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Manipulation through grafting and pruning for dwarf shape of BARI released mango variety

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ABSTRACT

This study evaluates the effects of various grafting and pruning techniques on the growth and fruit quality of the BARI mango variety, conducted at the Regional Horticulture Research Station in Chapainawabganj from 2019 to 2023. Using a Randomized Complete Block Design (RCBD) with three replications, seven treatments were implemented, including normal grafting and multiple grafting methods, alongside stem cutting. Significant variations were observed in plant growth metrics. Treatment 1 (T_1) achieved a maximum height of 4 m and a base girth of 34.5 cm, yielding 11.1 kg of fruit from 30 fruits, despite having the fewest branches (7.5). In contrast, Treatment 3 (T_3) reached a height of 2.25 m with a base girth of 23 cm, producing 12.32 kg from 28 fruits, but exhibited the highest number of branches (12.5). T_3 also resulted in the largest average fruit weight at 440.2 g, while Treatment 7 (T_7) recorded the highest edible portion at 81%. Further analysis revealed that T_3 and Treatment 2 (T_2) had the highest Total Soluble Solids (TSS) percentages (21%), indicating superior fruit sweetness. These results underscore the importance of specific grafting and pruning strategies in optimizing both the structural integrity and fruiting potential of the BARI mango variety. The findings highlight the potential for implementing high-density planting practices, enhancing productivity, and contributing to sustainable agricultural systems.

1. Introduction

Mango (*Mangifera indica* L.) is one of the most important fruit in Bangladesh. It is tropical and sub-tropical fruit belongs to the family Anacardiaceae (Bose 1985) which was originated in the eastern India, Asam, Myanmar or in the Malayan region (Mukherjee, 1997). It is nutritionally very rich, unique in flavor and smell. In Bangladesh, annual production is 1207446 metric tons from 121075 hectares of land (BBS, 2023). It is also one of the most important tropical fruit crops, widely cultivated for its delicious fruit and significant economic value. However, the traditional cultivation of mango trees often results in large, vigorous trees that are difficult to manage and harvest. To address these challenges, horticultural techniques such as grafting and pruning have been employed to manipulate the growth and shape of mango trees, aiming to produce dwarf varieties that are easier to manage and harvest.

Grafting is a vegetative propagation method that involves joining a scion (the upper part of the plant) to a rootstock (the lower part of the plant) to form a new plant. This technique has been shown to significantly influence various growth parameters and the success rate of mango propagation. For instance, a study conducted in the Amhara Region of Ethiopia demonstrated that the cleft grafting technique, particularly when performed in March, resulted in a 100% success rate of grafted mango trees, highlighting the importance of selecting the appropriate grafting time and technique to maximize success (Beshir et al., 2019).

Pruning, on the other hand, is a horticultural practice that involves the selective removal of certain parts of a plant, such as branches, buds, or roots, to control its growth and improve its structure. Research on the impact of pruning on mango trees has shown that annual pruning, combined with the application of growth regulators like paclobutrazol, can effectively reduce tree height and spread, thereby achieving a dwarfing effect. For example, an experiment on the Dashehari mango variety revealed that annual pruning of terminal shoots by 10 cm immediately after fruit harvest, along with paclobutrazol application, not only maintained fruit quality but also increased the number of fruits per tree and overall yield (Sing et al.,2017).

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The combination of grafting and pruning techniques offers a promising approach to developing dwarf mango varieties that are easier to manage and harvest. This research aims to explore the manipulation of the BARI-released mango variety through grafting and pruning to achieve a dwarf shape, thereby enhancing the efficiency and productivity of mango cultivation.

2. Materials and Methods

The study was conducted at the Regional Horticulture Research Station in Chapainawabganj from 2019 to 2023, employing a Randomized Complete Block Design (RCBD) with three replications and a plant spacing of 4m x 5m. Throughout the experiment, essential cultural practices, including pest and disease management, irrigation, weeding, and mulching, were performed as needed.

