



RESEARCH ARTICLE

# Effect of growing media combined with biofertilizers on growth and survival of air-layered water apple (*Syzygium samarangense* L.)

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## Abstract

The present study was conducted to evaluate the influence of various biofertilizer-enriched potting media on the survival and growth performance of air-layered saplings of water apple (*Syzygium samarangense* L.) under tropical conditions. Mature shoots from 2-year old trees at the Karunya Institute of Technology and Sciences (KITS), Coimbatore, were air-layered using IBA at 2000, 3000 and 4000 mg L<sup>-1</sup> concentrations, with sphagnum moss and cocopeat as rooting media during August to October, 2022. Successfully rooted layers were transplanted into 7 different potting mixtures consisting of soil, sand and farmyard manure (FYM) (1:1:1) either alone (control) or amended with various biofertilizers including *Trichoderma viride*, vermiwash (1 %), humic acid, *Azospirillum brasilense*, plant growth-promoting rhizobacteria (PGPR) and vesicular-arbuscular mycorrhiza (VAM). The study was conducted using a randomized complete block design (RCBD) comprising 3 replications. Plant height, leaf number, shoot number, root parameters and survival percentage were observed at 30, 60 and 90 days after potting (DAP). Results revealed that potting media enriched with vermiwash - 1 % (T<sub>3</sub>) significantly outperformed other treatments, showing the highest survival rate (100 %) and superior root attributes, including root length (21.80 cm), primary roots number (43.35), secondary roots number (89.17) and primary root diameter (3.50 mm) at 90 DAP. The study concludes that the integration of vermiwash with a soil, sand and FYM base enhances the survivability and root development of water apple air layers, offering a promising technique for efficient propagation under tropical nursery conditions.

**Keywords:** air layer; biofertilizers; growing media; survivability; wax apple

## Introduction

The water apple (*Syzygium samarangense* L.) is a tropical fruit crop that comes under the family *Myrtaceae* and is native to Philippines, Indonesia and Malaysia. It is naturally distributed from southern India to eastern Malaysia and is commonly cultivated in India, Southeast Asia, Indonesia, Hawaii and Trinidad (1). In India, it is specifically grown in Andhra Pradesh, Kerala and the Western Ghats. This fruit thrives in a tropical climate, preferring warm and humid conditions. It is well-suited for cultivation in heavy and fertile soils but is sensitive to frost. Propagation of water apple occurs through both sexual and asexual ways, with air layering being the commonly used method (2). However, the success of air layering can vary, as there are challenges such as high mortality rates of layers after separation from the mother plant and the establishment of the root system in the nursery (3).

Air layering of water apple trees is usually carried out during the rainy season, specifically in July and August and tends to yield more successful results due to increased rooting potential.

The success of rooting is based on factors such as the specific cultivar, location, season and the age of the branch being utilized. The percentage of successful rooting in water apple layers is influenced by various factors, including the overall health of the mother plant, the specific portion of the tree from which air layers are taken, the timing of the operation, the choice of media, levels of rainfall, temperature fluctuations and post-air layering care, among others (3).

Moreover, the survival and development of air layers in water apple trees are significantly affected by various environmental conditions and the choice of growing media. The selection of rooting media stands out as a crucial factor influencing the success of root formation and overall plant survival. Various media options, such as soil, sand, vermiculite, farmyard manure (FYM), vermicompost, etc., plays a pivotal role in the rooting and cutting success (3). Certain media types exhibit a higher capacity to retain moisture while remaining lightweight, thereby promoting better root development. Consequently, air layers demonstrate superior results when exposed to different media types.

Studies have reported enhanced shoot and root growth in cuttings of pomegranate (4), air layers of litchi (5), air layers of pomegranate (6) and stem cuttings of dragon fruit (7, 8) using diverse combinations of media. After detachment of air layers, newly planted trees often face challenges in acquiring sufficient nutrients from the growing media. In such scenarios, the use of biofertilizers becomes crucial as they facilitate the easy availability of nutrients for the newly planted air-layered plants by enhancing nutrient solubility.

