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RESEARCH ARTICLE

Valorizing treated sludge for sustainable growing media to improve rooting and growth of Co. 1- Gundumalli (*Jasminum sambac* (L.) Aiton) stem cuttings

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Abstract

The suitability of treated sewage sludge for vegetative propagation of ornamental crops has received little rigorous evaluation. The present study evaluated the physicochemical characteristics of treated sludge (TS) and its potential as a component of growing media for the propagation of *Jasminum sambac* (L.) Aiton through stem cuttings. Different combinations of organic and inorganic substrates were prepared and compared with TS to assess their effects on rooting and growth of *J. sambac* semi hardwood stem cuttings. The best results for all growth parameters including earlier sprouting (12.46 days), highest rooting % (86.66 %), number of roots (9.12), root length (12.74 cm), shoot length (21.50 cm) and vigour index (2967.24) were recorded in the combination of vermicompost (VC) + cocopeat (CP) + TS in a 2:1:1 ratio. The highest root fresh weight (11.34 g) and root dry weight (2.32 g) was also detected in this medium, suggesting an optimal nutrient and moisture balance. Based on correlation analysis, nitrogen and phosphorus had strong positive relationship, whereas potassium had weaker but positive relationship with all the physical parameters recorded. This study shows TS as a sustainable and efficient rooting media component when combined with VC and CP, enhancing nutrient utilization, rooting efficiency and seedling vigour in *J. sambac* cuttings.

Keywords: correlation; *Jasminum sambac*; rooting; SEM analysis; treated sludge

Introduction

Jasmine (*Jasminum sambac* (L.) Aiton) also referred as Gundumalli or Arabian Jasmine, is a member of the family Oleaceae (1). This plant is valued for its fragrant flowers that have significant cultural, ornamental and economic importance, especially in tropical and subtropical regions (2). Jasmine flowers are widely used in traditional medicine, perfumery and religious offerings. The total area under floriculture in India is 371860 ha with annual loose flower production of 2608850 metric tons. Out of this Jasmine cultivation occupies 27080 ha resulting in annual production of 273910 metric tons. Tamil Nadu is the leading producer of loose flower with 647010 metric tons production from 47460 ha. Out of this, 17020 ha were under jasmine cultivation with annual production of 173400 metric tons of flowers (3).

Vegetative propagation through stem cuttings remains the most effective method in jasmine multiplication. It enables the production of genetically identical, true-to-type plants within short duration (4). The jasmine flowers are widely used for garlands, religious rituals, social ceremonies, wedding decorations, preparation of perfumes, essential oils and cosmetic formulations, making jasmine a highly valued loose flower crop in domestic and international markets (5). The factors governing root development and establishment of cuttings are type of rooting media used, growth regulators applied and environmental conditions during propagation (4, 6). Commercial propagation of *J. sambac* is typically achieved through semi hardwood stem cuttings using traditional media combinations of farmyard manure (FYM), red earth and sand in 1:1:1 ratio (7). However, these conventional media face limitations including inconsistent quality and resource scarcity.

As sustainable agricultural practices and circular economic concepts gain more attention, there is an increasing interest in the use of organic waste materials in the formulation of growing media (8). Rapid urbanization has resulted in generations of enormous quantity of sewage sludge, posing serious disposal challenges that are detrimental to environment. India has 1093 operational sewage treatment plants (STPs) with a total capacity of 26869 million liters per day (MLD) (9). These plants produce around 3.8 million tons of dry sludge annually. Treated sludge (TS), a byproduct of wastewater plants has high nutrients and organic matter. This makes it a potential alternative to traditional growing media on cauliflower, broccoli and lettuce (10). Utilizing TS in horticulture not only helps address waste management issues but also provides a cost-effective method for plant propagation while alleviating the pressure on scarce natural resources (11). Studies on TS based rooting media for various plant species have shown both benefits and possible risks. Despite its nutrient richness and soil-enhancing properties, it may contain heavy metals (Fe, Cu, Mn, Zn, B, Pb, Ni, Cd and Cr) and pathogens that pose potential environmental and health risk (12). Therefore, a complete characterization of TS viz., physical (pH, electrical conductivity (EC), porosity, water holding capacity) and nutrient properties (organic matter and NPK) is necessary to assess its suitability for use in horticulture. So far, studies on the use of TS for ornamental species propagation, especially *J. sambac* are scarce despite its potential benefits. Understanding the influence of TS on the rooting and growth performance of *J. sambac* cuttings, is essential for developing sustainable propagation techniques that balance economic efficiency, environmental responsibility and plant health while contributing to circular economic implementation in ornamental horticulture.

The present investigation was conducted to assess the potential use of TS, both individually and in combination with cocopeat (CP), vermicompost (VC), FYM, red earth, sand, vermiculite (V) and perlite (P) in different proportions for the propagation of *J. sambac* through stem cuttings. This study focused on evaluating its effects on rooting %, root morphology, survival rate, vegetative growth and plant quality indices.

