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Influence of rooting substrates and their physicochemical properties on adventitious rooting and growth of guava (*Psidium guajava* L.) softwood cuttings

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ABSTRACT

Rooting substrate selection is an important factor influencing the efficiency of clonal multiplication through stem cuttings. The present study evaluated seven rooting substrates for their effects on adventitious rooting, growth, survival and nutrient accumulation in softwood cuttings of guava (*Psidium guajava* L.) cv. Arka Poorna. Cuttings treated with spermine (0.5 mM) followed by IBA (4000 mg L⁻¹) were evaluated in a completely randomized design with 30 replications. Rooting responses varied significantly among substrates. Cocopeat produced the highest number of primary roots (15.50), while sand promoted maximum secondary roots (59.83) and root biomass (5.53 g fresh and 1.25 g dry weight). Maximum survival (72.50%) was recorded in cocopeat and sand:soil:FYM (1:1:1). Cocopeat had low bulk density (0.08 g cm⁻³) and high water-holding capacity (799.54%), whereas sand exhibited contrasting physical properties. The sand:soil:FYM mixture favoured greater accumulation of N, K and Mg in rooted plantlets. The results indicate that rooting success was governed by the combined physical and nutritional characteristics of the substrates rather than nutrient content alone. Overall, cocopeat and sand:soil:FYM (1:1:1) were promising substrates for efficient clonal propagation of guava softwood cuttings.

Keywords: Guava, Adventitious rooting, Rooting media, Physicochemical properties

Introduction

Guava (*Psidium guajava* L.) is one of the most popular fruit crops of Myrtaceae family, widely cultivated across the tropical and subtropical regions of many countries. Owing to its prolific and early bearing nature coupled with amenability to crop regulation to extend the fruiting periods, guava has attained economic significance in several nations. The crop is commercially propagated through vegetative methods. Nevertheless, clonal propagation via cuttings, layers, grafting and budding are the most preferred method for true to type planting material production in guava. Wide-scale adoption of emerging technologies like high density planting and meadow orchard systems have resulted in tremendous area expansion and increased demand for high volume quality planting materials in guava. To meet this burgeoning demand, guava is currently propagated majorly through clonal stem cuttings, even though it is considered as a hard to root species (Kumar *et al.*, 2022)^[1].

Rooting medium is the basic and indispensable requirement in clonal propagation of crops through cuttage. A suitable rooting substrate should provide adequate moisture and air movement besides facilitating proper anchorage and nutrition to effect successful rooting (Joshi, 2024)^[2]. Further, adventitious root formation and growth of cuttings are largely influenced by the physical and chemical properties of growing media, as reported in several previous studies (Shilpa Shree *et al.*, 2021; Vanitha *et al.*, 2023; Bhusari *et al.*, 2025)^[4, 5, 3]. Previously, potting mixture consisting of soil, sand and farm yard manure was the predominant substrate for rooting of cuttings. Due to the current scenario of fast and wide spreading nematode infestation in nursery soil medium (Poornima *et al.*, 2021)^[6], the conventional potting media in guava and many other crops is currently substituted with other substrates. Various organic as well as inorganic substrates are used as growing media for stem cuttings (Mariyappillai and Arumugam, 2020)^[7]. Nonetheless, the rooting success and survival of plants are highly specific to crop, varieties and media. No ideal rooting substrate or mixture is available that could provide all the optimal conditions and requirements of plant species. Moreover, the substrate for growing cuttings should be easily available, environment safe and sustainable for large-scale production. Therefore, the present experiment was undertaken to investigate the influence of growing media on adventitious rooting response of softwood cuttings of the difficult to root guava variety Arka Poorna.

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Materials and methods

The present investigation was carried out Keeraipatti village in Dharmapuri District, Tamil Nadu and the laboratory analyses were undertaken at ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka during 2024-25. The experiment was laid out in completely randomized design (CRD) with 30 replications. Three to four years old field grown healthy mother plants of guava variety Arka Poorna were pruned for induction of new shoots. Shoots from the pruned mother plants were collected after 70 to 90 days post-pruning. Green softwood cuttings of 10-15 cm length, having two to four nodes were prepared and treated with Spermine (0.5 mM) for 20 minutes followed by quick dipping in IBA (4000 mg L⁻¹) for 60 seconds. The treated cuttings were planted in protrays (50 cavity, 6.0 cm deep and 5.0 cm opening diameter) containing different growth media and placed in a low-cost walk-in propagation chamber for induction of rooting. The cuttings were irrigated daily once and the growth chamber was sealed tightly to maintain the temperature (34 to 37 °C during day and 25 to 28 °C during night hours) and relative humidity (>90 %) inside the chamber. The cuttings were drenched with Carbendazim 50% WP (0.5%) three days post-planting to prevent fungal infections. The rooted cuttings were carefully transferred to polythene bags containing potting media of red soil, sand and well-decomposed FYM in 1:1:1 proportion at 45 days after planting. Morphometric observations on rooting and growth parameters were recorded periodically. The physical and chemical properties of the different rooting substrates were determined prior to initiation of the experiment. The physical properties such as bulk density (g/cc) and maximum water holding capacity (%) of the different rooting substrates were assessed by Keen's cup method (Shilpa Shree *et al.*, 2021)^[4]. The total nitrogen in rooting media were estimated by micro Kjeldhal distillation method as described by Piper (1996)^[8] while the pH and total phos-