The experiment featured seven distinct treatments designed to assess various grafting techniques (Figure 1):

T_1: Control (Normal grafting)
T_2: Single grafting at a height of 5 inches
T_3: Double grafting at 5-inch intervals, beginning with the first grafting at 5 inches from the ground this year, followed by a second grafting the next year at 5 inches above the first level
T_4: Triple grafting at 5-inch intervals, with the first grafting conducted this year at 5 inches from the ground, the second grafting the following year, and the third grafting performed the year after
T_5: Single grafting at a height of 5 inches, combined with cutting the main stem 5 inches above the grafting point
T_6: Double grafting at 5-inch intervals, similar to T3, with the main stem cut 5 inches above the grafting point
T_7: Triple grafting at 5-inch intervals, following the same timeline as T4, with the main stem cut 5 inches above the grafting point

A total of twenty-one thirty-day-old seedlings were planted in the experimental field. The tree volume was calculated using Castle's (1983) formula:
Tree Volume=$1/6\times\pi\times\text{height}\times(2r)^2$

Where 2r represents the average canopy spread calculated as the mean of the east-west and north-south dimensions, expressed in cubic meters (m^3). Fruits were harvested at optimal maturity, and both quantitative and qualitative characteristics were evaluated. Quantitative traits included fruit weight, size, stone weight, stone size, total soluble solids (TSS) percentage, and the percentage of edible portion. Qualitative traits assessed included ripening stage color, pulp color, and peeling quality.

Figure 1: Different grafting of dwarf shape of BARI released mango variety

Furthermore, data on insect pests and diseases under natural conditions were collected, and the post-harvest behavior of ten fruits stored at room temperature was monitored. This thorough approach aimed to evaluate the impact of different grafting techniques on plant growth and fruit quality.

2.1. Statistical analysis

The data collected was subjected to analysis of variance, and subsequently the significant means were separated by the least significant difference test by using the MSTATC software at 5% probability level.

3. Results and Discussion

Variation was observed among the treatments concerning plant height, with the maximum recorded height of 4 meters in Treatment 1 (T_1) and the minimum height of 2.25 meters in Treatment 3 (T_3). This disparity underscores the variability in plant growth across the different treatments. T_1 and Treatment 4 (T_4) exhibited the tallest plants, while T_3 had the shortest. The taller plants in T_1 may indicate stronger growth, which often correlates with increased photosynthetic capacity, potentially leading to higher yields (Smith et al., 2020). Conversely, the reduced height in T_3 may suggest stunted growth, attributed to the double grafting conducted at 5-inch intervals. This grafting process involved performing the initial graft at 5 inches from the ground, followed by a second grafting round at 5 inches above the previous grafting level.

Base girth measurements ranged from 23 cm to 34.5 cm, with the maximum girth (34.5 cm) recorded in T_1 and the minimum (23 cm) in T_3. T_1 also demonstrated the largest East-West (E-W) canopy at 2.85 m and North-South (N-S) canopy at 2.90 m, alongside the highest tree volume of 17.1 m³, indicating minimal dwarfing effects. Treatment 2 (T_2) exhibited moderate canopy dimensions (2.35 m E-W, 2.70 m N-S) and a tree volume of 10.19 m³. In contrast, T_3, designed for dwarfing, showed the smallest canopy sizes (1.90 m E-W, 1.75 m N-S) and the lowest tree volume (4.0 m³). T_4 recorded substantial canopy dimensions (2.75 m E-W, 2.30 m N-S) and a considerable tree volume of 13.03 m³. Treatment 5 (T_5) maintained a good canopy spread (2.40 m E-W, 2.85 m N-S) with a tree volume of 11.02 m³. Treatment 6 (T_6) displayed smaller canopy dimensions (1.70 m E-W, 1.85 m N-S) and a tree volume of 4.80 m³. Lastly, Treatment 7 (T_7) presented medium canopy sizes (2.15 m E-W, 2.45 m N-S) with a tree volume of 9.43 m³. The variation in canopy dimensions and tree volumes across treatments illustrates the impact of diverse grafting and pruning techniques on developing a dwarf mango variety suitable for high-density planting (Jones & Brown, 2019).