Biofertilizers enriched with beneficial bacteria and fungi enhance soil biological activity, increase phosphate solubilization and ultimately improve crop productivity (9). Certain bacteria play a significant role in providing growth-promoting substances and aiding in phosphate solubilization (10). Therefore, finding the optimal combination of biofertilizers and growing media that can stimulate the growth and survival of water apple air layers is of great interest. Previous studies on litchi air layering (11) and guava (12, 13) have reported encouraging results, highlighting the significant influence of biofertilizers and growing media on the survival of air-layered propagules. Considering their crucial role, the present study was undertaken to evaluate the impact of different biofertilizers and growing media combinations on the survivability of air layers in wood apple.

## Materials and Methods

The mature shoots used for air layering in the present study were selected from mini orchard maintained at North farm, School of Agricultural Sciences, Karunya Institute of Technology and Sciences (KITS), Coimbatore. In the mother block, 2-year old plants established at a spacing of 5 × 5 m were pruned back in March 2022. After approximately 4–5 months, the regenerated shoots

reached a suitable developmental stage for subsequent layering procedures. Such shoots are known to behave as mature shoots physiologically. The air layering was done in 3 months i.e., August, September and October with 3 different concentrations of IBA i.e., 2000 mg L<sup>-1</sup>, 3000 mg L<sup>-1</sup> and 4000 mg L<sup>-1</sup> with 2 different rooting media i.e., cocopeat and sphagnum moss. 30 g of dried cocopeat and 25 g of dried sphagnum moss per layer was used (after soaking & squeezing: ≈ one small compact handful). Six layers were prepared for each treatment combination which was replicated 3 times. A total of 9 plants were selected; trees are divided into 3 equal parts to carry out the research in 3 different months. Each tree represented one replication and within each tree 5 shoots were randomly selected per treatment. A total of 6 treatments were applied, resulting in 30 shoots per tree. The same experimental procedure was followed for the remaining 2 trees to obtain 3 replications for the air layering study. Graphical representation of the steps followed in air layering of water apple are given in Fig. 1. The mean monthly meteorological data is given in Table 1.

The successful air layers from the above were taken for this study. The experiment was laid out in a randomized complete block design (RCBD) with 7 potting media combinations. Ten rooted air layers were used for each treatment combination which was replicated 3 times.

### Treatments details

The treatment details, combinations and their notations are given in the Table 2.

### Potting media

For all the treatments, different potting media were used and it was prepared with 1:1:1 proportion of soil, sand and FYM, which is denoted by notation A in the Table 2.