phorus were determined as per Jackson (1973)^[9]. The potassium, calcium and magnesium contents of the media were analysed following the methods outlined by Jackson (1973)^[9] while the micronutrients (Cu, Zn, Mn and Fe) were estimated by atomic absorption spectrophotometry adopting Page *et al.* (1982)^[10]. The leaf tissues of 90 days old plantlets were also analysed for the major and minor nutrient status following wet digestion and estimation adopting Jackson (1973)^[9], Isaac and Johnson (1985)^[11] and Kalra (1998)^[12].

Statistical analysis: The morphological and physico-chemical data were subjected to analysis of variance (ANOVA) using RAISINS (R & AI Solutions for Inferential Statistics) software (Hisham *et al.*, 2025)^[13]. The data transformations were performed for count data (square root transformation) and percentage data (arc sine transformation) for normalizing the data.

Results

Root growth parameters

Adventitious root production in guava softwood cuttings was significantly influenced by the rooting substrates (Table 1). Number of primary and secondary roots were significantly higher in cuttings grown in cocopeat (15.50 & 56.83 respectively) and sand media (14.83 & 59.83), followed by Sand: Soil: FYM (13.50 & 50.50) while cuttings grown in Cocopeat: vermicompost medium produced less number of primary (7.00) and secondary (26.17) roots. Fresh and dry root biomass was significantly higher in cuttings planted in sand (5.53 and 1.25 g respectively), while cuttings rooted in Cocopeat: vermicompost recorded minimum fresh as well as dry root weight (2.54 and 0.64 g respectively). The root production in guava cuttings planted in Sand: Soil: FYM substrate was also at par with sand or cocopeat media in terms of number of primary and secondary roots as well as root biomass.

Table 1. Influence of growth substrates on root growth of guava stem cuttings

Treatments	Number of primary roots	Number of secondary roots	Fresh root weight (g)	Dry root weight (g)
S ₁ -Sand: Soil: FYM (1:1:1)	13.50 ^{ab} (3.67)	50.50 ^{ab} (7.11)	4.50 ^{bc}	1.14 ^{ab}
S ₂ -Sand	14.83 ^a (3.85)	59.83 ^a (7.72)	5.53 ^a	1.25 ^a
S ₃ -Cocopeat: vermiculite: perlite (1:1:1)	11.83 ^b (3.44)	39.17 ^{cd} (6.25)	3.98 ^c	1.03 ^b
S ₄ -Cocopeat: vermicompost (1:1)	7.00 ^d (2.64)	26.17 ^e (5.10)	2.54 ^d	0.64 ^c
S ₅ -Arka fermented cocopeat inoculated with Arka microbial consortium	14.83 ^a (3.85)	45.33 ^{bc} (6.73)	4.78 ^b	1.15 ^{ab}
S ₆ -Cocopeat: Soil (1:1)	10.00 ^c (3.16)	33.67 ^d (5.80)	3.08 ^d	0.77 ^c
S ₇ -Cocopeat	15.50 ^a (3.94)	56.83 ^a (7.54)	4.99 ^{ab}	1.23 ^{ab}
<i>p</i> value	0.00	0.00	0.00	0.00
CD	0.26	0.65	0.72	0.21
SE(m)	0.09	0.21	0.24	0.07
CV(%)	4.3	5.6	9.8	11.8

Shoot growth and survival of plantlets

The shooting parameters of guava softwood cuttings exhibited significant variations while planted in different growing media (Table 2). The cuttings planted in media such as Sand: soil: FYM, Cocopeat: vermiculite: perlite sprouted early (51.33 days) which were at par with Cocopeat: vermicompost (52.33 days) and Cocopeat: Soil (53.00 days). Delayed sprouting of cuttings was noted in Sand (61.67 days) as well as in Cocopeat (59.67 days). Number of sprouts per plantlet did not show any statistically significant difference however cuttings grown in Cocopeat and Cocopeat: vermiculite: perlite media had maximum number of sprouts (1.60). Rooting substrate significantly influenced the shoot length of cuttings. Planting in Cocopeat:

Vermicompost media resulted in higher average shoot length (24.30 cm) while it was lowest in Cocopeat (14.10 cm). Shoot length in Sand alone and Sand: soil: FYM media (21.33 and 21.10 cm) were also comparable with Cocopeat: vermicompost medium. Sprout length of cuttings was not statistically significant, however longer sprouts were produced in cuttings planted in Cocopeat: vermiculite: perlite (19.83 cm) while sprouts were shorter in Cocopeat (10.47 cm) and Cocopeat: soil media (10.37 cm). Number of leaves produced by the cuttings varied significantly with rooting substrate. Cuttings rooted in Cocopeat: vermicompost medium put forth higher number of leaves (13.13) which was at par with those planted in Arka fermented cocopeat (12.67), Cocopeat: soil (12.27), Cocopeat: vermi-

culite: perlite (12.13) and Sand: soil: FYM (12.00). Cuttings planted in cocopeat alone produced less number of leaves (10.40). Leaf area was not significantly affected by the rooting substrate, however cuttings planted in Sand medium produced larger leaves (35.82 cm²), followed by Cocopeat: vermicompost (32.05 cm²), while smaller leaves were observed in cuttings planted in cocopeat (22.97 cm²).

Survival of guava stem cuttings was significantly influenced by the rooting substrates, with higher rooting success in Cocopeat (72.50%) and Sand: soil: FYM (72.50%) media. The rooting and survival of planted cuttings were lowest in Cocopeat: vermicompost medium (Table 2).

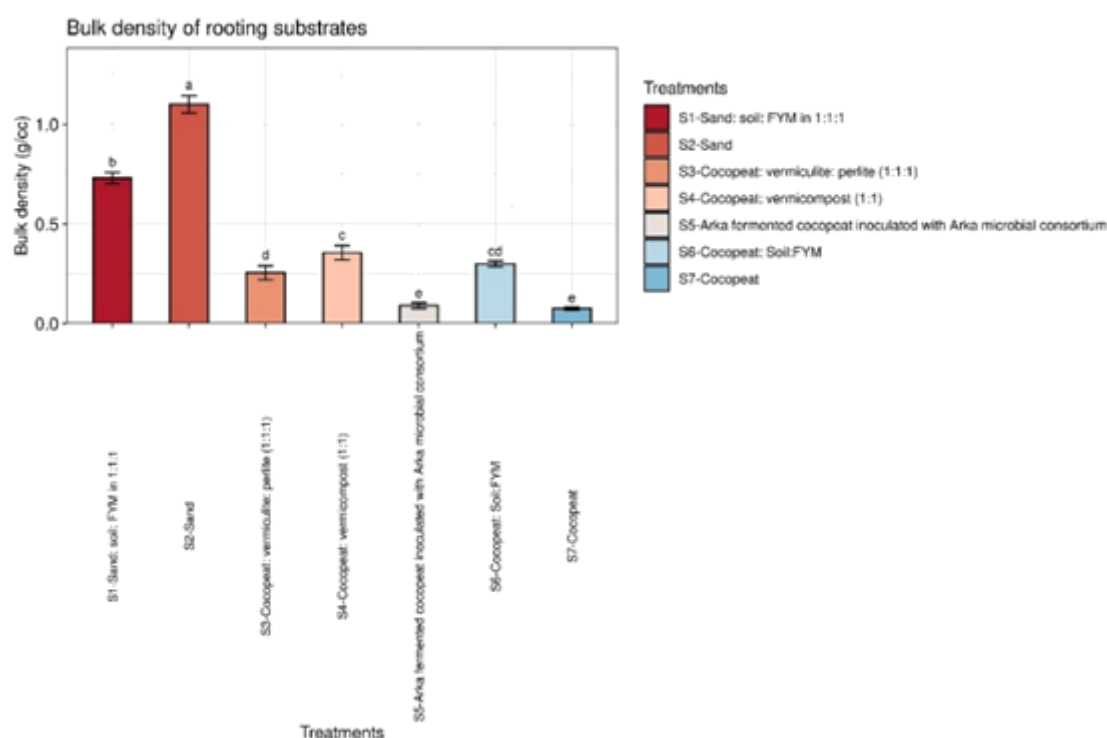
Table 2. Influence of growth substrate on shoot growth and survival of guava stem cuttings

