

**Article**

## **Improving Air Layering Efficiency in Mango (*Mangifera indica* L.) Using Natural Substrates**

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**Abstract:** Conventional propagation methods such as seed propagation and grafting are limited by genetic variability, long juvenile periods, and technical constraints, restricting large-scale mango production. This study evaluated air layering as an alternative propagation method using natural biostimulants (honey and cinnamon) compared with an untreated control during two seasons (March and September) on the 'Jahrawy' mango strain. Rooting percentage, number of roots, root length, and subsequent vegetative growth parameters were assessed. Results showed that honey significantly outperformed other treatments, achieving the highest rooting percentage (up to 100% in September), along with enhanced root development, stem diameter, and branching, while cinnamon showed moderate improvement. Seasonal variation was evident, with September superior to March in rooting efficiency, vegetative growth, and overall plant vigor. Notably, plantlets treated with honey exhibited early flowering within 150 days after planting, indicating a reduction in the juvenile phase. These findings demonstrate that integrating eco-friendly natural substances with air layering provides a sustainable, low-cost, and efficient approach for rapid propagation and improved performance of mango cultivars.

**Key words:** Mango; Jahrawy strain; air layering; honey; rooting; propagation.

### **1. Introduction**

Mango (*Mangifera indica* L.) is a major tropical fruit crop of high nutritional and economic value, widely cultivated in Egypt and worldwide. It exhibits considerable diversity in fruit shape and peel color, highlighting the importance of conserving its germplasm. Vegetative propagation is a preferred method, as it preserves desirable genetic traits, ensures uniformity, shortens the juvenile phase, and maintains cultivar identity (Degrande *et al.*, 2006 and Asaah *et al.*, 2012). Air layering is an efficient, low-cost vegetative propagation method, particularly suitable for woody perennials, in which the branch remains

attached to the parent plant during root formation. Its success is influenced by environmental factors such as temperature, light, and humidity (Johanson, 1957 and Tomar, 2016). Studies have shown that air layering can outperform stem cuttings by producing better-developed root systems and higher survival rates after transplanting (Oosthuysen, 1991 and Bose *et al.*, 1997). Recently, there has been increasing interest in replacing synthetic rooting hormones with natural, eco-friendly alternatives.

Several natural substances, including coconut water, willow extract, seaweed extract, honey, and Aloe vera gel etc., (Rashedy, 2022). Honey, in particular, has received attention for its biochemical profile rich in sugars, vitamins, amino acids, and polyphenols that act synergistically to stimulate root initiation. Classic work by White and Doner (1980) demonstrated its effect in various horticultural crops, and more trials that are recent confirmed its efficacy in mango and other tropical trees (Firth and Trask, 2017 and Nair *et al.*, 2018). Similarly, Aloe vera and cinnamon have shown to enhance the rooting performance of bioactive compounds. Such results emphasize that natural additives can function as sustainable substitutes for synthetic hormones, providing effective propagation outcomes without compromising environmental safety. Their role is especially relevant in the context of sustainable agriculture, where organic and low-input practices are increasingly prioritized Rajan and Singh, (2021). Combining low-cost natural extracts with air layering offers a more resilient propagation approach. In mango, natural enhancers such as Aloe vera gel and honey have shown promising effects on rooting, survival, and subsequent growth. For example, Aloe vera improved root initiation and vigor in the ‘Mallika’ cultivar, matching or exceeding synthetic hormones (Mirihaqalla and Fernando, 2020). These findings support the use of natural alternatives in propagation. Therefore, this study evaluates air layering using honey and cinnamon in the ‘Jahrawy’ mango strain and assesses subsequent plant growth to determine its potential for early fruiting and efficient propagation.

## 2. Materials and Methods

### Plant material and experimental site

The study was conducted from 2022 to 2024 in a private orchard, located in Umm Al-Rida, Kafr El-Battikh Centre, Damietta Governorate, Egypt, on the plant material in the rootstock mango Jahrawy strain (locally known as Sadar Alyamamah). Two-year-old branches with a diameter ranging from 1.5 to 3.0 cm were selected for the layering.

### Air-layering procedure

Air layering was applied by removing a bark ring approximately 4–5 cm in width from the selected branches. The exposed area was immediately covered with a handful of moistened clay and then wrapped tightly with black polyethylene film to conserve humidity, and both ends were secured with stainless steel wire. Root initiation was assessed 30–40 days after layering. Layers were separated from the mother plant 60 days after treatment, planted in pre-prepared soil, and monitored for survival and establishment. Rooting and early seedling performance were evaluated according to the methodology described by Mergen (1953) and Tomar (2016).