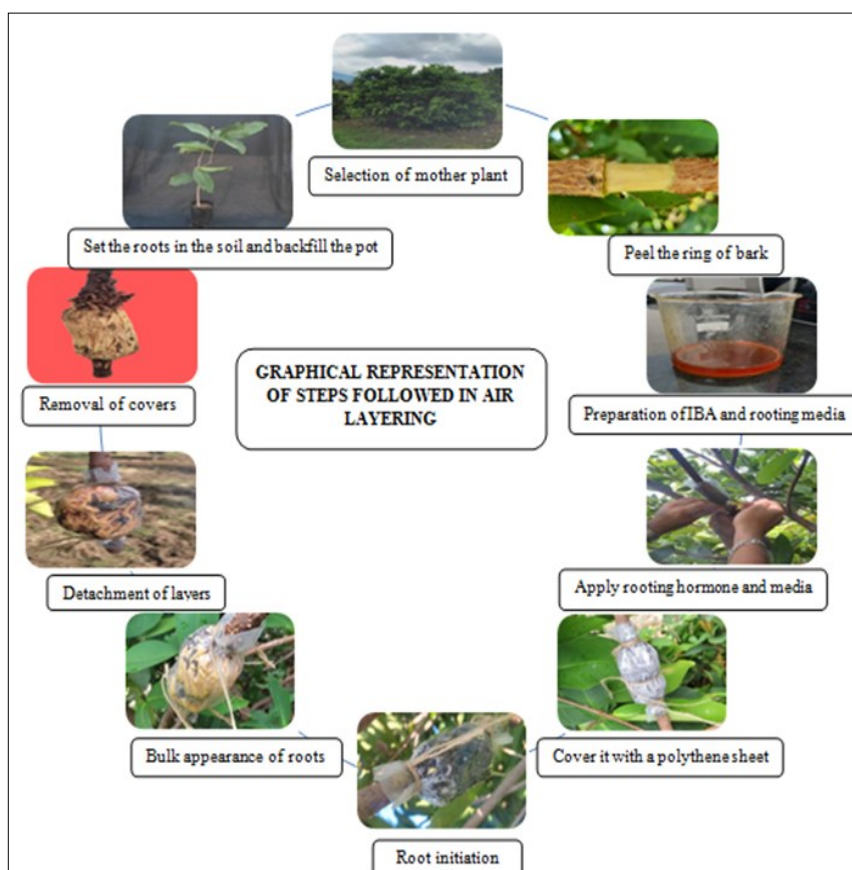


Fig. 1. Graphical representation of steps followed in air layering of water apple.

**Table 1.** Mean monthly meteorological data for the Year 2022–2023 at North farm, Karunya Institute of Technology and Sciences (KITS), Coimbatore

Year	Month	Max. T (°C)	Min. T (°C)	RF (mm)	Rainy Day (No.)	RH (%)	Avg. Pre. (mm)	Avg. Evp. (mm)
2022	August	26.98	20.79	363.0	18.0	88.80	18.95	4.47
	September	27.29	20.49	52.75	4.0	89.71	5.04	8.39
	October	27.25	20.26	113.75	11.0	87.22	11.60	7.00
	November	26.12	19.65	109.75	15.0	89.06	13.69	4.07
	December	26.34	18.47	90.75	11.0	86.58	2.92	3.55
2023	January	26.81	15.56	46.25	2.0	78.45	0.86	8.82
	February	30.60	14.80	1.75	1.0	64.00	0.20	8.40

Max. T- Maximum temperature; Min. T- Minimum temperature; RF- Rainfall; RH- Relative humidity; Avg. Pre.- Average precipitation; Avg. Evp.- Average evaporation.

**Table 2.** Details of the treatment combinations and their notations

Sl. No.	Treatments details	Notation
1.	A - control	T <sub>1</sub>
2.	A with Trichoderma - <i>Trichoderma viride</i>	T <sub>2</sub>
3.	A with vermiwash-1 %	T <sub>3</sub>
4.	A with humic acid	T <sub>4</sub>
5.	A with Azospirillum- <i>Azospirillum brasilense</i>	T <sub>5</sub>
6.	A with VAM-vesicular-arbuscular mycorrhiza	T <sub>6</sub>
7.	A with PGPR - plant growth promoting rhizobacteria	T <sub>7</sub>

#### Application of *Trichoderma viride*

*Trichoderma viride* (3 g) was taken and dissolved in 1 L of distilled water and then applied as a growing media by using the method of soil drenching immediately after potting (14).

#### Application of vermiwash

Vermiwash liquid (10 mL) was mixed with 1 L of distilled water and applied in the soil surface as soil drenching immediately after potting (15).

#### Application of humic acid

Humic acid powder (20 g) was taken and dissolved in 1 L of distilled water and applied to the growing medium by soil drenching immediately after potting (16).

#### Application of *Azospirillum*

*Azospirillum* (2 g per 1 kg soil) was mixed with the media and air layered saplings were planted in it at the time of potting (17).

#### Application of VAM (Vesicular-arbuscular mycorrhiza)

VAM (100 g) was taken and applied in the surface of each air layered saplings immediately after potting (18).

#### Application of PGPR (plant growth promoting rhizobacteria)

Plant growth promoting rhizobacteria (PGPR) (10 g) was applied in each polybag of air layered saplings immediately after potting (19).

#### Survival percentage of transplanted air-layers to potting media and establishment study

After detaching the layers from mother plant, the layers were defoliated retaining the petioles intact and carefully transplanted into polythene bags (12 × 15 cm) filled with different potting mixtures. These bagged layers were allowed to grow inside shade net and watered daily. The observations of plant height (cm), leaves per layer (No.), average length of roots (cm), shoots per layer (No.), primary roots (No.), secondary roots (No.), primary roots diameter (mm), survival (%) of air layers were recorded at 30 days, 60 days and 90 days after potting (DAP).

#### Observations recorded

##### Plant height (cm)

Height of the plant was taken from the soil level to the base of fully established youngest leaf of the layers which was recorded at 30, 60 and 90 DAP and expressed in centimeters.