Materials and Methods

Physiochemical characterization of TS

Treated sludge was obtained from the Covestro Pvt. Limited, located at Karunguzhi, Chengalpet, Tamil Nadu (12°33'0" N, 79° 54'0" E). The physical (pH, EC, porosity, water holding capacity) and nutrient properties (organic matter and NPK) of the sludge were analyzed in the Department of Environmental Science at Tamil Nadu Agricultural University, Coimbatore. The surface morphology of the sludge was observed using a field emission scanning electron microscope (FE-SEM) operated at 2.0 kV EHT with a 10000× magnification. The TS was placed on the stub and coated with gold. Field emission scanning electron microscope (FE-SEM) was operated at 2 kV of acceleration voltage at the magnification of 5000× to visualize the TS. The elemental composition of the sample was identified using an energy dispersive x-ray spectroscopy (EDX) unit attached to the FE-SEM.

Preparation of growing media and experimental layout

This research was carried out in the nursery of the Department of Floriculture and Landscaping Architecture, Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The experimental location is at 11.02° N latitude and 77.03° E longitude with an elevation of approximately 426.72 m above the mean sea level. During the study period, the average temperature varied from 24 to 32 °C and relative humidity ranged between 65 to 75 %. The experiment was conducted from November 2023 to January 2024.

The semi hardwood cuttings of *J. sambac* variety Co.1-Gundumalli were used for this experiment. Uniform cuttings of 15 cm length, each containing 4 - 5 nodes, were selected for planting. The leaves on the lower portion of the cutting were removed, retaining only 2 - 3 pairs of leaves at the top to reduce transpiration while still permitting adequate photosynthesis. To stimulate root initiation, the basal ends of the cuttings were dipped in indole-3-butyric acid (IBA) at a concentration of 1000 ppm for 5 sec before planting. Fourteen different rooting media combinations were evaluated, incorporating various proportions of TS, FYM, CP, red soil, sand, VC, V and P. The standard mixture of FYM, red soil and sand in a 1:1:1 ratio was used as the control. The media composition used in the experiment are given in Table 1.

This experiment was laid out in completely randomized design (CRD) with fourteen treatments and 3 replications, following experimental protocols described previously (13). Each replication contained 10 cuttings, resulting in a total of 420 cuttings for the entire experiment. The cuttings were planted in black color polyethylene bags (20 × 10 cm) filled with the respective growing media as per the treatment specifications and were arranged on raised platforms in a mist chamber.

Observations recorded

In this study, measurements were carefully gathered for all key propagation parameters at 60 days after the establishment. For assessing days to sprouting, the period from planting to the initial emergence of new shoots in each cutting was tracked and the mean was determined for each substrate combination. In order to calculate rooting %, the proportion of cuttings that

Table 1. Treatment details for treated sludge as rooting media

Treatments		Particulars
T_1-C	:	Control – FYM + red earth + sand (1:1:1 ratio)
T_2-TS+CP (1:1)	:	Treated sludge + cocopeat (1:1 ratio)
T_3-TS+CP (2:1)	:	Treated sludge + cocopeat (2:1 ratio)
T_4-FYM+CP (1:1)	:	FYM + cocopeat (1:1 ratio)
T_5-FYM+CP (2:1)	:	FYM + cocopeat (2:1 ratio)
T_6-VC+CP+TS (1:1:1)	:	Vermicompost + cocopeat + treated sludge (1:1:1 ratio)
T_7 -VC+CP+TS (2:1:1)	:	Vermicompost + cocopeat + treated sludge (2:1:1 ratio)
T_8-V	:	Vermiculite
T_9-P	:	Perlite
T_{10}-V+P (1:1)	:	Vermiculite + perlite (1:1 ratio)
T_{11}-V+CP (1:1)	:	Vermiculite + cocopeat (1:1 ratio)
T_{12}-V+TS (1:1)	:	Vermiculite + treated sludge (1:1 ratio)
T_{13}-P+CP (1:1)	:	Perlite + cocopeat (1:1 ratio)
T_{14}- P+TS (1:1)	:	Perlite + treated sludge (1:1 ratio)

C- Control, TS- Treated sludge, FYM- Farmyard manure, VC- Vermicompost, CP - Cocopeat, V- Vermiculite, P- Perlite developed roots out of the total number of cuttings planted (14). It is expressed as % and calculated using the following formula (Eqn. 1):

$$\text{Success \%} = \frac{\text{Number of successfully rooted cuttings}}{\text{Total number of cuttings planted}} \times 100 \quad \text{(Eqn. 1)}$$

Root formation was characterized by counting the number of roots produced by each successful cutting and the mean value was worked out for each treatment. The dominant root from every rooted sample was measured using a scale to determine root length. Main shoot length was measured from its base at the cutting site to the growing tip as described in horticultural sampling protocol and the mean was calculated for each group.

The number of leaves present on each rooted cutting was counted directly in the final sampling, ensuring consistency across all treatments. Fresh and dry weight of roots were taken and the vigour index was calculated using the method integrated both root and shoot measurements with rooting success (15), using the following equation (Eqn. 2):

Vigour index = Rooting % × (Mean shoot length + Mean root length) (Eqn. 2)

Estimation of macronutrient content in growing media

Treated sludge, CP, VC, FYM, red earth, sand, V and P were mixed in various proportions as per the treatment specifications and were used for the propagation of *J. sambac* through semi hard wood stem cuttings. The prepared media mixtures were homogenized, air-dried and sieved prior to nutrient analysis. By using common laboratory techniques, the available macronutrients -nitrogen, phosphorus and potassium were examined. Available nitrogen was estimated by the alkaline potassium permanganate method as described previously (16), in which organic nitrogen present in the sample is oxidized by alkaline $KMnO_4$, releasing ammonia. The released ammonia is then absorbed in boric acid and subsequently titrated with standard sulfuric acid to estimate the nitrogen content. Available phosphorus was determined by the Bray No. 1 method (17) using an extractant containing 0.03 N NH_4F and 0.025 N HCl. The phosphorus content in the extract was quantified calorimetrically at 660 nm after colour development with ammonium molybdate and stannous chloride reagents. Available potassium was estimated by the neutral normal ammonium acetate (1 N NH_4OAc) extraction method as described previously (18) and the potassium concentration was determined using a flame photometer. All analyses were performed in triplicate and the nutrient values were expressed on oven-dry weight basis.