### Experimental design and treatments

Air layering was evaluated using three treatments: (i) honey derived from citrus flowers, (ii) cinnamon paste at 10% concentration, and (iii) a control without additives. Air layering was performed twice annually in March (spring) and September (autumn) following Everett (n.d.), using clay soil as the rooting medium and polyethylene wrapping. After separation and transplanting, plantlets were assessed at 2, 6, and 12 months for growth performance. The chemical composition of honey used in this study was consistent with the values reported by Ball (2007), cited in Massoud *et al.* (2017). It typically contains 18% water, 31% fructose, and 43% glucose. The vitamin content, 0.52% for vitamin C, 0.1% for vitamin B1, 0.12% for vitamin B2, 0.2% for vitamin B3, 0.1% for vitamin B4, and 0.5% for vitamin B6. In addition, honey contains organic acids and various flavonoids.

## Soil and water analysis

Soil samples from the farm, irrigation water, and saturated soil paste used in layering were chemically analyzed at the laboratories of the Soil and Water Research Institute. Table 1 summarizes the chemical properties of the soil, irrigation water, and soil paste extract.

**Table (1). Chemical properties of soil, irrigation water, and saturated soil paste used in the layering experiment**

Chemical analysis		Soil components	Irrigation water	Saturated soil paste
PH		8.2	8.4	7.8
E.C		0.25 (ms/cm)	1523.2 (PPm)	3.54 (ds/m)
CaCO <sub>3</sub> (%)		0.07	---	---
Cations (+) (Meq/L)	Ca <sup>+2</sup>	2.1	3.2	12.12
	Mg <sup>+2</sup>	0.3	3.9	2.16
	Na <sup>+</sup>	0.43	14	17.83
	K <sup>+</sup>	0.30	0.32	0.44
Anions (-) (Meq/L)	HCO <sub>3</sub> <sup>-</sup>	0.39	2.3	3.30
	Cl <sup>-</sup>	1	12.2	16.95
	So <sub>4</sub>	1.95	5.71	12.30
Macroelements (mg/kg)	N	35	---	40.0
	P	22	---	10.22
	K	154	---	176
Microelements (mg/kg)	Fe	3	---	10.27
	Cu	0.6	---	0.04
	Zn	0.7	---	0.33
	Mn	1.5	---	1.26
S.A.R		---	9.73	---
R.S.C		---	4 -	---
S.S.P (%)		---	71.8	65

## Measurements recorded

After separation, seedlings were evaluated for rooting success percentage, average number of roots, and root length. Growth assessment continued after transplanting: number of new buds and length after two months; number of leaves and length after six months; and number and length of branches and main stem diameter after twelve months.

## Statistical analysis

All data were subjected to analysis of variance (ANOVA) following the procedures outlined by **Steel *et al.* (1997)**. Treatment means were compared using the least significant difference (LSD) test. Multivariate analysis, including principal component analysis (PCA), was performed using the software WEB AGRL STAT PA (WASP 1), following the approach of **Tang *et al.* (2023)**.

## 3. Results and Discussion

### Evaluation after 60 days of air layering

Seedling measurements after separation from the mother plant, including rooting percentage, number of roots, and root length (Table 2), showed that natural materials significantly improved rooting

performance. Honey gave the highest rooting percentages (80% and 70% in the two seasons), followed by cinnamon paste, while the control recorded the lowest values (20% and 18%). Seasonal effects were evident, with September outperforming March; the highest rooting percentage (100% and 80%) was obtained in September under honey treatment. A similar trend was observed for root number, where honey produced the highest values, followed by cinnamon, whereas the control showed the lowest performance. Root length did not differ significantly among treatments, although honey showed a tendency to increase root length (6.9 and 6.3 cm) compared with the control (1.7 cm in both seasons). Seasonal effects were evident, with September producing longer roots (7.53 and 6.33 cm) than March. The interaction effect showed the maximum root length (10.6 and 9.8 cm) under honey treatment in September, while the minimum values (1.2 and 1.4 cm) were recorded in March without natural materials. Rooting responses 60 days after air layering in ‘Jahrawy’ mango (Fig. 1) indicated that natural materials markedly improved rooting traits compared with the control, while September consistently outperformed March, confirming the role of both biostimulants and seasonal timing in enhancing early root formation and development.