##### Leaves per layer (No.)

After transferring rooted air layers from mother plant to polythene bag, the total number of leaves emerged was recorded at 30, 60 and 90 days of transferring and mean value was calculated for 9 layers.

##### Shoots per layer (No.)

The shoot numbers per rooted air layered plant were counted and averaged.

##### Average length of roots per layer (cm)

The average root length per rooted air layered plant was measured from the root tip to the collar region in centimeter using a measuring scale and the average value was determined using 9 layers.

##### Primary roots per layer (No.)

By choosing 3 rooted air layered plants from each treatment at 30, 60 and 90 DAP, the total primary roots number was counted and the mean primary roots number was computed.

##### Secondary roots per layer (No.)

The polythene sheet and rooting medium were gently removed using forceps, ensuring that the roots were not disturbed or damaged during the process. Number of secondary roots was calculated at 30, 60 and 90 DAP and expressed in number.

##### Diameter of primary roots (mm)

Primary root diameter was recorded in millimeters (mm) using a digital Vernier caliper between the collar region and the root tip and mean value was calculated.

##### Survival of air layers (%)

Polythene bags were used for planting the air layers. Observations were taken properly with 30 days of interval up to 90 days of planting in order to check the establishment of layers in polybags. The data was applied in the formula below:

$$\text{Survival percentage} = \frac{\text{Total number of plants established}}{\text{Total number of plants layered}} \times 100$$

#### Statistical analysis of experimental data

In this study, design used for arranging all the treatments was RCBD with 3 replicates. All data were analyzed using ANOVA with the help of STAR (The statistical tool for agricultural research).

When the F-value indicated significant differences at  $p \leq 0.05$ , Fisher's protected Least Significant Difference (LSD) test was applied for mean separation.

## Results and Discussion

### Effect of different potting media on plant height, shoots, leaves and survival percentage

#### Effect of different potting media on plant height and shoots

The data indicated that the 7 potting media had no significant influence on plant height at 30 (43.06 cm), 60 (45.03 cm) and 90 DAP (46.98 cm) and number of shoots per rooted air layers at 30 (1.73), 60 (1.73) and 90 DAP (1.73). The various potting media also showed non-significant effect on number of shoots per rooted air layers. However, the number of shoots depends on the initial data, it has neither any influence nor significant difference after potting.

#### Effect of different potting media on leaves and survival percentage

The data indicated that the different potting media had significant influence on number of leaves at 30 (12.31), 60 (15.12) and 90 DAP (18.05) and survival (%) at 30 (84.13 %), 60 (74.60 %) and 90 DAP (63.49 %) of air layers. Moreover, the use of a balanced media composition, consisting of soil, sand and FYM in equal proportions, provided a suitable substrate for the development of healthy and robust roots.

However, (T<sub>3</sub>) A with vermiwash at 1 % after 90 DAP had the maximum number of leaves (21.88) in rooted air layers over the rest of the potting media. This might be due to the effect of vermiwash which is said to produce the most productive plants with an increased number of branches with higher plant dry weight, improved root growth metrics and improved physicochemical, biological and microbiological soil qualities (20). Vermiwash acts as plant tonic, because it contains plant friendly microorganisms, actinomycetes, enzymes, growth hormones and multi-nutrients (21). Comparable results were stated in cowpea (22) and gladiolus (23). Adding *Azospirillum* to a potting mixture of soil, sand and vermicompost (1:1:1) greatly increased the metrics of days to sprouting, length of sprout and number of leaves, per plant (24). High levels of organic materials may have facilitated successful germination. The findings in sapota (25) and jojoba (26), which revealed an increase in plant height of layers in media consisting of soil + FYM as one of the constituents, are consistent with these

results. The organic matters help quick growth success; layers can be propagated with a high success rate. When relative humidity approached saturation, sap flow was high and there was an abundance of oxygen, a high success rate was achieved.