Statistical analysis

The experimental data were analyzed statistically by analysis of variance (ANOVA) using R software (version 3.6.0). The differences among treatments were assessed for significance at the 5 % level using the least significant difference test. Additionally, correlation analysis was carried out to examine the association between the nutritional characteristics of the sludge and the measured plant growth parameters.

Results and Discussion

Physio-chemical characterisation of TS

The TS had a mildly acidic pH (5.76) an electrical conductivity of 4.40 dSm^{-1} and was odourless. The moderate salinity of TS could influence nutrient solubility (19) and microbial activity in soils (20, 21). The TS was odourless due to the effective removal of volatile malodorous compounds during treatment process (22). Even though the TS has the moisture content of 6 %, yet it has a high water-holding capacity (130 %). Despite low moisture content, TS shows high water holding capacity because its porous organic structure and charged colloids enable rapid absorption and retention of water when provided. The organic carbon content was 14 %. Macronutrient analysis shows that the TS contains nitrogen at 1.18 %, phosphorus at 0.11 % and potassium at 0.10 %, supporting its suitability as a nutrient source for plants. Different concentrations of micronutrients were found in TS, including calcium (0.33 %), manganese (266 mg kg^{-1}), iron (11890 mg kg^{-1}) and zinc (197 mg kg^{-1}). These levels fall within ranges beneficial for plant nutrition.

Scanning electron microscopy (SEM) imaging at 10000× magnification showed that the TS has irregularly shaped particles with rough, cracked and porous surfaces often forming aggregates of varied sizes (Fig. 1). These surface morphology characteristics are typical for sludge subjected to biological treatment and imply high surface area, which can enhance adsorption, water retention and colonization of microbe potential when applied to soils. Elemental analysis using energy dispersive x-ray spectroscopy (EDS) confirmed carbon (≈51 %) and oxygen (≈41 %) as dominant elements (Fig. 2) consistent with the high organic matter content determined in physicochemical analysis. Silicon and calcium each accounted for 4 % of the elemental composition, suggesting the presence of silicates and calcium-based minerals such as carbonates or oxides. Elemental mapping (Fig.3) further illustrated that carbon and oxygen were widely distributed across the sludge surface, whereas silicon and calcium appeared as localized patches, indicating discrete mineral inclusions.

The minerals present in the TS can contribute to structural stability, regulated nutrient uptake and pH buffering of the growing media used to propagate jasmine cuttings (23, 24). The heterogeneous distribution of organic and mineral phases may influence nutrient release dynamics and pollutant adsorption behavior in amended soils. The physicochemical character and surface morphology indicated that TS is a promising soil conditioner, offering organic matter, essential nutrients and enhanced water-retention capacity.

Macronutrient (NPK) content in prepared media

The macronutrient composition of different growing media combinations used for jasmine cuttings exhibited considerable variation depending on the constituent materials (Table 2). Among the various treatments, the highest nitrogen content of 0.93 % was observed in T_2-TS+CP (1:1) and T_7 -VC+CP+TS (2:1:1) growing media, followed by T_2-TS+CP (1:1) and T_6 -VC+CP+TS (1:1:1) with 0.80 and 0.88 %, respectively. The lowest nitrogen content of 0.00 and 0.01 % observed in T_8- V and T_9- P. The abundant N in TS presented media could be due to the presence of nitrogen in organic form up to 60 and 40 % as mineral form in sewage biosolids at higher concentration, as earlier reported (25). In T_7 -VC+CP+TS (2:1:1) and T_6 -VC+CP+TS (1:1:1) highest phosphorus contents of 0.32 and 0.27 % was recorded respectively. Followed by T_4 - FYM+CP (1:1) and T_5-

Table 2. Macronutrients (NPK) in prepared media

Treatments	Nitrogen (%)	Phosphorous (%)	Potassium (%)
T_1-C	0.17	0.07	0.17
T_2-TS+CP (1:1)	0.80	0.17	0.09
T_3-TS+CP (2:1)	0.93	0.15	0.09
T_4-FYM+CP (1:1)	0.46	0.21	0.29
T_5- FYM+CP (2:1)	0.47	0.21	0.36
T_6 -VC+CP+TS (1:1:1)	0.88	0.27	0.15
T_7 -VC+CP+TS (2:1:1)	0.93	0.32	0.18
T_8-V	0.00	0.00	0.01
T_9 -P	0.01	0.01	0.03
T_{10}-V+P (1:1)	0.01	0.01	0.02
T_{11}-V+CP (1:1)	0.21	0.11	0.05
T_{12}-V+TS (1:1)	0.59	0.06	0.06
T_{13}-P+CP (1:1)	0.22	0.12	0.06
T_{14}-P+TS (1:1)	0.60	0.06	0.07