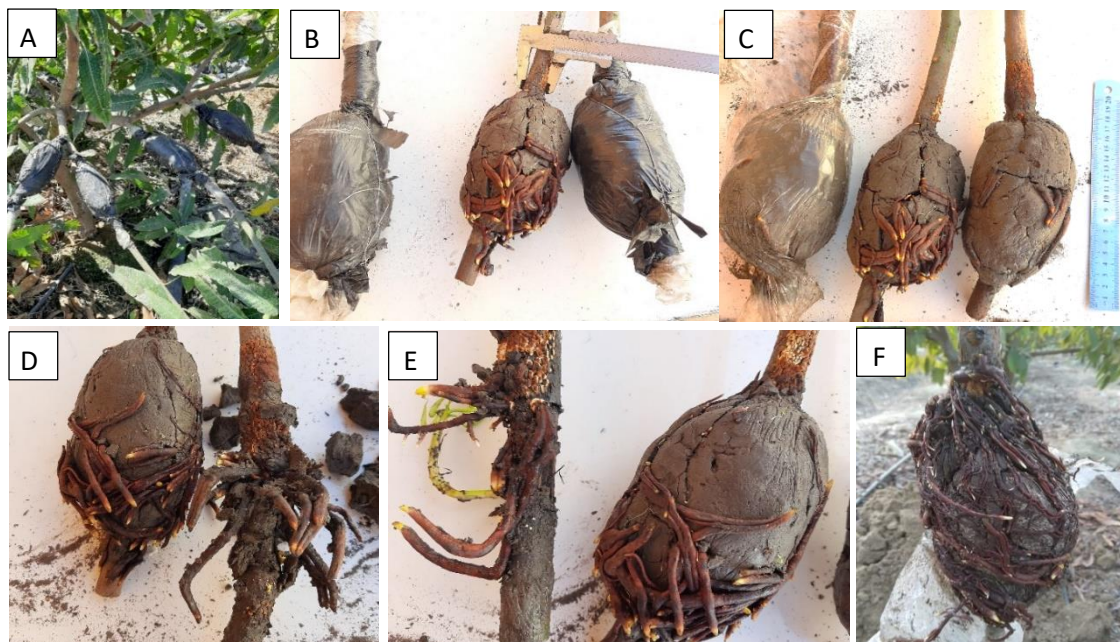
**Table (2). Percentage of rooting ability, the Average number and the length of roots of seedlings after separation from the mother plant during two seasons**

A. Time air-layering B. Materials	1 <sup>st</sup> (2022)			2 <sup>nd</sup> (2023)		
	March	Sept.	Mean B	March	Sept.	Mean B
<b>Percentage of rooting ability (%)</b>						
Without(control)	20 <sup>d</sup>	20 <sup>d</sup>	20 <sup>C</sup>	18 <sup>d</sup>	22 <sup>d</sup>	20 <sup>C</sup>
Natural honey	60 <sup>c</sup>	100 <sup>a</sup>	80 <sup>A</sup>	60 <sup>b</sup>	80 <sup>a</sup>	70 <sup>A</sup>
Cinnamon paste	60 <sup>c</sup>	80 <sup>b</sup>	70 <sup>B</sup>	40 <sup>c</sup>	60 <sup>b</sup>	50 <sup>B</sup>
Mean A	46.6 <sup>B</sup>	66.6 <sup>A</sup>		39.3 <sup>B</sup>	54.0 <sup>A</sup>	
<b>Average number of roots (No.)</b>						
Without(control)	1.2 <sup>d</sup>	1.4 <sup>d</sup>	1.3 <sup>C</sup>	1.0 <sup>c</sup>	1.8 <sup>c</sup>	1.4 <sup>C</sup>
Natural honey	3.4 <sup>c</sup>	13.8 <sup>a</sup>	8.6 <sup>A</sup>	3.0 <sup>bc</sup>	10.8 <sup>a</sup>	6.9 <sup>A</sup>
Cinnamon paste	3.0 <sup>c</sup>	7.8 <sup>b</sup>	5.4 <sup>B</sup>	1.4 <sup>c</sup>	7.0 <sup>ab</sup>	4.2 <sup>B</sup>
Mean A	2.53 <sup>B</sup>	7.66 <sup>A</sup>		1.80 <sup>B</sup>	6.53 <sup>A</sup>	
<b>Average length of roots (cm)</b>						
Without(control)	1.2 <sup>b</sup>	2.2 <sup>b</sup>	1.7 <sup>B</sup>	1.4 <sup>b</sup>	2.0 <sup>b</sup>	1.7 <sup>B</sup>
Natural honey	3.2 <sup>b</sup>	10.6 <sup>a</sup>	6.9 <sup>A</sup>	2.8 <sup>b</sup>	9.8 <sup>a</sup>	6.3 <sup>A</sup>
Cinnamon paste	2.8 <sup>b</sup>	9.8 <sup>a</sup>	6.3 <sup>A</sup>	1.6 <sup>b</sup>	7.2 <sup>a</sup>	4.4 <sup>AB</sup>
Mean A	2.40 <sup>B</sup>	7.53 <sup>A</sup>		1.93 <sup>B</sup>	6.33 <sup>A</sup>	

Means with the same letters in the 2022 or 2023 seasons, are insignificantly different at  $p \leq 0.05$ .

