wood, collected after seven days of hardening, was cut into a 3.5–4.0 cm wedge. The scion was inserted into the split stem, and the union was tightly wrapped with polythene strips, later removed after callus formation to avoid girdling. Shoots below the graft union were removed once scion leaves appeared. Data on growth parameters were recorded at 30, 60, 90, 120, and 150 DAG, while time to bud sprout, graft success percentage, and survival rate were assessed. The days from grafting to first bud burst were recorded. Graft success was assessed at 10-day intervals up to 120 DAG, with a graft considered successful when a shoot emerged from the terminal bud. Success percentage was calculated as (successful grafts/total grafts) × 100. Survival was evaluated from 15 DAG onward for four months, with actively growing plants counted and failed grafts noted. Survival percentage was calculated as [(total grafts – failed grafts)/total grafts] × 100.

Plant growth parameters were recorded at 30-day intervals. Plant height (cm) was measured from the rootstock base to the scion tip, and the mean per treatment was calculated. The total number of leaves per graft and the number of branches emerging after bud sprout were counted, and averages were computed. Rootstock diameter was measured 5 cm above the collar region, and scion diameter 5 cm above the graft union, using a digital Vernier caliper; values were expressed in millimeters as treatment means. The dataset was reduced to two principal components (PC1 and PC2), PCA simplifies the interpretation of the multi-dimensional data while capturing most of the variation within it. The two selected components, PC1 and PC2, represent different aspects of the grafting process. PC1, which explains the highest variance, is predominantly influenced by growth-related factors like rootstock height, scion height, and stoinic height. On the other hand, PC2 captures variance linked more closely to grafting outcomes, with significant contributions from bud burst days, graft success, and graft survival. The data were subjected to statistical analysis as per the procedure outlined by Gomez and Gomez, (2) and were compared by critical difference value calculated at a 5% level of significance

RESULTS AND DISCUSSION

Performing wedge grafting resulted in earliest (16.43 days) bud break under T_1, while T_2, T_5, T_6, and T_7 were at par to T_1 contrastingly, T_3 required maximum (38.58 days) time. The highest (55.1%) graft success rate was observed under T_7, while T_1 was found to be at par to T_7. However, T_4 had lowest (15.22%) success rate (Fig. 1). Remarkably, T_1 consistently had maximum survival rates at 60 DAG (79.96%), 120 DAG (70.18%), and, T_2 performing at par with T_1. In contrast, plants grafted under T_4 were observed having the lowest survival rates at 60 DAG (83.32%) and 120 DAG (44.06%) (Fig. 1). These results suggest different times of grafting play a crucial role in influencing bud break, grafting success, and survival rates. Various factors affecting

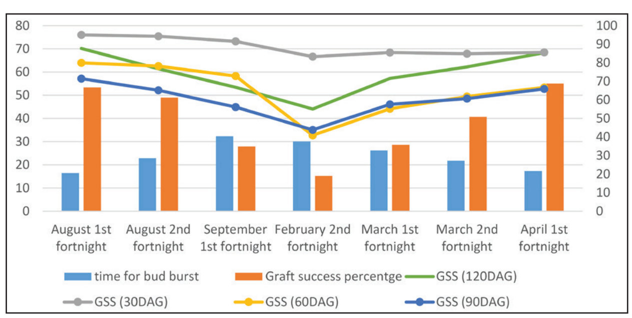

Fig. 1. Effect of wedge grafting time on bud burst, graft success and survival (%). GSS: Graft success and survival.

graft success, such as relative humidity, temperature, and rainfall, as noted in previous studies (Patel and Amin 16; Singh *et al.,* 19), may contribute to these outcomes. Notably, plants grafted under T_1, specifically in August, exhibited early bud break, higher graft success, and increased survival, possibly due to prevailing rainy season which resulted in higher relative humidity (Table 1). However, the scion collected was in dormant stage with bud swollen in bulging condition, more over partial defoliation of scion resulted in higher accumulation of carbohydrate reserves in the towards the bud and enhance early bud break. The maximum survivability of grafts was due to the rainy season and persistent higher humidity resulting in quick and strong vascular connections also the grafts had enough time prior to commencement of harsh winters in comparison to other treatments.