C- Control, TS- Treated sludge, FYM- Farmyard manure, VC- Vermicompost, CP- Cocopeat, V- Vermiculite, P- Perlite

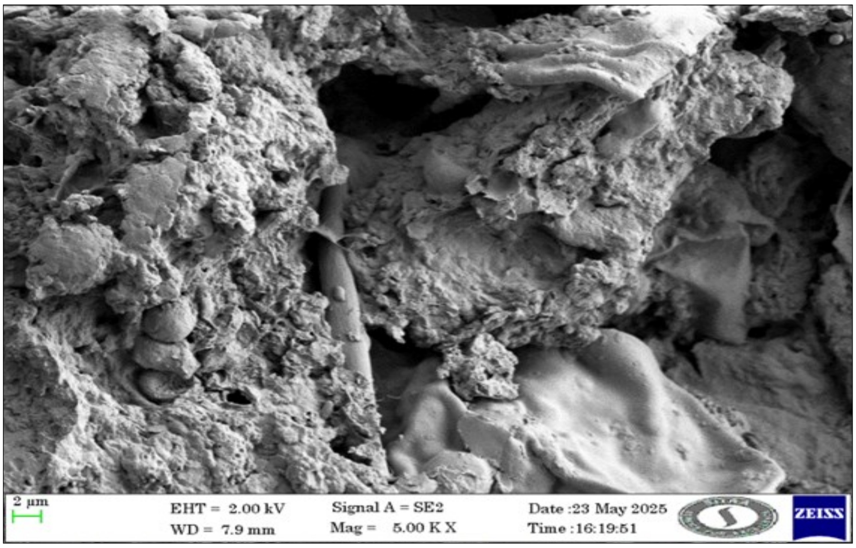

Fig. 1. Scanning electron microscopic image to treated sludge.

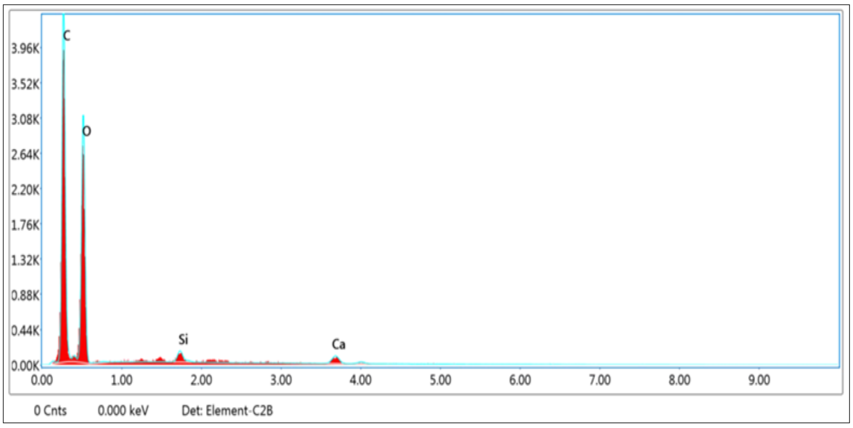

Fig. 2. EDAX analysis of treated sludge.

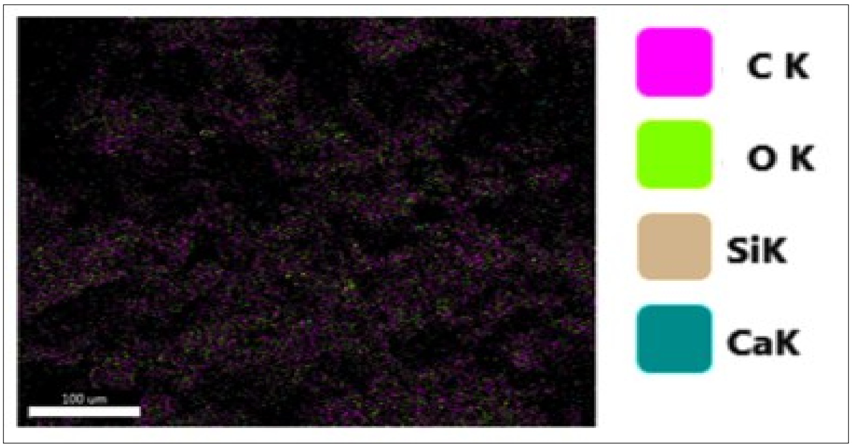

Fig. 3. Element overlay image of treated sludge.

FYM+CP (2:1) had the phosphorus content of 0.21 % each. The treatments T_8- V, T_9- P and T_{10}- V+P (1:1) had the lowest phosphorus content of 0.01 %. The phosphorus content of TS was low in comparison to the other organic manures because phosphorus is frequently eliminated during the initial precipitation treatment of sludge (26). Potassium was highly present in T_5- FYM+CP (2:1) with 0.36 %, followed by T_4 - FYM+CP (1:1) with 0.29 % and T_7 -VC+CP+TS (2:1:1) with 0.18 %. The lowest potassium content of 0.01 - 0.03 % was observed in treatments T_8- V, T_9- P and T_{10}- V+P (1:1). The reduced potassium content in the higher ratio of TS treatment is due to the presence of lower potassium content in TS (0.1) and the same content was observed in other study (27), (0.16 %) potassium in TS taken from sewage treatment plant than (0.37 %) in house compost.