The superior performance of honey is consistent with evidence that natural substances can enhance rooting in vegetative propagation. Honey has been reported to improve root number and quality in several species, likely due to its carbohydrate content and antimicrobial properties that protect wounded tissues during callus formation and root initiation (Bowden *et al.*, 2025; Firth and Trask, 2017). Similar effects have been observed with other natural extracts such as Aloe vera, which enhanced rooting in different fruit species compared with synthetic growth regulators (Mirihagalla and Fernando, 2020; Kumarasinghe *et al.*, 2024), supporting the growing use of plant-based biostimulants as sustainable alternatives to auxins (Cardarelli *et al.*, 2024). Seasonal variation also played a key role,

with September outperforming March, likely due to favorable temperature and humidity conditions that promote callusing and root initiation, as reported in guava and other woody species (Singh *et al.*, 2019; Tomar, 2016). In contrast, root length showed limited differences among treatments, suggesting that biostimulants mainly enhance root initiation rather than elongation, which is more dependent on endogenous hormones and environmental conditions (Guan *et al.*, 2019; Hartmann *et al.*, 2011).



**Fig. (1).** Stages of mango air layering and root development. (A) Air layers wrapped on branches in the field. (B–C) Root initiation and development inside the soil–plastic wrapping. (D–E) Adventitious roots emerging after removing the wrapping, showing callus and new root growth. (F) Well-developed root system covering the layered portion, ready for separation and transplanting.

### Evaluation of seedling growth

Estimate the number of new buds after two months of planting in permanent soil. Table 3 showed that the highest growth rate for new buds was for seedlings produced by layering in March, at 3.86 and 3.10 in both seasons, respectively. Meanwhile, the honey treatment recorded the highest growth in both seasons, at 4.2 and 4.1, respectively. The honey layering treatment during March also recorded the highest number of new bud growths, at 4.4 and 4.6 in both seasons, respectively. The results indicated that the number of new buds was influenced by both the season of layering and the use of natural materials. March layering generally resulted in a higher bud initiation rate compared to September, suggesting that early-season conditions may provide a favourable balance of temperature and carbohydrate accumulation conducive to bud break (Tomar, 2016).

The honey treatment produced the most buds in both seasons, demonstrating the efficacy of natural materials by enhancing soil fertility and structure, as well as by affecting root architecture and nutrient uptake. According to Trevisan *et al.* (2010), organic material, mainly widespread in nature, benefits plant physiology. This finding aligns with previous reports highlighting the stimulatory effect of honey on bud sprouting due to its sugars, vitamins, and phenolic compounds (White and Doner, 1980; Nair *et al.*, 2018 and Dunsin *et al.*, 2014).

**Table (3). Evaluation of seedling growth by estimating the number of new buds (No.) after two months**

A. Time air-layering B. Materials	1 <sup>st</sup> (2022)			2 <sup>nd</sup> (2023)		
	March	Sept.	Mean B	March	Sept.	Mean B
<b>Number of new buds after two months</b>						
Without(control)	3.2 <sup>ab</sup>	2.6 <sup>b</sup>	2.9	1.5 <sup>d</sup>	2.3 <sup>cd</sup>	1.9
Natural honey	4.4 <sup>a</sup>	4.0 <sup>a</sup>	4.2	4.6 <sup>a</sup>	3.6 <sup>b</sup>	4.1
Cinnamon paste	4.0 <sup>a</sup>	3.2 <sup>ab</sup>	3.6	3.2 <sup>bc</sup>	3.2 <sup>bc</sup>	3.2
Mean A	3.86	3.26		3.10	3.03	

Means with the same letters in the 2022 or 2023 seasons, are insignificantly different at  $p \leq 0.05$ .



**Fig. (2). Growth of new buds after two months.**

Furthermore, the interaction between factors showed that honey applied in March yielded the maximum number of new shoots. Similar observations have been reported in other fruit crops where honey or organic extracts enhanced shoot proliferation, confirming its potential as an eco-friendly alternative to synthetic hormones (Mirihagalla and Fernando, 2020 and Rashedy, 2022). Overall, these results emphasise that combining optimal timing (March) with natural bio-stimulants such as honey can maximise early shoot growth and improve the vigour of propagated mango seedlings.