Stionic height followed a consistent pattern, with T_1 reaching the maximum height (22.53 cm) at 30 DAG and T_6 the minimum (19.1 cm). However, by 150 DAG, T_1 exhibited the maximum height (31.50 cm), while T_4 recorded the minimum (22.92 cm) (Fig. 2). The monsoon season, characterized by high relative humidity, fostered increased meristematic cell activity, contributing to rapid and robust growth. Favorable climatic conditions, such as high humidity, enhanced photosynthesis, cell division, and carbohydrate accumulation, promoting growth. These findings are consistent with Karna *et al.* (6), Mandal *et al.* (10) Pereira *et al.* (18) and Kumar *et al.* (9) who reported maximum stionic height in plants grafted in August. The maximum number of leaves (10.0) at 30 DAG was observed under treatments T_1 and T_3. Conversely, the least number of leaves (4.08) was found in treatment T_4, while T_5 and T_6 were significantly at par to T_4. Similar, pattern was observed 150 DAG, were T_7 recorded maximum number of leaves (15.51), and the minimum (6.52) was observed in T_4 (Fig. 3 & 4). These results may be attributed to the early bud burst and robust graft union formation, facilitating better nutrient uptake and supporting overall plant growth, resulting in a higher leaf count. This observation aligns with the findings of (Karna *et al.* 7) in grafting conducted on September 15th, and (Palande *et al.,* 15; Pathak *et al.,* 17) in tamarind.

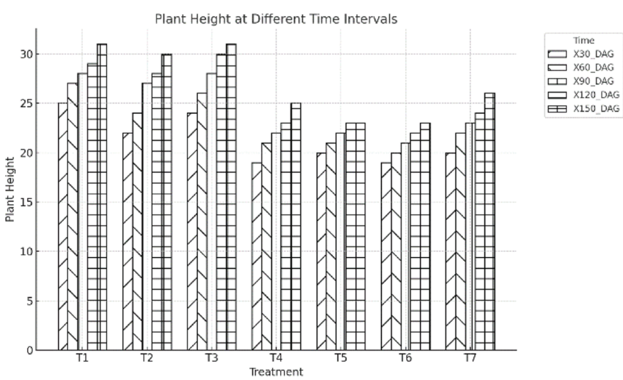

Fig. 2. Effect of time of wedge grafting on plant height.

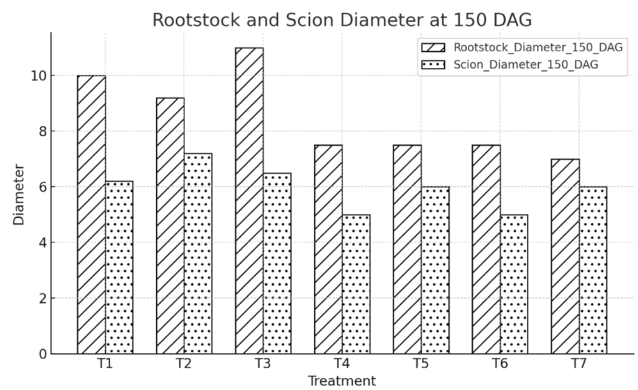

Fig. 3. Effect of time of wedge grafting on stionic parameters.

Table 1: Effect of different grafting time on rootstock height, scion height, stionic height, rootstock diameter and scion diameter 150 days after grafting.

Treatment	Rootstock height (cm)	Scion height (cm)	Stoinic height (cm)	Rootstock diameter (mm)	Scion diameter (mm)
August 1st fortnight	19.237	12.258	31.495	10.048	6.132
August 2nd fortnight	17.935	11.438	29.373	9.067	6.637
September 1st fortnight	18.983	11.858	30.842	11.61	6.87
February 2nd fortnight	13.96	9.272	23.232	7.858	4.97
March 1st fortnight	14.055	8.868	22.923	7.738	6.092
March 2nd fortnight	13.838	9.245	23.083	7.542	5.347
April 1st fortnight	15.095	10.532	25.627	7.07	5.932
C.D (0.05)	0.521	0.786	0.967	0.371	0.546
C.V	1.93	4.164	2.018	2.372	5.063

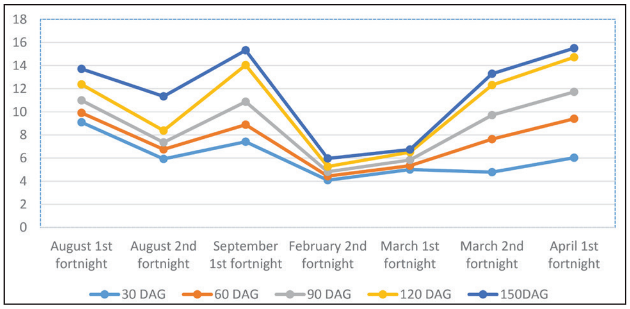

Fig. 4. Leaf production response to different grafting times.