Effect of different growing media on the rooting of *J. sambac*

In the present study, different combinations of organic and inorganic media, including TS, VC, CP, P and V were evaluated for their influence on the rooting performance of the cuttings. The results revealed significant variation among treatments, showing the importance of substrate composition in root initiation, shoot development and overall seedling vigour. The detailed results for each parameter are presented and discussed below.

Days taken for sprouting

The number of days required for sprouting varied significantly among the different growing media, indicating the influence of substrate composition on the early physiological activity of jasmine cuttings. The shortest day to sprouting was observed in T_7 -VC+CP+TS (2:1:1) with 12.46 days, followed closely by T_6-VC+CP+TS (1:1:1) with 12.66 days and T_2-TS+CP (1:1) with 12.85 days. In contrast, T_{10}- V+P (1:1) exhibited the longest days for sprouting with 14.81 days (Fig. 4). The reduced sprouting period in TS and VC amended growing media can be due to their superior nutrient content, particularly nitrogen and phosphorus and increased moisture retention property, both of which promote metabolic activation and bud differentiation. Vermicompost based organic substrates resulted in earlier sprouting by maintaining optimal aeration and moisture balance in Coleus and Kesavardhini plants (28).

Shoot length (cm) and number of leaves per rooted cuttings

Shoot length and number of leaves on rooted cuttings is a manifestation of the overall plant vigour and the efficiency of photosynthate allocation following root establishment. The highest shoot length (21.50 cm) and number of leaves (6.65 leaves/ cutting) was observed in T_7 -VC+CP+TS (2:1:1), followed closely by T_6-VC+CP+TS (1:1:1) with shoot length of 20.40 cm and number of leaves of 6.39/ rooted cutting. The lowest shoot length (11.68 cm) and number of leaves (3.35) was found in T_8-V (Fig. 4). The significant improvement in shoot elongation in TS and VC combinations could be attributed to balanced nutrient supply, particularly nitrogen and potassium and enhanced microbial activity, which improves nutrient mineralization and uptake. Cocopeat's excellent moisture-retention property further ensures a steady supply of water for cellular expansion. These results align with previous study (7) reporting the enhanced shoot growth and a higher number of leaves per shoot in jasmine propagated in a soil + sand + FYM (1:1:1) mixture with better nutrient and physical properties compared to sand + FYM (1:1).

Rooting percentage, number of roots per cutting and root length

Rooting parameters such as rooting %, number of roots per cutting and root length serves as a critical indicator of successful vegetative propagation. The results showed a clear enhancement in rooting success with the inclusion of TS and VC. The experimental results demonstrated that adding TS and VC significantly improved rooting. The treatment T_7-VC+CP+TS (2:1:1) recorded highest rooting % (86.66 %), maximum number of roots (9.12) and longest root length (12.74 cm). This was followed by T_6-VC+CP+TS (1:1:1) with rooting % of 83.31 %, number of roots per cutting of 8.75 and root length of 11.46 cm. The treatment T_8- V had the lowest root number (4.49), while T_{10}- V+P (1:1) had the lowest rooting % and root length of 60.33 % and 5.07 cm respectively (Fig. 5). The superior performance in media containing TS and VC may be ascribed due to the presence of humic acid, micronutrients and beneficial microbial communities that enhance endogenous auxin production and stimulate root meristem activity. These results highlight the importance of VC as a natural source of indole-3-acetic acid (IAA), which promote root development in tomato plants (29). Thus, the positive response in jasmine cuttings reflected the overall of organic amendments on root induction in jasmine cuttings.

Root fresh weight and dry weight

The root fresh and dry weight of jasmine cuttings varied significantly (p<0.001) among the different growing media combinations tested. The results showed that the highest root fresh weight of 11.34 g was observed in T_7 -VC+CP+TS (2:1:1), followed by T_6-VC+CP+TS (1:1:1) with 10.97 g and T_2-TS+CP (1:1) with 10.12 g. In contrast, the lowest root fresh weight (3.98 g) was obtained in T_8- V, followed by T_1-C (FYM + red earth + sand in 1:1:1 ratio) with 4.22 g (Fig. 6).

A similar trend was observed for root dry weight, where T_7 -VC+CP+TS (2:1:1) recorded the maximum value of 2.32 g, followed by 2.15 g in T_6-VC+CP+TS (1:1:1) and 2.02 g in T_2-TS+CP (1:1). The lowest root dry weight (0.74 g) was observed in T_8- V (Fig. 6).

The enhanced root biomass in media containing TS, VC and CP can be attributed to the higher organic matter content and improved nutrient availability that favour root initiation and elongation. These substrates are known to provide good aeration and moisture retention, both of which support root metabolism and biomass accumulation. VC contains macronutrients, micronutrients, humic acid and plant growth regulators that increase nutrient absorption and synthesis of protein in plant tissues (29, 30). On the other hand, the low root dry and wet weight in T_8– Vand T_9– P alone might be due to their inert nature, very low nutrient availability and reduced organic content, which may reduce root development.