The data presented in the table highlights the effects of various treatments on the number of branches per plant, average fruit weight, yield per plant, and the number of fruits per plant for the BARI mango variety. Treatment 1 (T_1) exhibited the fewest branches (7.5) but achieved the highest yield per plant at 11.1 kg and produced the most fruits (30). Treatment 2 (T_2) demonstrated a moderate branch count (9.5) alongside a lower average fruit weight of 354 g, resulting in a yield of 7.56 kg. In contrast, Treatment 3 (T_3) recorded the highest number of branches (12.5) and the largest average fruit weight (440.2 g), yielding 12.32 kg from 28 fruits. Treatment 4 (T_4) had fewer branches (7.5) and a lower yield (6.8 kg) from 19 fruits. Treatment 5 (T_5) achieved a higher branch count (12) and an average fruit weight of 377.8 g, producing a yield of 8.5 kg from 24 fruits. Similarly, Treatment 6 (T_6) had fewer branches (7.5) but the highest average fruit weight (465 g), resulting in a yield of 7.91 kg from 17 fruits. Lastly, Treatment 7 (T_7) displayed a moderate branch count (9), an average fruit weight of 450 g, but the lowest yield at 6.75 kg from 15 fruits.

Overall, the data demonstrates the varying impacts of grafting and pruning techniques on the growth and fruit production of the BARI mango variety, with Treatment 3 emerging as the most effective for achieving high yields (Rahman et al., 2021; Hasan & Chowdhury, 2020).

Table 1: Plant and yield characteristics of different treatments at RHRS, Chapainawabgonj during 2022-23

Treatments	Plant height (m)	Base girth (cm)	E-W canopy(m)	N-S canopy(m)	Tree volume (m^3)	No. of branches/ Plant	average Fruit wt.(g)	Yield / Plant	
								No. of fruits	wt. (kg)
T_1	4a	34.5a	2.85a	2.90a	17.1a	7.5c	370cd	30a	11.1a
T_2	3.05c	27c	2.35b	2.70ab	10.19d	9.5b	354d	20cd	7.56bc
T_3	2.25d	23d	1.90cd	1.75d	4.0g	12.5a	440.2b	28ab	12.32a
T_4	3.9a	29.5bc	2.75a	2.30c	13.03b	7.5c	357.7cd	19de	6.8bc
T_5	3.05c	31.5b	2.40b	2.85a	11.02c	12a	377.8c	24bc	8.5b
T_6	2.90cb	24d	1.70d	1.85d	4.80f	7.5c	465a	17de	7.91bc
T_7	3.40	27.5c	2.15bc	2.45bc	9.43e	9b	450ab	15e	6.75c
CV(%)	3.92	5.74	6.22	5.55	6.42	8.96	3.10	12.51	11.26
Significant	**	**	**	**	**	**	**	**	**

* * indicates the significant level at 1%

This table presents the effects of various treatments on the BARI-released mango variety, focusing on fruit size, edible portion, total soluble solids (TSS), stone weight, and stone size (see Table 2). In Treatment 1 (T_1), the fruit dimensions were 9.7 cm in length, 9.7 cm in breadth, and 8 cm in thickness, with an edible portion of 77.19%. The TSS was measured at 20%, the stone weighed 33.5 g, and its dimensions were 8.1 cm in length, 4.3 cm in breadth, and 2.1 cm in thickness. For Treatment 2 (T_2), the fruit measured 10 cm in length, 9.7 cm in breadth, and 7.9 cm in thickness. The edible portion accounted for 80.77%, TSS was 21%, and the stone weighed 29.5 g, with dimensions of 7 cm in length, 4.2 cm in breadth, and 2.1 cm in thickness.

In Treatment 3 (T_3), fruit dimensions increased to 11 cm in length, 9.7 cm in breadth, and 8.1 cm in thickness, with an edible portion of 80.64%, TSS at 21%, and a stone weight of 41 g. The stone's dimensions were 8.3 cm in length, 4.6 cm in breadth, and 2.3 cm in thickness. Treatment 4 (T_4) produced fruit measuring 10 cm in length, 9.3 cm in breadth, and 7.8 cm in thickness, with an edible portion of 78.84%, TSS at 20%, and a stone weighing 33.2 g. The stone size was 7.9 cm in length, 4.3 cm in breadth, and 2.2 cm in thickness.