Treatments	No of days to first sprouting	Number of sprouts	Shoot length (cm)	Sprout length (cm)	Number of leaves	Leaf area (cm ²)	Survival (%)
S ₁ -Sand: Soil: FYM (1:1:1)	51.33 ^c	1.53 (1.24)	21.10 ^{abc}	15.93	12.00 ^{ab} (3.46)	30.57	72.50 ^a (58.39)
S ₂ -Sand	61.67 ^a	1.53 (1.24)	21.33 ^{abc}	17.80	11.33 ^{bc} (3.36)	35.82	55.00 ^b (47.87)
S ₃ -Cocopeat: vermiculite: perlite (1:1:1)	51.33 ^c	1.60 (1.26)	23.07 ^{ab}	19.83	12.13 ^{ab} (3.48)	29.39	47.67 ^c (43.66)
S ₄ -Cocopeat: vermicompost (1:1)	52.33 ^c	1.47 (1.21)	24.30 ^a	14.50	13.13 ^a (3.62)	32.05	17.50 ^d (24.69)
S ₅ -Arka fermented cocopeat inoculated with Arka microbial consortium	57.33 ^b	1.53 (1.24)	18.07 ^{bcd}	15.20	12.67 ^{ab} (3.56)	29.95	52.50 ^{bc} (46.43)
S ₆ -Cocopeat: Soil (1:1)	53.00 ^c	1.53 (1.24)	16.33 ^{cd}	10.37	12.27 ^{ab} (3.50)	25.75	54.17 ^b (47.39)
S ₇ -Cocopeat	59.67 ^a	1.60 (1.26)	14.10 ^d	10.47	10.40 ^c (3.22)	22.97	72.50 ^a (58.39)
CD	2.20	-	5.81	-	0.22	-	2.98
SE(m)	0.72	0.04	1.92	2.90	0.07	3.67	0.98
CV(%)	2.3	5.9	16.8	33.7	3.7	21.6	3.64

Physico-chemical properties of the substrates

The physical properties of the rooting substrates such as bulk density and maximum water holding capacity (MWHC) varied significantly (Figure 1). Among the different media, Sand recorded comparatively higher bulk density (1.10 g/cc), followed by Sand: soil: FYM (0.73 g/cc) while it was minimum in Cocopeat (0.08 g/cc) and Arka Fermented Cocopeat (0.09 g/cc). Other cocopeat based media mix-

tures showed moderate bulk densities ranging from 0.26 to 0.30 g/cc (Figure 1a). Arka Fermented cocopeat inoculated with Arka Microbial Consortium possessed higher MWHC (832.90 %), followed by Cocopeat (799.54%) while sand medium had lower MWHC (30.70%). Other cocopeat based media had moderate MWHC (Figure 1b).