Vigour index

Vigour index, which integrates both shoot and root length with rooting %, provides a comprehensive measure of seedling performance. The highest vigour index of 2967.24 was recorded T_7 -VC+CP+TS (2:1:1), followed by 2654.26 in T_6-VC+CP+TS (1:1:1) and 2531.75 in T_2-TS+CP (1:1). The treatment T_8- V had lowest vigour index of 1010.53 (Fig. 7), due to its inert nature and weak nutrient content. The elevated vigour in TS and VC media can be attributed to the synergistic effects of organic matter, microbial activity and adequate physical properties of the media, which together promote rapid and uniform growth. These findings align with previous study in *Chrysanthemum*, who reported that higher organic enrichment as a major factor that improved vigour indices (31). These results clearly

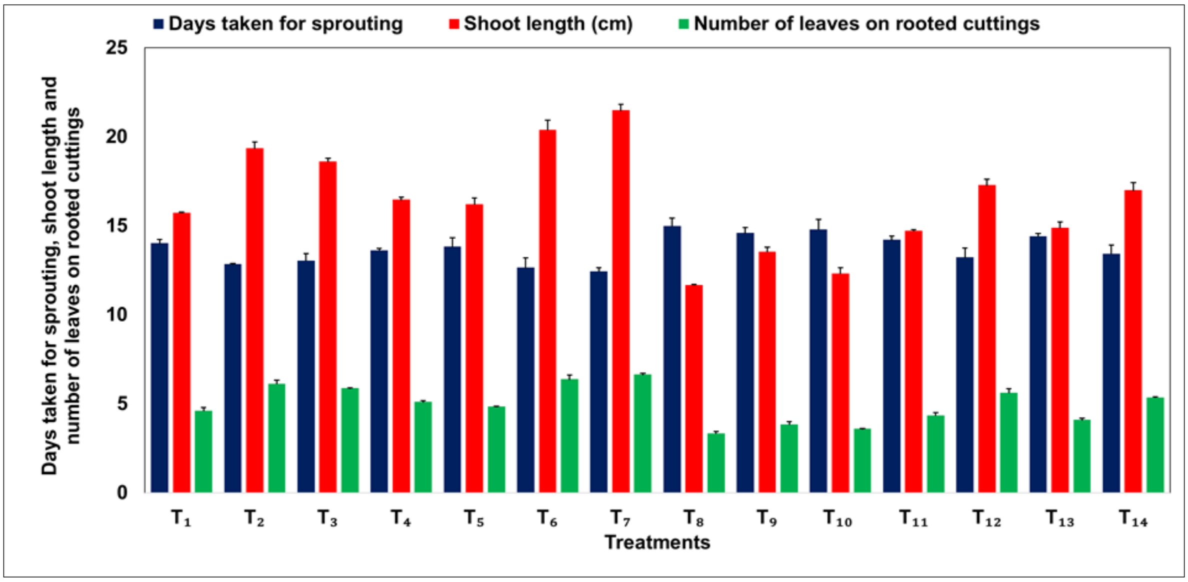

Fig. 4. Effect of different growing media on the days for sprouting, shoot length (cm) and numbers of leaves per rooted cutting of *J. sambac*.

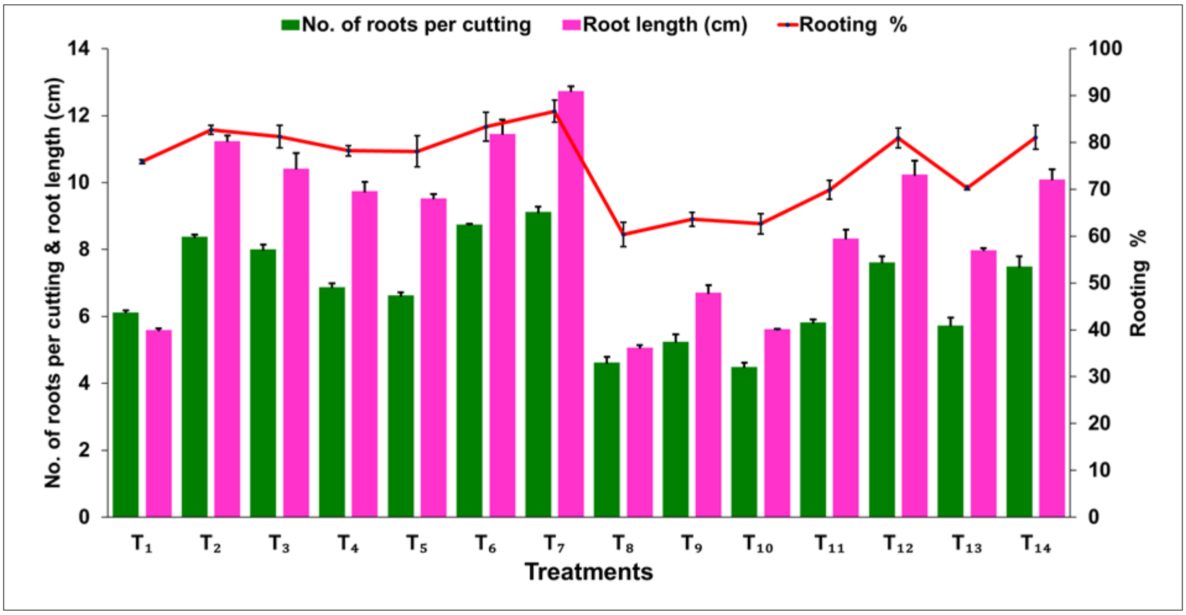

Fig. 5. Effect of different growing media on number of roots per cutting, root length (cm) and rooting % of *J. sambac*.