#### **Observing the progress of plantlets growth**

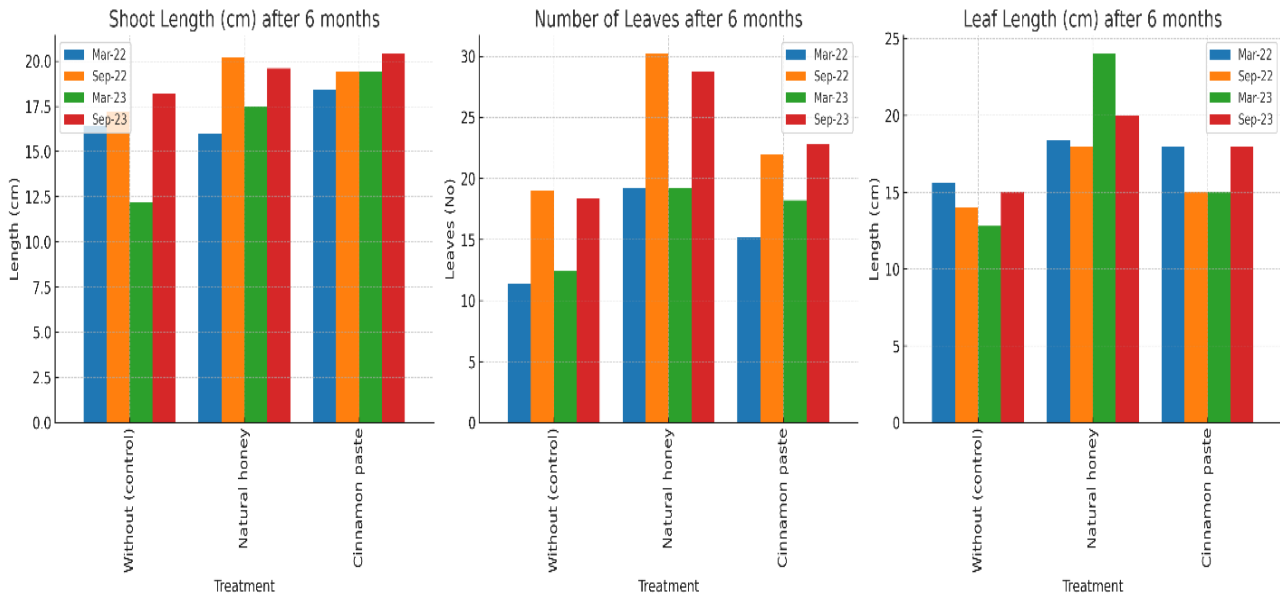
The data in Figure 3 illustrates the measurements of plantlet growth. Monitoring the progress of plantlets' growth after six months revealed clear differences between air layering times (March vs. September) and applied natural materials (honey, cinnamon paste, and control).

**Shoot length:** The highest values were consistently observed in September layering across both seasons (18.93 and 19.40 cm). Among the treatments, cinnamon paste recorded the longest shoots (18.9 and 19.9 cm), while the maximum individual values reached 20.2 cm (honey, September 2022) and 20.4 cm (cinnamon paste, September 2023). The lowest shoot lengths were recorded under control in March (16.4 and 12.2 cm).

**Number of leaves:** The results showed that September layering enhanced leaf production (23.73 and 23.33 leaves in both seasons). Honey treatment produced the highest leaf numbers (24.7 and 24.0 leaves), with September layering combined with honey showing peak values of 30.2 and 28.3 leaves across seasons.

**Leaf length:** The average leaf length varied with season and treatment. The overall means were 17.3 cm (March 2022) and 18.6 cm (September 2023). Honey treatment promoted longer leaves (18.2 and 22.0 cm), and the longest individual leaves were recorded under March layering with honey (18.4 cm in 2022 and 24.0 cm in 2023).

Natural treatments, particularly honey and cinnamon paste, enhanced growth compared to the control. Honey acted as a natural source of sugars and antimicrobial agents, which not only improved rooting but also provided energy for subsequent shoot and leaf development. Similarly, cinnamon paste, known for its antioxidant and growth-promoting compounds, improved vegetative growth traits, especially shoot length.