a. Bulk density of rooting substrates

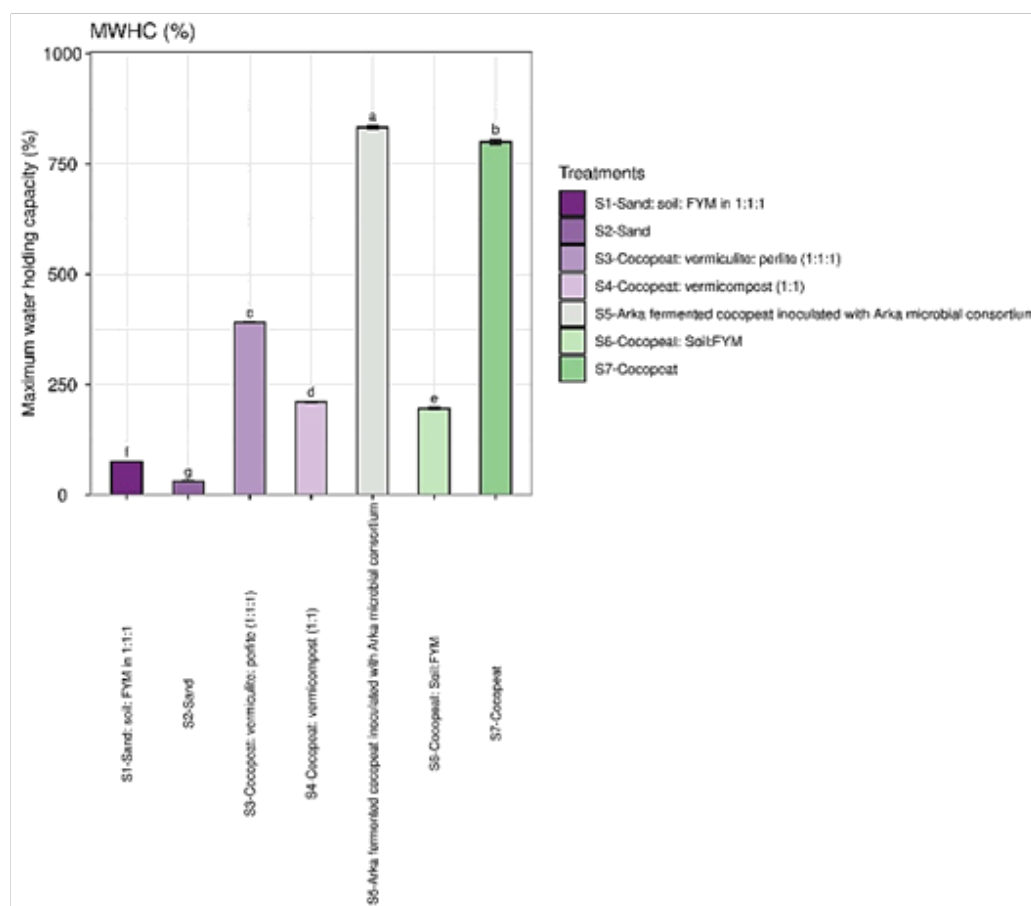


Figure 1. Physical properties of rooting substrates for guava stem cuttings
b. Maximum water holding capacity of rooting substrates

The chemical properties of the different growing substrates such as pH, major and minor nutrients composition were analyzed and found significantly varying (Table 3). The total nitrogen content was higher in Cocopeat: vermicompost (0.49 %) and commercial cocopeat (0.44%) media while nitrogen was not detected in sand. Higher phosphorus level was found in Sand: soil: FYM (0.30 %), which was on par with Cocopeat: Vermicompost media (0.26%), while it was lowest in Sand and Cocopeat (0.02%). Potassium levels were higher in Cocopeat: vermiculite: perlite medium (1.65%), followed by Cocopeat: vermicompost (0.75%) and the lowest K content was in sand (0.01%). Higher calcium content was found in Arka Fermented cocopeat (7.18%), magnesium (Mg) in Cocopeat: Vermiculite: Perlite (1.03%) and sulphur (S) in Cocopeat (0.24%). The minor nutrient elements such as zinc (Zn) and copper (Cu) were higher in Cocopeat: vermicompost medium (41.88 and 58.50 ppm respectively) while iron (Fe) content was high in Sand: soil: FYM (88.76 ppm) and Cocopeat: Soil (83.82 ppm) media. Manganese levels were statistically non-significant. The pH of the rooting substrates varied significantly, with higher pH in Sand (6.95) and lowest in Arka Fermented Cocopeat (6.07).

Plant nutrient composition

The major nutrient composition of guava cuttings was significantly influenced by the growing substrates (Table 4). Total nitrogen content ranged from 1.30 to 1.89%, with the highest value recorded in cuttings grown in sand: soil: FYM (1.89%), while the lowest was observed in those grown in sand (1.30%). Total phosphorus in plant tissues ranged from 0.17 to 0.26%, with the maximum content recorded in plantlets grown in sand: soil: FYM (1:1:1) and cocopeat: vermicompost media (0.26% each), whereas the P was minimum in sand grown plants (0.17%). The total potassium content ranged from 1.90 to 3.11%, with the highest accumulation in sand: soil: FYM (1:1:1) (3.11%), while sand recorded the lowest value (1.90%). The maximum Ca content (1.18%) was recorded in plants grown in sand as well as cocopeat: soil mixture (1:1), while the minimum (0.95%) was observed in cocopeat: vermiculite: perlite (1:1:1) grown plantlets. Magnesium content of the leaves ranged from 0.44 to 0.63%, with the highest value recorded in sand: soil: FYM (0.63%), followed by the ones grown in sand (0.57%) and cocopeat: vermiculite: perlite (0.52%). The lowest Mg content was recorded in cocopeat grown plants (0.44%). Sulphur content ranged from 0.86 to 1.21%, with the highest value recorded in cuttings rooted in cocopeat: vermiculite: perlite (1:1:1) (1.21%), followed by cocopeat: soil (1.09%) and sand (1.08%), while the lowest value was recorded in plants of Arka fermented cocopeat (0.86%).