Maximum survival (%) of air layers was recorded in (T<sub>3</sub>) mixture of A with vermiwash at 1 % (100.00 %) and in (T<sub>4</sub>) mixture of A with Humic acid (100.00 %) after 30 DAP. While after 60 DAP (100.00 %) and 90 DAP (100.00 %) (T<sub>3</sub>) mixture of A with vermiwash at 1 % showed more survival than others as mentioned in Table 3, 4 and 5 and Fig. 2, 3. Vermiwash being a nutrient-rich liquid extract and is known to contain various plant growth-promoting substances, such as hormones, enzymes, vitamins and beneficial microorganisms. Combination of biofertilizer and media results in reduced mortality of transplanted air layers hence increased survivability percentage. The higher survival percentage can be attributed to the media mixtures enriched with biofertilizers, providing a favorable environment for the establishment of rooted layers and accelerating nutrient availability at an early stage. This early advantage in nutrient accessibility likely contributed to the higher survivability of layers. The combination of biofertilizers and media resulted in a reduced mortality rate for transplanted air layers, thereby increasing the overall survivability percentage. Similar positive outcomes have been reported in the context of air layers of pomegranate (5) and air layers of guava (27).

### Effect of different potting media on primary and secondary roots, diameter of primary roots and length of roots

The data indicated that the different potting media had significant influence on number of primary roots after 30 (30.96), 60 (34.65) and 90 DAP (37.07); number of secondary roots after 30 (70.91), 60 (76.34) and 90 DAP (81.43); diameter of primary roots after 30 (2.63 mm), 60 (2.73 mm) and 90 DAP (2.85 mm) length of roots after 30 (13.34 cm), 60 (15.68 cm) and 90 DAP (17.83 cm).

However, the highest number of primary roots after 30 DAP (36.02), 60 DAP (40.55) and at 90 DAP (43.35); highest number of secondary roots after 30 DAP (79.47), 60 DAP (84.57) and 90 DAP (89.17); wider diameter of primary roots after 30 DAP (3.35 mm), 60 DAP (3.39 mm) and 90 DAP (3.50 mm); highest length of roots after 30 DAP (16.80 cm), 60 DAP (19.80 cm) and 90 DAP (21.80 cm) were recorded in (T<sub>3</sub>) mixture of A with vermiwash at 1 % over other potting media. Vermiwash strengthens the air layers sprouting and surviving. Vermiwash is a nutrient-rich liquid extract derived from vermicomposting, known to contain various plant growth-promoting substances, such as hormones, enzymes,

**Table 3.** Effect of different potting media on growth parameters after 30 days after planting (DAP) in water apple

S.No	Treatments	PH	LPL	LRL	SPL	PRL	SRL	DPR	SAL
1.	T <sub>1</sub>	41.46	8.86	10.25	1.78	25.36	55.83	2.19	44.44
2.	T <sub>2</sub>	41.19	16.44	12.01	2.00	27.80	68.12	2.51	66.67
3.	T <sub>3</sub>	45.24	15.87	16.80	1.67	36.02	79.47	3.35	100.00
4.	T <sub>4</sub>	43.55	9.18	12.92	1.78	30.70	72.06	2.47	100.00
5.	T <sub>5</sub>	45.09	12.19	14.09	1.23	32.66	74.37	2.64	88.89
6.	T <sub>6</sub>	42.49	13.68	15.12	2.11	33.71	76.34	2.94	88.89
7.	T <sub>7</sub>	42.39	9.97	12.23	1.56	30.47	70.20	2.31	100.00
	<b>Mean</b>	43.06	12.31	13.34	1.73	30.96	70.91	2.63	84.13
	<b>S.Em±</b>	NS	0.45	0.53	NS	0.91	2.07	0.09	6.42
	<b>CD (p = 0.05)</b>	NS	1.39	1.63	NS	2.81	6.38	0.29	19.77

\*F test at probability 0.05 level

T<sub>1</sub>- A - Control, T<sub>2</sub>- Soil, sand, FYM (1:1:1) with *Trichoderma Trichoderma viride*, T<sub>3</sub>- Soil, sand, FYM (1:1:1) with Vermiwash - 1 %, T<sub>4</sub>- Soil, sand, FYM (1:1:1) with humic acid, T<sub>5</sub>- Soil, sand, FYM (1:1:1) with *Azospirillum- Azospirillum brasilense*, T<sub>6</sub>- Soil, sand, FYM (1:1:1) with VAM - Vesicular arbuscular mycorrhiza, T<sub>7</sub>- Soil, sand, FYM (1:1:1) with PGPR - plant growth promoting rhizobacteria, PH- plant height (cm), LPL- leaves per layer (no.), LRL- length of roots per layer (cm), SPL- shoots per layer (no.), PRL- primary roots per layer (no.), SRL- secondary roots per layer (no.), DPR- diameter of primary roots (mm), SAL- survival of air layers (%).