Regarding rootstock diameter, T_3 recorded the maximum (19.24 mm), while T_6 exhibited the minimum (13.84 mm) at 150 DAG (Fig. 3). The increase in the stock girth can be attributed to favorable climatic conditions and a higher leaf count, promoting increased food production and contributing to the improved diameter of the scion. These findings are consistent with the results where grafting in September resulted in a comparable treatment with the maximum diameter, and are also in line with the findings of (Nalage *et al.,* 13).

The maximum (12.26 mm) recorded diameter of the scion was found in plants under T_3, while T_5 resulted in the minimum (8.87 mm) diameter at 150 DAG (Fig. 3). The increase in scion girth could be due to the presence of suitable temperature and high relative humidity during this time in the nursery block, contributing to the increment in the scion diameter. These results are in agreement with the findings of Karna *et al.* (6) where the maximum diameter was recorded in September, and are supported by research from (Kelaskar *et al.,* 8) in mango. Overall, the rapid and robust union formation in T_1 and T_3 seems to have facilitated better nutrient uptake, enhanced plant growth, and resulting in a higher leaf count.

Suitability of grafting season on the basis of PCA and correlation analysis provide insights about PCA and correlation studies within different time of grafting and parameters (Fig. 5 & 6). The PCA analysis and the accompanying correlation studies provide a clear way to assess the suitability of different periods for grafting operations based on various factors such as growth measurements, graft success, and survival rates. In the PCA plot, points corresponding to different fortnights are positioned based on the combined influence of these factors. The periods in August, particularly "August 1st fortnight" and "August 2nd fortnight," are positioned relatively close together, indicating that they share similar favourable conditions. These fortnights exhibit balanced performance in both growth and grafting success, as reflected by their placement in the middle of the principal component space, away from extremes like February or March fortnights, which show less favourable conditions for grafting.

The fortnights in August have moderate values for both principal components, suggesting that during this

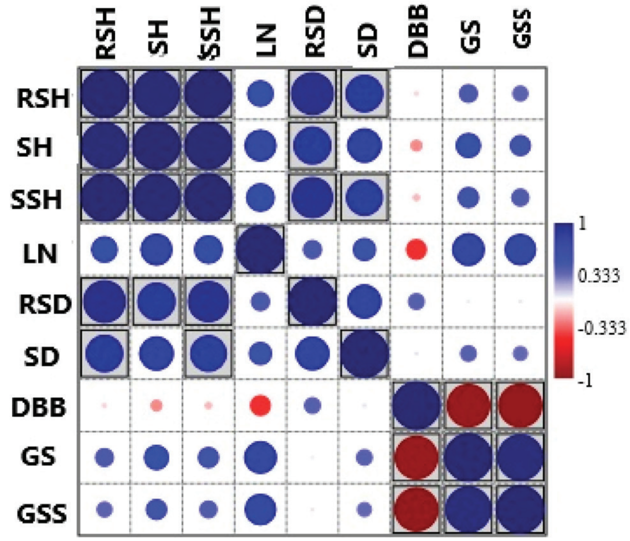

Fig. 5. Correlation analysis among different grafting parameters. The correlation matrix illustrates the relationships between rootstock height (RSH), scion height (SH), stionic height (SSH), leaf nitrogen (LN), rootstock diameter (RSD), scion diameter (SD), days to bud burst (DBB), graft success (GS), and graft survival (GSS). Blue circles indicate positive correlations, red circles indicate negative correlations, and the size/intensity of the circles represents the strength of correlation.

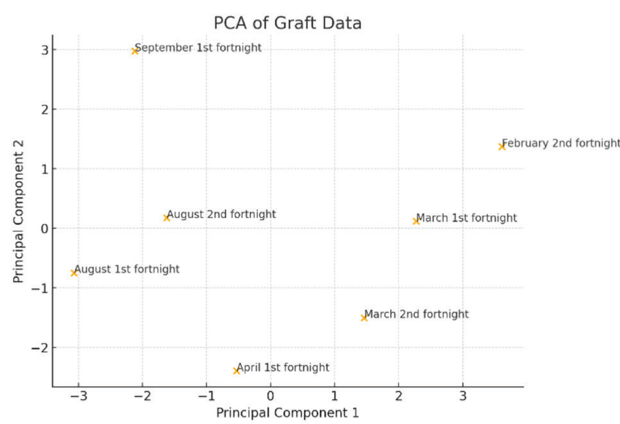

Fig. 6. Principal component analysis (PCA) of grafting time treatments. The biplot shows the distribution of seven grafting times (first and second fortnights of August, first fortnight of September, second fortnight of February, first and second fortnights of March, and first fortnight of April) along principal component 1 and principal component 2 axes.

time, growth factors and grafting success are optimal. In contrast, periods like February and early March are further apart on the PCA graph, reflecting lower graft success and survival rates, possibly due to less favourable environmental or physiological conditions. Overall, the PCA shows that August offers a more consistent and optimal combination of both growth and successful graft outcomes, making it the most suitable period for conducting grafting operations. The positioning of August fortnights near the centre of the PCA plot, with high graft survival and good growth metrics, supports the conclusion that this month provides the best conditions for grafting success.