Table 3. Nutrient composition and pH of rooting substrates

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	pH
S ₁ -Sand: Soil: FYM (1:1:1)	0.17 ^{bc}	0.30 ^a	0.65 ^{bc}	3.54 ^c	0.90 ^b	0.10 ^b	32.88 ^b	88.76 ^a	147.00	22.30 ^c	6.56 ^c
S ₂ -Sand	0.00 ^d	0.00 ^d	0.01 ^e	0.02 ^e	0.01 ^d	0.00 ^d	16.47 ^d	47.47 ^b	50.80	29.70 ^{cd}	6.95 ^a
S ₃ -Cocopeat: vermiculite: perlite (1:1:1)	0.21 ^b	0.08 ^{bc}	1.65 ^a	5.81 ^b	1.03 ^a	0.05 ^c	9.04 ^c	40.94 ^b	170.00	24.35 ^e	6.56 ^c
S ₄ -Cocopeat: vermicompost (1:1)	0.49 ^a	0.26 ^a	0.75 ^b	6.34 ^{ab}	0.97 ^{ab}	0.11 ^b	41.88 ^a	40.33 ^b	103.00	58.50 ^a	6.19 ^d
S ₅ -Arka fermented cocopeat inoculated with Arka microbial consortium	0.25 ^b	0.06 ^c	0.70 ^{bc}	7.18 ^a	0.93 ^{ab}	0.07 ^{bc}	22.98 ^c	42.52 ^b	109.30	33.25 ^c	6.07 ^e
S ₆ -Cocopeat: Soil (1:1)	0.11 ^c	0.10 ^b	0.60 ^{cd}	3.58 ^c	0.94 ^{ab}	0.11 ^b	39.39 ^a	83.82 ^a	205.50	25.85 ^{de}	6.61 ^c
S ₇ -Cocopeat	0.44 ^a	0.02 ^d	0.50 ^d	1.19 ^d	0.44 ^c	0.24 ^a	29.00 ^b	50.56 ^b	73.00	53.95 ^b	6.72 ^b
CD	0.08	0.04	0.11	0.88	0.10	0.04	5.37	29.77	NS	4.14	0.09
SE(m)	0.03	0.01	0.03	0.26	0.03	0.01	1.61	8.90	39.68	1.24	0.03
CV(%)	14.98	12.89	6.67	9.39	5.41	17.72	8.30	22.34	45.75	4.95	0.61

The plant nutrient concentrations of minor elements, viz., Fe, Mn, Zn and Cu also differed significantly among the substrates. Total Fe content ranged from 385.75 to 1113.49 ppm, with the highest concentration recorded in cuttings grown in Arka fermented cocopeat inoculated with Arka microbial consortium (1113.49 ppm). This was followed by sand: soil: FYM (877.17 ppm) and cocopeat: soil (852.20 ppm), while plants grown in sand recorded the lowest Fe concentration (385.75 ppm). The highest Mn concentration was recorded in cuttings grown in cocopeat: soil (148.50 ppm), followed by sand (139.05 ppm). The lowest Mn concentration was recorded in plants raised in sand: soil: FYM mixture (80.90 ppm). The Zn concentration was highest in plants grown in cocopeat: vermiculite: perlite mixture (37.13 ppm), followed by Arka fermented cocopeat (36.57 ppm) and sand (32.25 ppm). The lowest Zn concentration was minimum in cocopeat: vermicompost grown plants (26.57 ppm). Highest Cu accumulation in plants was recorded in sand medium (73.10 ppm), followed by Arka fermented cocopeat (38.10 ppm) and cocopeat: vermicompost (31.20 ppm), whereas the lowest Cu concentration (13.20 ppm) was observed in cocopeat grown plants (Table 4).

Discussion

Root development in guava stem cuttings varied significantly among the growing substrates, indicating that the rooting environment played an important role in determining root initiation, proliferation and

biomass accumulation. Differences among substrates may be related to their contrasting capacities for moisture retention, aeration and drainage. A suitable balance between water availability and oxygen supply around the basal portion of the cutting is particularly important during adventitious root formation. Similar substrate-dependent differences in guava cutting propagation have been reported by Sheikh *et al.* (2023) [14] and Akram *et al.* (2025) [14, 15]. Cocopeat and sand media were the most suitable rooting substrates for root induction and development in guava var. Arka Poorna. Cuttings planted in cocopeat recorded the maximum number of primary roots (15.50), whereas sand and Arka Fermented Cocopeat enriched with Arka Microbial Consortium (AMC) were statistically comparable, each producing 14.83 primary roots. Sand recorded the greatest number of secondary roots (59.83). These responses suggest that both substrates provided suitable conditions for root initiation and branching, although their physical characteristics differ considerably. The high porosity and drainage of sand may facilitate oxygen availability at the cutting base. Cocopeat can retain substantial moisture while maintaining adequate pore space. Sheikh *et al.* (2023) [14] similarly reported better root development of guava cuttings in cocopeat-containing substrates than in topsoil alone.