**Table 4.** Effect of different potting media on growth parameters after 60 days after planting (DAP) in water apple

S.No	Treatments	PH	LPL	LRL	SPL	PRL	SRL	DPR	SAL
1.	T <sub>1</sub>	43.65	11.70	11.25	1.78	29.33	61.67	2.27	22.22
2.	T <sub>2</sub>	43.77	19.60	13.67	2.00	31.67	73.27	2.58	55.56
3.	T <sub>3</sub>	46.77	18.63	19.80	1.67	40.55	84.57	3.39	100.00
4.	T <sub>4</sub>	45.02	12.01	15.25	1.78	34.44	77.28	2.56	88.89
5.	T <sub>5</sub>	46.33	14.83	17.09	1.23	36.33	80.10	2.79	77.78
6.	T <sub>6</sub>	44.72	16.34	18.12	2.11	37.33	81.91	3.11	88.89
7.	T <sub>7</sub>	44.97	12.75	14.56	1.56	32.88	75.57	2.44	88.89
	<b>Mean</b>	45.03	15.12	15.68	1.73	34.65	76.34	2.73	74.60
	<b>S.Em±</b>	NS	0.56	0.52	NS	1.02	2.23	0.08	9.23
	<b>CD (p = 0.05)</b>	NS	1.71	1.60	NS	3.15	6.87	0.26	28.45

\*F test at probability 0.05 level

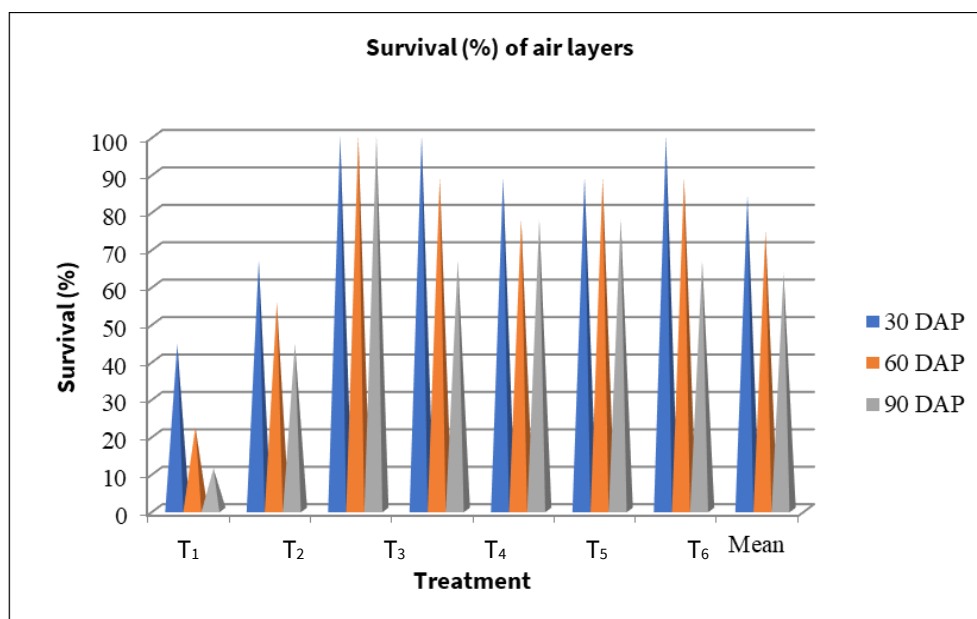
T<sub>1</sub>- A - Control, T<sub>2</sub>- Soil, sand, FYM (1:1:1) with *Trichoderma viride*, T<sub>3</sub>- Soil, sand, FYM (1:1:1) with Vermiwash - 1 %, T<sub>4</sub>- Soil, sand, FYM (1:1:1) with humic acid, T<sub>5</sub>- Soil, sand, FYM (1:1:1) with *Azospirillum- Azospirillum brasilense*, T<sub>6</sub>- Soil, sand, FYM (1:1:1) with VAM - Vesicular arbuscular mycorrhiza, T<sub>7</sub>- Soil, sand, FYM (1:1:1) with PGPR- plant growth promoting rhizobacteria, PH- plant height (cm), LPL- leaves per layer (no.), LRL- length of roots per layer (cm), SPL- shoots per layer (no.), PRL- primary roots per layer (no.), SRL- secondary roots per layer (no.), DPR- diameter of primary roots (mm), SAL- survival of air layers (%).