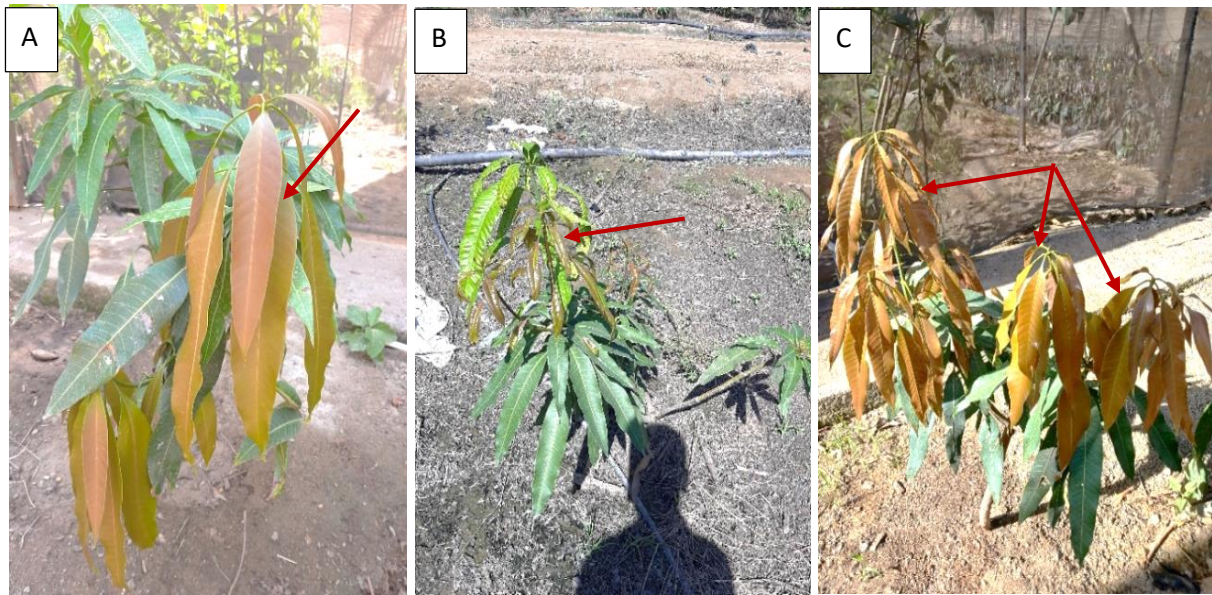


**Fig. (3).** PCA biplot illustrating the relationships among treatments (control, natural honey, cinnamon paste) and growth traits (shoot length, number of leaves, and leaf length) after six months.

In Figure 3, the treatments according to their effect on vegetative growth parameters. Natural honey treatment clustered in close association with higher shoot length and number of leaves, indicating its strong positive effect. Cinnamon paste showed intermediate positioning, with moderate contribution to leaf number and shoot length, whereas the control group was located opposite to these traits, reflecting its relatively poor performance.

The present PCA analysis provides an integrated visualization of growth responses under different air-layering treatments. The projection of traits and treatments on the same biplot highlights the consistency of natural honey in enhancing both shoot elongation and leaf production, which corroborates its superior performance. According to **Bose *et al.* (1986)**, the season plays a crucial role in the successful layering of woody plants since rooting on layers is facilitated by light, adequate moisture, and the right temperature; also, material natural applying in September air layering significantly boosts plantlet growth **Kumar (2012)**. Figure 4 shows the morphological changes of mango seedlings at different growth stages, the appearance of newly emerged leaves with a light brown color, leaves in the process of maturation showing a transition from light green to darker green, and multiple new growth flushes emerging in different directions.

The results indicate that both the time of air layering and the applied natural material significantly influenced seedling growth traits. September layering was superior to March across all parameters, reflecting the favorable climatic and physiological conditions during late summer and early autumn. This may be attributed to enhanced carbohydrate accumulation and more active hormonal balance (auxins and cytokinins) during this period, which support vigorous shoot elongation and leaf formation.



**Fig. (4). Morphological changes of mango seedlings at different growth stages. (A) Appearance of newly emerged leaves with light brown color, (B) Leaves in the process of maturation showing transition from light green to darker green, (C) Multiple new growth flushes emerging in different directions.**

Interestingly, cinnamon paste, while not as effective as honey, still demonstrated a positive association with vegetative growth traits, possibly due to its antifungal properties and secondary metabolites that improve plant defense and metabolic activity. These results suggest that cinnamon may serve as a supportive natural treatment, although not consistently superior. On the other hand, the control treatment was positioned away from the growth traits in the PCA plot, confirming its limited ability to promote vigorous shoot or leaf development. Overall, the PCA results highlight the potential of natural honey as a simple, effective, and eco-friendly material for improving vegetative propagation in tree crops. Further validation across different species and environments would strengthen the recommendation of honey-based treatments as a sustainable alternative to synthetic growth regulators.