Table 4. Nutrient composition of guava cuttings grown in different substrates

Treatments	Total N (%)	Total P (%)	Total K (%)	Total Ca (%)	Total Mg (%)	Total S (%)	Total Fe (ppm)	Total Mn (ppm)	Total Zn (ppm)	Total Cu (ppm)
S1-Sand: soil: FYM in 1:1:1	1.89 ^a	0.26 ^{bc}	3.11 ^a	1.15 ^{ab}	0.63 ^a	0.88 ^d	877.17 ^b	80.90 ^d	27.91 ^{cd}	14.61 ^c
S2-Sand	1.30 ^d	0.17 ^d	1.90 ^e	1.18 ^a	0.57 ^b	1.08 ^b	385.75 ^f	139.05 ^b	32.25 ^b	73.10 ^a
S3-Cocopeat: vermiculite: perlite (1:1:1)	1.63 ^b	0.67 ^a	2.86 ^b	0.95 ^c	0.52 ^{bc}	1.21 ^a	658.80 ^d	119.00 ^c	37.13 ^a	18.85 ^c
S4-Cocopeat: vermicompost (1:1)	1.49 ^c	0.26 ^b	2.44 ^c	1.12 ^b	0.45 ^d	0.95 ^c	649.67 ^{de}	136.40 ^b	29.41 ^{bcd}	31.20 ^b
S5-Arka fermented cocopeat inoculated with Arka microbial consortium	1.46 ^c	0.21 ^{cd}	2.26 ^d	0.98 ^c	0.45 ^d	0.86 ^d	1113.49 ^a	117.30 ^c	26.57 ^d	38.10 ^b
S6-Cocopeat: Soil	1.47 ^c	0.27 ^b	2.38 ^{cd}	1.18 ^a	0.49 ^{cd}	1.09 ^b	852.20 ^c	148.50 ^a	29.76 ^{bcd}	16.20 ^c
S7-Cocopeat	1.54 ^{bc}	0.22 ^{bc}	2.77 ^b	1.14 ^{ab}	0.44 ^d	0.98 ^c	635.75 ^e	133.50 ^b	31.54 ^{bc}	13.20 ^c
CD	0.09	0.05	0.15	0.04	0.06	0.05	15.11	6.28	3.66	7.67
MSE	0.00	0.00	0.00	0.00	0.00	0.00	40.83	7.06	2.40	10.51
SE(m)	0.03	0.01	0.04	0.01	0.02	0.02	4.52	1.88	1.10	2.29
CV(%)	2.34	6.72	2.49	1.63	5.00	2.17	0.86	2.13	5.05	11.06

Root biomass also revealed the favourable response to sand, which recorded the highest fresh (5.53 g) and dry (1.25 g) root weights of cuttings. Cocopeat planted cuttings produced statistically comparable root biomass, with 4.99 g fresh and 1.23 g dry weight. Thus, sand appeared particularly favourable for secondary root proliferation and

biomass production, while cocopeat supported both primary root initiation and subsequent root development. Akram *et al.* (2025) [15] observed similar improved root number, length and biomass of guava softwood cuttings in sand when combined with an appropriate IBA treatment. These findings indicate that adequate root-zone aeration

can be particularly important for the development of a vigorous root system.

Arka Fermented Cocopeat enriched with AMC also produced encouraging rooting response, recording 14.83 primary roots, 45.33 secondary roots and root fresh and dry weights of 4.78 and 1.15 g, respectively. Fermented cocopeat possesses favourable physical characteristics for nursery production, while AMC introduces beneficial microorganisms associated with nutrient transformations and plant-growth promotion. The favourable rooting observed in this substrate may therefore be related to the combined physical and biological characteristics of the medium as suggested by Barman *et al.* (2016) [16] in jamun.

The conventional sand:soil:FYM (1:1:1) mixture produced an intermediate response in quality root production, with 13.50 primary roots, 50.50 secondary roots, 4.50 g fresh root weight and 1.14 g dry root weight of the cuttings. Although this mixture combines the drainage properties of sand with the structural and nutritional contributions of soil and FYM, it did not surpass sand or cocopeat alone. This suggests that, during the initial rooting phase, favourable physical conditions around the cutting base may be more important than increasing the nutrient content of the substrate. In contrast, cocopeat:vermicompost (1:1) produced the comparatively poorest root system, recording the lowest number of primary (7.00) and secondary roots (26.17) as well as the lowest fresh (2.54 g) and dry (0.64 g) root weights. Addition of vermicompost or soil may have altered the physical environment provided by cocopeat alone, thereby influencing moisture distribution, aeration or substrate structure. The cocopeat:vermiculite:perlite (1:1:1) mixture showed an intermediate rooting response, despite these materials being widely regarded as suitable components of propagation substrates. Interestingly, Sheikh *et al.* (2023) [14] obtained superior rooting of guava cuttings with cocopeat:vermiculite:perlite in a 3:1:1 ratio, whereas the present study used these components in equal proportions. This difference suggests that the relative proportion of individual components, rather than their presence alone, may influence substrate performance. A higher proportion of cocopeat could provide a different balance of moisture retention and aeration. However, differences in genotype, cutting material and propagation environment between experiments should also be considered (Joshi, 2024) [2].