Rootstock height is strongly correlated with scion height (0.971) and stionic height (0.996). Similarly, scion height is strongly correlated with Stionic height (0.988). Number of leaves were found having moderated co- relation with RSH (0.538), SH (0.656) and SSH (0.585). Similar trend was observed between rootstock diameter with SH (0.783) and SSH (0.852) while was strongly correlated with RSH (0.882). Bud burst days show weak correlations with most parameters but have a moderate positive relationship with rootstock D (0.500). Graft success is moderately correlated with scion H (0.511), Stoinic H (0.428), and strongly with Leaf Number (0.670). A strong negative correlation with bud burst days (-0.800) suggests that fewer bud burst days lead to higher graft success. Graft survival is highly correlated with graft success (0.957), indicating that successful grafts are more likely to survive. It also shows moderate positive correlations with leaf number (0.648) and scion H (0.425) and a negative correlation with bud burst days (-0.807).

The results derived from correlation analysis were found complementing the PCA insights and provide overview of how plant parameters and grafting time interact and influence the grafting success. Rootstock height (RSH), scion height (SH), and stoinic height (SSH) are strongly correlated (RSH-SH: 0.971, RSH-SSH: 0.996, SH-SSH: 0.988). This aligns well with the above mentioned PCA results, where PC1 is heavily influenced by growth-related parameters. The strong correlations between these growth variables have resulted in high loadings on PC1. the number of leaves were moderately correlation with RSH, SH, and SSH. Similarly, rootstock diameter (RD) had moderate to strongly correlation with SH and SSH. These moderate relationships are captured in both PC1 and PC2 in the PCA plot. The contributions of leaf number and rootstock diameter to PC1 are smaller compared to height-related parameters but still significant. This reflects that while they are important, their influence is not as dominant, which is consistent with the moderate correlations observed in the correlation analysis. Days for bud burst present a weak correlation with most parameters, except for rootstock diameter and a strong negative correlation with graft success. Same was reflected in the PCA, where days to bud burst has a high positive loading on PC2, while graft success has a strong negative loading on PC2. This means PC2 captures this inverse relationship between the two variables, reinforcing the idea that early bud burst is associated with better graft success.

The correlation analysis highlights a strong positive correlation between graft success and graft survival, indicating that successful grafts are highly likely to survive. In the PCA, graft success and graft survival both loads heavily on PC2, showing that this second principal component was driven by these graft-related variables. This suggests that PC2 primarily captures the variation in grafting outcomes, which aligns with the strong correlation between success and survival.

Both graft success and graft survival are negatively correlated with bud burst days. PCA also have similar results, where bud burst days has a high positive loading on PC2, and graft success and graft survival have strong negative loadings. This shows that early bud burst contributes to higher graft success and survival rates. The PCA analysis divided the dataset into two main components: PC1 emphasizes plant growth performance, influenced by factors like Rootstock and Scion Height, while PC2 highlights graft-related variables, linking higher graft success and survival with early Bud Burst. The PCA plot indicates that the August fortnights are optimal for both growth and graft success. Additionally, correlation analysis reveals strong relationships among growth parameters and a significant correlation between graft success and graft survival (0.957), alongside a negative correlation with days Bud Burst (-0.800).

Wedge grafting, particularly under T_1, demonstrated early bud break, high success rates, and increased survival, while T_4 exhibited the opposite trend. Climatic conditions, including humidity and temperature, played a crucial role in influencing plant height, leaf count, and rootstock and scion diameters. The technique's success in enhancing nutrient uptake and promoting robust growth suggests its potential for optimizing horticultural practices. The results were fully supported by correlation and PCA studies. The current study provided useful insight for standardizing the month of august for carrying out successful wedge grafting in mango. Future prospects may involve refining grafting timing strategies based on climatic conditions for further improvements in plant development and overall productivity, contributing to advancements in sustainable agriculture and horticulture.

AUTHORS' CONTRIBUTION

Conceptualization, original draft preparation, visualization, methodology design, formal analysis, and interpretation of result (SKS). Conceptualization, Supervision (SKB). Data collection and interpretation (URP, N).

DECLARATION

It is being declared that we have no conflict of interest.

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