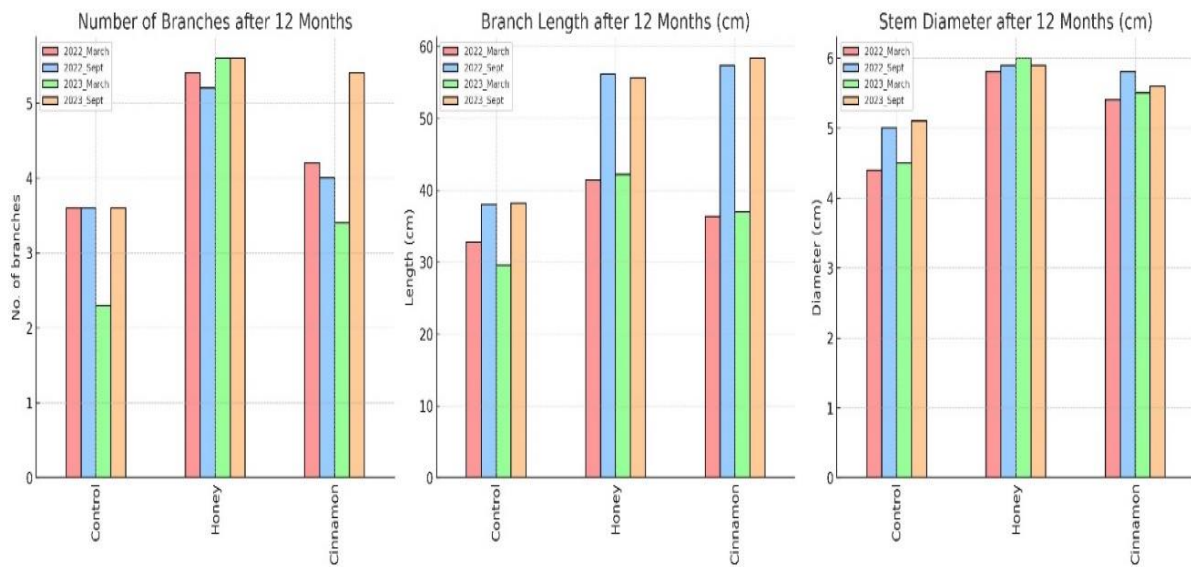
#### **Monitoring the quality of trees**

Figure 5 illustrates the following: quality, measured by the number and length of branches and the diameter of the main stem, after one year of planting.

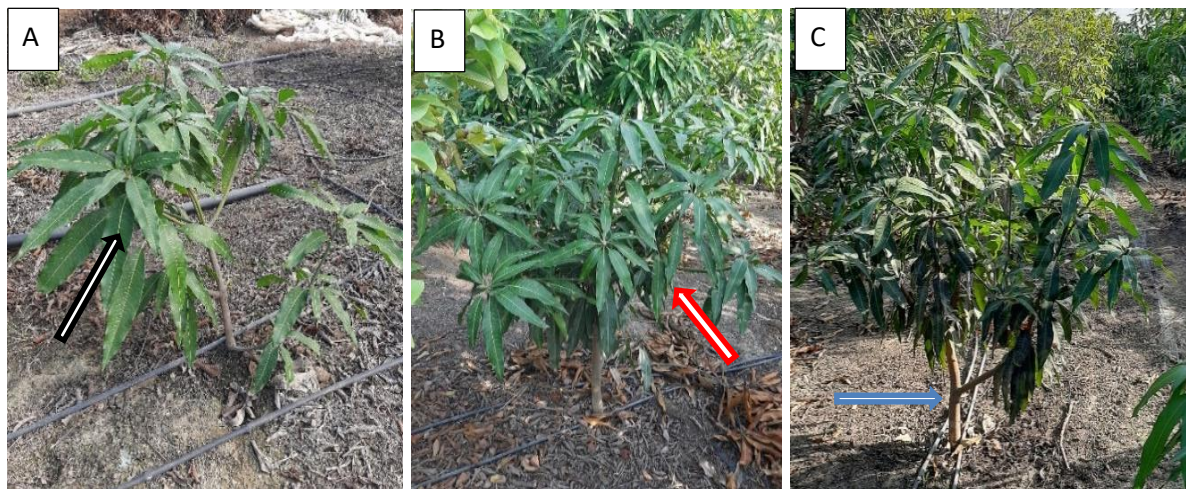
**Number of branches after 12 months of planting:** There were no significant differences in the plantlets resulting from air layering dates in the two seasons, while the difference was significant for the natural materials used in the layering process. The results showed that natural honey treatment produced the highest number of branches in both seasons, reaching 5.6 branches in September 2023. On the other hand, the control recorded the lowest values, particularly 2.3 branches in March 2023. This indicates that honey significantly enhanced branching compared to untreated plants.

**Branch length (cm):** Both honey and cinnamon paste treatments achieved the longest branches, especially in September 2022 (57.4 cm with cinnamon). In contrast, the control treatment showed the shortest branches (29.6 cm in March 2023). These findings emphasize the positive role of natural treatments in promoting branch elongation.

**Stem diameter (cm):** The greatest stem diameter was obtained with honey treatment (6.0 cm in March 2023), whereas the lowest value was observed in the control (4.4 cm in March 2022). This demonstrates that honey treatment improved stem vigor and thickness more effectively than the other treatments.



**Fig. (5).** PCA biplot illustrating the relationships among treatments (control, natural honey, cinnamon paste) and growth traits (shoot length, number of leaves, and leaf length) after six months.