Treatment 5 (T_5) yielded fruit dimensions of 9.2 cm in length, 9 cm in breadth, and 7.1 cm in thickness, with an edible portion of 72.25%, TSS at 21%, and a stone weight of 40 g. The stone dimensions were 7.4 cm in length, 4.2 cm in breadth, and 2.2 cm in thickness. Treatment 6 (T_6) produced fruit that was 10.3 cm in length, 10 cm in breadth, and 8.3 cm in thickness, with an edible portion of 77%, TSS at 20%, and a stone weighing 35 g, measuring 8 cm in length, 5 cm in breadth, and 2.1 cm in thickness. Finally, Treatment 7 (T_7) yielded fruit dimensions of 11.1 cm in length, 10 cm in breadth, and 8.3 cm in thickness, with an edible portion of 81%, TSS at 19%, a stone weight of 44 g, and dimensions of 8.2 cm in length, 5 cm in breadth, and 2.4 cm in thickness.

The data indicate significant variations in fruit and stone characteristics across different treatments, with Treatment 7 showing the highest edible portion percentage, while Treatment 3 displayed larger fruit size and substantial stone size. This study underscores the importance of selecting appropriate grafting and pruning techniques to optimize mango production, achieve the desired dwarf shape, and facilitate high-density planting. These insights will guide future practices in mango farming, enhancing both productivity and sustainability. The various treatments illustrate how targeted horticultural practices can manipulate plant characteristics to meet specific agricultural objectives. By analyzing these data points, growers can make informed decisions to improve yield, fruit quality, and overall tree management. This approach not only benefits the immediate crop but also contributes to long-term agricultural practices that are productive and sustainable (Rahman et al., 2021; Ahmed & Khan, 2020).

Table 2: Fruit and stone characteristics of different treatments at RHRS, Chapainawabganj during 2022-23

Treatments	Fruit size (cm)			Edible portion (%)	TSS (%)	Stone wt. (g)	Stone size(cm)		
	Length	Breadth	Thickness				Length	Breadth	Thickness
T_1	9.7b	9.7a	8bc	77.19b	(cm)20ab	33.5c	8.1abc	4.3c	2.1c
T_2	10b	9.7a	7.9cd	80.77a	21a	29.5d	7e	4.2c	2.1c
T_3	11a	9.7a	8.1b	80.64a	21a	41ab	8.3a	4.6b	2.3ab
T_4	10b	9.3a	7.8d	78.84ab	20ab	33.2c	7.9c	4.3c	2.2bc
T_5	9.2b	9a	7.1e	72.25c	21a	40b	7.4d	4.2c	2.2bc
T_6	10.3ab	10a	8.3a	77b	20ab	35c	8bc	5a	2.1c
T_7	11.1a	10a	8.3a	81a	19b	44a	8.2ab	5a	2.4a
CV (%)	4.38	2.94	0..87	2	5.02	5.46	1.88	2.86	4.55
Significant	**	**	**	**	NS	**	**	**	*

* indicates the significant level at 5%, * * indicates the significant level at 1%, NS: Non significant

3.1. Comparison of performance among all the treatments

Treatment 1 (T_1) demonstrated significant growth potential, featuring the tallest plants and the largest base girth. In contrast, Treatment 3 (T_3) exhibited the shortest plants and smallest base girth, likely due to the double grafting technique that contributed to its dwarf shape. T_1 also had the largest canopy spread and tree volume, indicating strong overall growth with minimal dwarfing. T_3, designed specifically for dwarfing, fulfilled the objective of creating a more compact tree structure with its smaller canopy dimensions and tree volume.

Additionally, T_3 recorded the highest number of branches per plant, which could enhance fruit production by promoting a denser canopy. Despite having the fewest branches, T_1 still achieved high yields, showcasing its overall effectiveness. The highest yield per plant was observed in T_1 at 11.1 kg with 30 fruits, while T_3 also showed impressive productivity with 12.32 kg from 28 fruits, indicating effective fruit production despite its smaller size.

Figure 2: Comparison of performance among the treatments

Notably, T_3 produced the largest fruits, appealing for commercial production and demonstrating the efficacy of the grafting and pruning techniques used. Furthermore, T_3 and Treatment 7 (T_7) had the highest edible portion percentages, making them attractive to consumers seeking greater fruit flesh content. Treatments 2 and 3 exhibited the highest Total Soluble Solids (TSS), suggesting potentially sweeter fruits. Overall, T_3 emerged as the most efficient approach for developing a dwarf shape while achieving high yields and large fruit sizes.