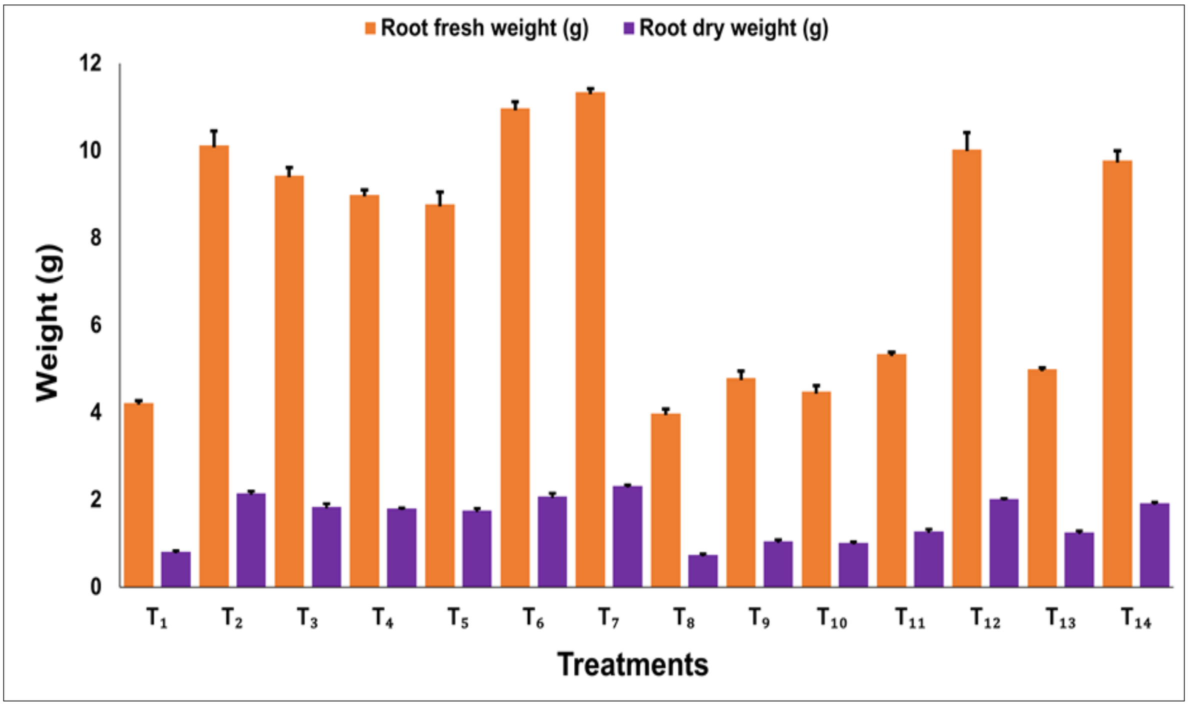

Fig. 6. Effect of different growing media on root fresh and dry weight (g) of *J. sambac*.

indicate that mixed organic substrates provide a superior physiological environment for jasmine propagation compared to inorganic or single-component media.

Correlation analysis between nutrient and physical parameters of *J. sambac*

The correlation analysis between nitrogen, phosphorous and potassium content in different growing media and growth parameters of jasmine cuttings revealed that nitrogen and phosphorous exhibited strong positive associations with growth parameters of jasmine cuttings, while potassium exhibited lower correlation with these traits. There was a strong correlation between nitrogen content of growing media and important growth parameters of jasmine cuttings like rooting % (r = 0.93), number of roots per cutting (r= 0.97), root length (r = 0.94), shoot length (r= 0.95), number of leaves on rooted cuttings (r=0.97), root fresh weight (r=0.94) and root dry weight (r=0.93) (Fig. 8). A significant correlation between nitrogen and physical parameters suggests its key involvement in cell division, meristematic activity and the promotion of shoot and root growth. Nitrogen is a major component of amino acids, proteins and nucleic acids, which supported increased plant height, branching and overall vigour with higher nitrogen supply (32).

There was a strong positive correlations between phosphorus and growth parameters such as rooting % (r = 0.75), number of roots per cutting (r = 0.77), root length (r = 0.80), shoot length (r = 0.82), number of leaves on rooted cuttings (r = 0.77), root fresh weight (r = 0.73) and root dry weight (r = 0.74) (Fig. 8). Phosphorus helps in energy transfer, root establishment and lateral development, it promotes strong rooting and shoot growth supporting findings from related studies had found that higher phosphorus enhanced plant spread (33).

Potassium exhibits lower correlation compared to nitrogen and phosphorous for all the growth parameters viz., rooting % (r= 0.49), number of roots per cutting (r= 0.34), root length (r = 0.37), shoot length (r = 0.38), number of leaves on rooted cuttings (r = 0.35), root fresh weight (r = 0.41) and root dry weight (r = 0.37) (Fig. 8). The reduced correlation coefficients for potassium with all measured parameters exhibited the relatively limited role of in early vegetative development. However, there was no negative correlation between potassium and plant characters, as potassium is also involved in root development (34).

The strong positive correlations between nitrogen and phosphorus with most of the physical traits of jasmine, like rooting %, number of roots, root and shoot length, seedling length, number of leaves, root fresh and dry weights, showed that these nutrients are very important for the growth of jasmine cuttings.