**Fig. (6).** Morphological changes of mango seedlings at different growth stages. (A) Appearance of newly emerged leaves with light brown color, (B) leaves in the process of maturation showing transition from light green to darker green, (C) multiple new growth flushes emerging in different directions.

Overall, the statistical results (Fig. 5) highlight that natural honey and cinnamon paste treatments consistently outperform the control, resulting in higher branching, longer branches, and thicker stems (Fig. 6). These outcomes underline the effectiveness of natural bio-stimulants in enhancing tree growth.

The present results indicate that plantlets produced by September air-layering exhibited superior vegetative performance after 12 months- recording the longest branches and the largest main stem diameter- relative to March. This seasonal advantage is consistent with studies showing that warm and humid periods favor rooting and subsequent establishment of air-layers in tropical fruit trees. For instance, rainy-season (July–August) layering increased rooting percentage and root development in

*Spondias pinnata* Tomar (2016) and water apple (*Syzygium* spp.) Ghosh (2008) also, found that, in terms of survivability and rooting effectiveness, August was the ideal month for air layering litchi. The findings are also consistent with those of Kumar (2000) in the case of litchi, Tomar (2011) in the case of jackfruit. Although the exact calendar window varies by climate, the alignment of September in Egypt with the late-summer/early-autumn warm period provides a plausible explanation for the observed advantage. Moreover, cultivar-dependent responses in mango air layering have been documented (UF/IFAS, 2023), reinforcing that optimized timing can compensate for inherent variability across genotypes.

Concerning additives, natural white bee honey significantly increased the number of branches and the main stem diameter, while branch length did not differ among materials. The stimulatory effect of honey on propagation is supported by both mechanistic and applied studies: honey's sugars, amino acids, vitamins, and polyphenols can support carbohydrate supply and provide antimicrobial protection at the wound site, improving survival and early rooting compared with untreated controls (White and Doner, 1980; Firth and Trask, 2017 and Bowden *et al.*, 2025). However, literature often reports stronger effects on rooting percentage and survival than on later shoot elongation, which may explain the absence of significant differences in branch length at 12 months in the present study. Regarding cinnamon paste, phenolic-rich extracts (notably trans-cinnamaldehyde) can modulate root architecture and exert antimicrobial activity (Hamidpour *et al.*, 2015 and Kowalska *et al.*, 2021). On the other hand, for other reasons, as noted by López-González *et al.*, (2023), low levels of trans-cinnamaldehyde are linked to elevated gene expression of the enzyme aldehyde dehydrogenase, which can facilitate the conversion of trans-cinnamaldehyde to cinnamic acid, thereby causing adventitious roots.

Taken together, the data agree with the broader literature that season (warm humid window) is a primary driver of air-layer success and downstream vigor, while natural additives, particularly honey, can improve establishment quality metrics (branch number, stem thickening) without necessarily altering elongation at one year. These outcomes are also compatible with reports that mango air-layering responses vary across cultivars and techniques (e.g., plastic wrapping, auxin carriers), which can mediate the magnitude of gains (Oosthuysen, 1991 and UF/IFAS, 2023). The present results thus contribute field-based evidence supporting eco-friendly substitutes for synthetic regulators in mango propagation, with practical emphasis on aligning layering with late-summer conditions and prioritizing honey where increased branching and stem robustness are desired.

### **Early Flowering Observation**

Figure 7 illustrates the initiation of flower buds 150 days after planting. Notably, the mother mango tree naturally begins its flowering stage in mid-April, and the observation of flower bud emergence in the propagated plantlets indicates that air layering successfully shortened the juvenile phase. This finding highlights the efficiency of air layering in overcoming the long production cycle of mango, which, under conventional propagation methods such as seedling growth and grafting, may require several years before reaching the reproductive stage (Awotedu *et al.*, 2021 and Asaah *et al.*, 2012). Similar outcomes were reported in other tropical fruit species where vegetative propagation methods significantly reduced the time to flowering compared to traditional techniques Mirihagalla and Fernando (2020).



**Fig. (7).** Effloresce in mango seedlings (flower buds) after 150 days of planting.

#### 4. Conclusion

Air layering using natural materials such as honey and cinnamon proved to be an effective method for mango propagation, with honey showing superior performance in rooting, root number, and shoot growth. Seasonal effects were evident, with September providing the best results in rooting and vegetative growth compared with March. Honey-based air layering in September represents a sustainable and environmentally friendly approach that ensures genetic stability, enhances early flowering, and improves orchard establishment. Overall, honey significantly enhanced early rooting success compared with the control, while September was identified as the optimal propagation period. Further studies are recommended to compare these natural substances with synthetic hormones and to evaluate long-term field performance.

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