This compact tree structure is ideal for high-density planting, with the potential to accommodate 500 plants per hectare at a spacing of 4 m x 5 m. The findings emphasize the importance of selecting appropriate grafting and pruning techniques to optimize mango tree growth, yield, and quality, ultimately promoting more sustainable agricultural practices.

3.2. Plant growth and canopy development

The treatments exhibited substantial differences in plant height, base girth, canopy spread, and tree volume. Treatment 1 (T_1), which followed normal grafting, resulted in the tallest plants (4.0 m) and the largest base girth (34.5 cm). In contrast, Treatment 3 (T_3) produced the most compact trees, with a height of 2.25 m and a significantly smaller canopy spread. The reduced height in T_3 is attributed to the double grafting method at 5-inch intervals, which likely restricted excessive vegetative growth (Thamarsha et al., 2024).

The importance of tree height control in mango cultivation has been well documented. Research by Singh et al. (2017) showed that annual pruning combined with growth regulators like paclobutrazol effectively controlled tree size without negatively affecting fruit yield. Similar findings were observed in this study, where treatments involving multiple grafting techniques (T_3, T_6, and T_7) resulted in smaller tree volumes, making them ideal for intensive farming systems.

3.3. Effect on branching and yield

The number of branches per plant varied significantly across treatments, with T_3 exhibiting the highest number of branches (12.5). Increased branching is beneficial as it promotes more fruit-bearing sites, leading to higher fruit production (Rahman et al., 2021). Despite having the fewest branches, T_1 achieved a high yield (11.1 kg per plant), suggesting that overall vegetative vigor can compensate for fewer branches in fruit production.

Treatment 3 also demonstrated a remarkable yield (12.32 kg per plant), despite its compact structure. This aligns with findings from Hasan and Chowdhury (2020), who reported that controlled pruning and grafting techniques can improve yield efficiency by optimizing resource allocation. The results indicate that careful selection of grafting techniques can maximize fruit production without requiring large tree canopies, supporting previous research on high-density planting systems (Jones & Brown, 2019).

3.4. Fruit quality and edible portion

Significant variations were also observed in fruit size, weight, and edible portion across treatments. Treatment 3 (T_3) produced the largest fruits (440.2 g) with a high edible portion (80.64%), making it attractive for commercial production. This aligns with the study by Beshir et al. (2019), which reported that certain grafting methods can enhance fruit quality by improving nutrient uptake efficiency.

Additionally, T_3 and Treatment 2 (T_2) had the highest Total Soluble Solids (TSS) percentage (21%), indicating sweeter fruit. These results align with Ahmed and Khan (2020), who found that strategic pruning and grafting techniques can enhance fruit sweetness by regulating carbohydrate partitioning in mango trees.

3.5. Implications for high-density planting

The findings highlight the potential for high-density mango cultivation using dwarf trees. The compact canopy structure observed in T_3 and T_7 allows for a planting density of up to 500 trees per hectare, maximizing land use efficiency. This is consistent with previous studies suggesting that controlled pruning and grafting methods can improve orchard productivity (Rahman et al., 2021).

Moreover, the ability to maintain smaller trees simplifies harvesting and management, reducing labor costs and improving fruit quality consistency. This approach has been successfully implemented in other high-value fruit crops, such as apples and citrus, where controlled tree size contributes to sustainable production systems (Smith et al., 2020).

4. Conclusion

This study highlights the significant impact of various grafting and pruning techniques on the growth and fruit production of the BARI-released mango variety. The findings demonstrate that double grafting at 5-inch intervals (T_3) is the most effective method for achieving a dwarf tree structure while maintaining high yields and superior fruit quality. T_3 exhibited the shortest plant height, the highest number of branches, and the largest fruit size, making it an ideal candidate for high-density planting. Additionally, T_3 and T_7 had the highest edible portion percentages, while T_2 and T_3 exhibited the highest Total Soluble Solids (TSS), indicating sweeter fruits.

Overall, the study confirms that specific grafting and pruning techniques can effectively manipulate mango tree architecture while maintaining high yields and superior fruit quality. The results suggest that double grafting at 5-inch intervals (T3) is the most effective strategy for developing compact, high-yield mango trees suitable for high-density planting. These findings provide valuable insights for mango growers looking to improve productivity through modern horticultural techniques.

Data availability

Data will be made available on request.

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