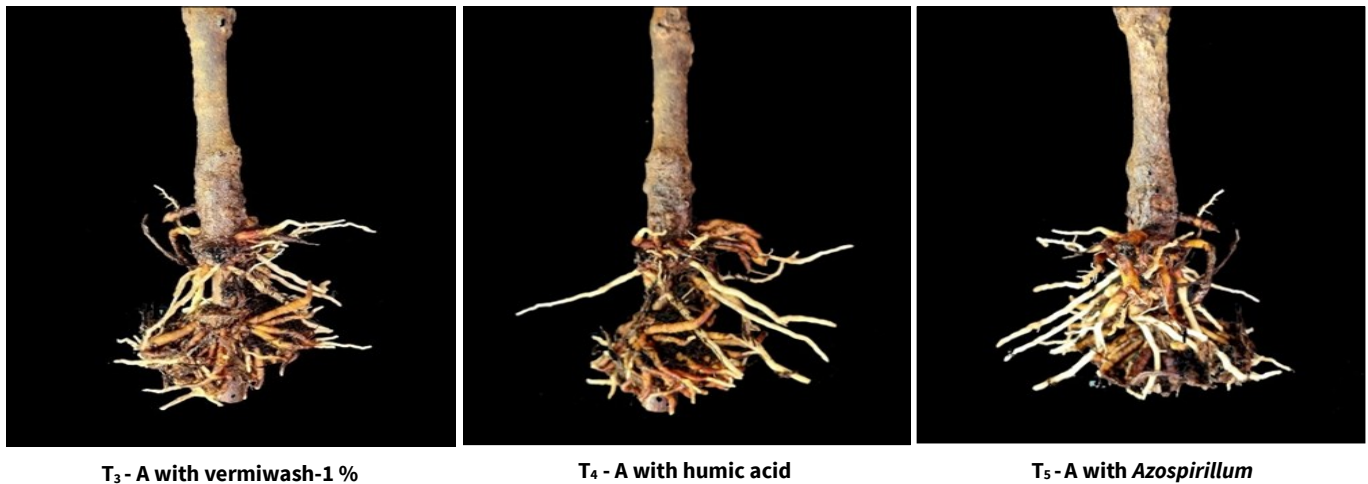
**Table 5.** Effect of different potting media on growth parameters after 90 days after planting (DAP) in water apple

S.No	Treatments	PH	LPL	LRL	SPL	PRL	SRL	DPR	SAL
1.	T <sub>1</sub>	45.71	13.98	12.96	1.78	31.12	66.41	2.38	11.11
2.	T <sub>2</sub>	46.54	21.42	15.37	2.00	34.41	78.59	2.65	44.44
3.	T <sub>3</sub>	48.34	21.88	21.80	1.67	43.35	89.17	3.50	100.00
4.	T <sub>4</sub>	46.69	15.71	17.39	1.78	37.15	82.64	2.71	66.67
5.	T <sub>5</sub>	48.49	17.43	19.55	1.23	38.20	85.15	2.94	77.78
6.	T <sub>6</sub>	46.47	19.48	20.80	2.11	39.91	87.12	3.22	77.78
7.	T <sub>7</sub>	46.62	16.46	16.91	1.56	35.34	80.89	2.56	66.67
	<b>Mean</b>	46.98	18.05	17.83	1.73	37.07	81.43	2.85	63.49
	<b>S.Em±</b>	NS	0.79	0.63	NS	1.09	2.37	0.09	5.94
	<b>CD (p = 0.05)</b>	NS	2.43	1.94	NS	3.35	7.30	0.27	18.30