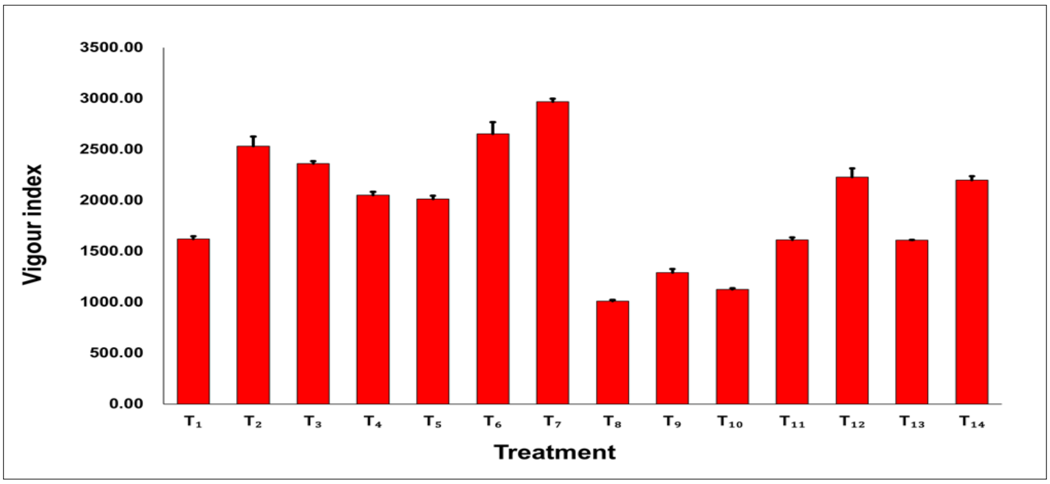

Fig. 7. Effect of different growing media on manure index of *J. sambac*.

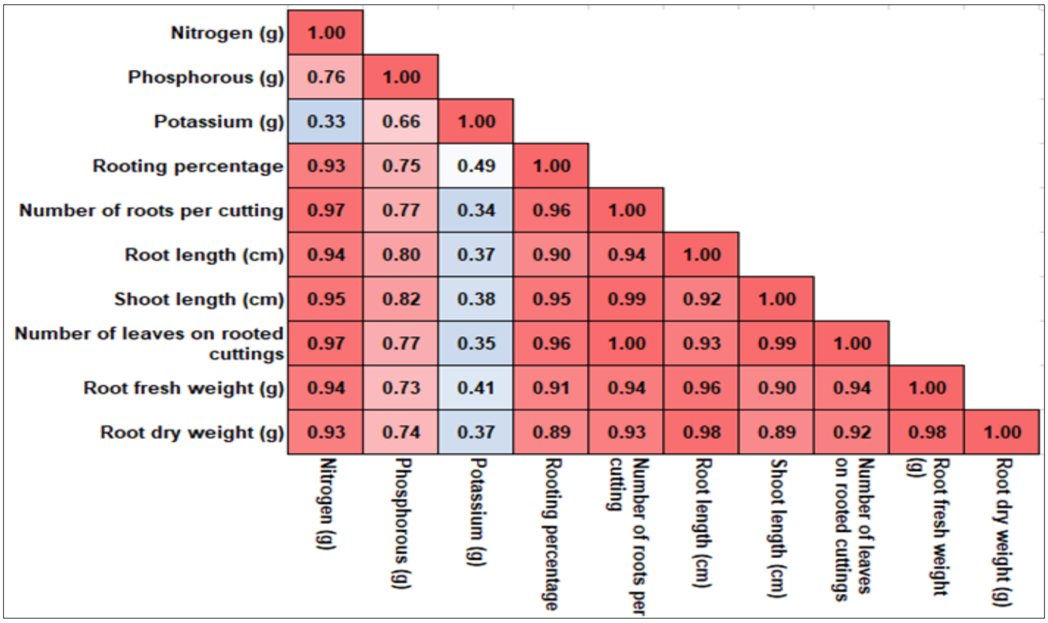

Fig. 8. Correlation analysis between nutrient content and physical parameters of *J. sambac*.

Conclusion

The rooting media T_7-VC+CP+TS (2:1:1) performed superiorly over other treatments, showed better effects on sprouting, rooting, shoot and root development, number of leaves, vigour and seedling growth in *J. sambac*. This medium has the advantages of both physical structure from CP (lightweight, high porosity, excellent water retention) and nutrient content from VC and TS. The addition of TS and VC improved the macro and micronutrient content in the soil that improve plant growth regulators such as auxins and cytokinins. In contrast, the low performance of V and P, either alone or in combination, shows their inert nature and inability to support root induction and vegetative growth. These findings indicate that integration of organic inputs viz., TS and VC with substrates like CP can significantly increase the propagation efficiency of jasmine. This practice not only enhances plant growth but also supports the circular bioeconomy by converting the organic waste into a valuable horticultural input, thereby promoting sustainable practices.

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Authors' contributions

ABA carried out the experiment, took observation and analyzed the data. RS guided the research by formulating the concept, helped secure funds and approved the final manuscript. MG contributed by reviewing the manuscript. SS and EP contributed by edit and summarise the manuscript. PM helped to outline and modify the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

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