\*F test at probability 0.05 level

T<sub>1</sub>- A - Control, T<sub>2</sub>- Soil, sand, FYM (1:1:1) with *Trichoderma viride*, T<sub>3</sub>- Soil, sand, FYM (1:1:1) with Vermiwash - 1 %, T<sub>4</sub>- Soil, sand, FYM (1:1:1) with humic acid, T<sub>5</sub>- Soil, sand, FYM (1:1:1) with *Azospirillum- Azospirillum brasilense*, T<sub>6</sub>- Soil, sand, FYM (1:1:1) with VAM - Vesicular arbuscular mycorrhiza, T<sub>7</sub>- Soil, sand, FYM (1:1:1) with PGPR - plant growth promoting rhizobacteria, PH- plant height (cm), LPL- leaves per layer (no.), LRL- length of roots per layer (cm), SPL- shoots per layer (no.), PRL- primary roots per layer (no.), SRL- secondary roots per layer (no.), DPR- diameter of primary roots (mm), SAL- survival of air layers (%).

**Fig. 2.** Effect of different potting media on survival (%) of air layers of water apple.



**Fig. 3.** Best potting media on survival percentage of water apple air layers.

vitamins and beneficial microorganisms (28). These components have the potential to positively influence shoot development and improve various shoot parameters. An abundance of metabolites, B-group vitamins and provitamin D presence also influence and enhances the above parameters, which further contribute to enhancing plant growth. This combination of materials provides adequate drainage, aeration and nutrient availability, promoting optimal root growth in the air layers. The ability of vermiwash extracts to regulate plant growth is primarily responsible for the potential increase in root length (29).

Whereas, the least number of primary roots after 30 DAP (25.36), 60 DAP (29.33) and 90 DAP (31.12); least number of secondary roots after 30 DAP (55.83), 60 DAP (61.67) and 90 DAP (66.41) mixture; lesser diameter of primary roots after 30 DAP (2.19 mm), 60 DAP (2.27 mm) and 90 DAP (2.38 mm); least length of roots after 30 DAP (10.25 cm), 60 DAP (11.25 cm) and 90 DAP (12.96 cm) were recorded in ( $T_1$ ) mixture of A-control.

This outcome is likely a consequence of the combined effects of biofertilizers and growing media, which contribute nutrients to the host plant either directly or indirectly by positively influencing root growth, morphology, or fostering beneficial symbiotic relationships (30). The observed increase in both fresh and dry root weights may be attributed to the formation of more roots, enhanced accumulation of food materials, longer root length and alterations in amino acid metabolism during root regeneration (31). The application of rhizobacteria possibly led to an augmentation in root length and overall growth, resulting in a greater root surface area. This, in turn, enabled the plant to access more nutrients from the soil, leading to improved root development in the air-layered plants. Consequently, the rooted layers benefited from this enhanced root system, exhibiting increased rates of water and mineral nutrient uptake and a higher root-to-shoot ratio on a fresh weight basis (30).

## Conclusion

The study demonstrated that the choice of potting media significantly influenced the survival and growth performance of air-layered water apple saplings. Among the 7 treatment combinations tested, the media containing soil, sand and FYM (1:1:1) supplemented with 1% vermiwash ( $T_3$ ) consistently outperformed other treatments across all observed parameters. This treatment recorded the highest survival percentage (100%) and significantly enhanced root attributes, including primary root and secondary

root number, root length and root diameter at 30, 60 and 90 DAP. Although plant height and shoot number did not differ significantly across treatments, the application of vermiwash showed a positive impact on leaf emergence and overall plant establishment. The useful effects of vermiwash may be attributed to its rich content of plant growth-promoting hormones, enzymes and microorganisms that improve nutrient availability and uptake. The outcome of the study explained the importance of integrating suitable biofertilizers into the potting mixture to improve the rooting success and survival of air-layered saplings, especially in sensitive crops like water apple. These findings can be effectively utilized in commercial nursery management and propagation programs to enhance the efficiency and success rate of vegetative propagation in tropical fruit crops.

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## Authors' contributions

GRS drafted, conceived and designed the study and carried out data acquisition. VTV and BA performed data analysis and interpretation. JD and JASR critically revised the manuscript. VTV and KPY conducted the statistical analysis. SK provided administrative, technical and material support. UBC supervised the study and approved the final version of the manuscript. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None

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