Growing substrate significantly influenced shoot growth and survival of guava stem cuttings, although differences in number of sprouts, sprout length and leaf area were non-significant. The earliest sprouting (51.33 days) was observed in sand:soil:FYM (1:1:1) and cocopeat:vermiculite:perlite (1:1:1), indicating that these substrates provided favourable conditions for early establishment. Sheikh *et al.* (2023) [14] similarly reported substantial variation in sprouting and vegetative growth of guava cuttings among different substrate combinations. The nutrient composition and availability of sand:soil:FYM medium and cocopeat:vermiculite:perlite media might have facilitated more efficient absorption of water and nutrients by the cuttings.

The cocopeat:vermicompost (1:1) mixture produced the longest shoots (24.30 cm) and highest number of leaves (13.13), possibly due to the combined moisture-retaining properties of cocopeat and nutritional contribution of vermicompost. However, this treatment had comparatively poor root development and low survival (47.50%), indicating that vigorous shoot growth alone may not represent successful establishment. In contrast, sand produced moderate shoot growth but supported greater secondary-root production and root biomass, demonstrating that substrates may influence root and shoot development differently. Akram *et al.* (2025) [15] similarly observed that the medium favouring maximum root development in guava did not necessarily produce the greatest shoot growth.

The highest survival (72.50%) was recorded with cocopeat and sand:soil:FYM (1:1:1). Cocopeat was particularly promising because its high survival was accompanied by the highest primary-root number and comparatively high secondary-root production and root biomass. The favourable performance of cocopeat is consistent with Yadav *et al.* (2026) [17], who obtained 90.01% rooting and superior

root development of an interspecific guava rootstock in cocopeat. Sheikh *et al.* (2023) [14] also reported improved rooting and growth of guava cuttings in cocopeat-rich substrates.

In the present study, marked differences in the physical characteristics of the growing media were reflected in the rooting, shoot development and survival of guava stem cuttings. Bulk density ranged from 0.08 (cocopeat) to 1.10 g cc⁻¹ (sand), while maximum water-holding capacity (MWHC) varied from 30.70 (sand) to 832.90 per cent (Arka Fermented cocopeat). However, the rooting responses did not follow a simple relationship with these parameters, indicating that successful rooting was determined by the overall physical environment surrounding the cutting base. Among the media tried, sand the highest bulk density (1.10 g cc⁻¹) and lowest MWHC (30.70%), and was comparable to root production in cocopeat medium. Cutting planted in sand produced 14.83 primary roots and recorded the highest secondary-root number (59.83), root fresh weight (5.53 g) and dry weight (1.25 g). The low water retention of sand may have prevented prolonged saturation around the cutting base, providing more aeration and maintained conditions conducive to root development under regular irrigation. Comparable responses have been reported in guava, where sand or mineral based substrates supported good rooting when adequate moisture was maintained (Qadri *et al.*, 2018; Akram *et al.*, 2025) [18, 15].

Cocopeat showed an entirely different physical properties profile, having the lowest bulk density (0.08 g cc⁻¹) and very high MWHC (799.54%), yet it also supported superior rooting. It produced the highest number of primary and secondary roots, along with fresh and dry root biomass. Survival was also high at 72.50%, statistically comparable with sand. The ability of cocopeat to retain substantial moisture within a lightweight matrix may have provided a favourable environment for newly developing roots. The suitability of cocopeat for guava propagation is supported by Yadav *et al.* (2026) [17], who obtained 90.01% rooting and superior root development of leafy shoot cuttings of an interspecific guava rootstock in cocopeat. The findings of the present study are in alignment with Shilpa Shree *et al.* (2021) [4] who have reported promising rooting ability of growing media with low bulk density and high MWHC.

The cocopeat:vermiculite:perlite (1:1:1) medium also combined low bulk density (0.26 g cc⁻¹) with relatively high MWHC (390.62%). It produced an intermediate root response (11.83 primary and 39.17 secondary roots), but promoted early sprouting (51.33 days) and relatively long shoots (23.07 cm). Sheikh *et al.* (2023) [14] obtained superior rooting of guava cuttings in cocopeat-rich mixtures containing vermiculite and perlite. However, their best mixture contained cocopeat:vermiculite:perlite in a 3:1:1 ratio, whereas the present treatment contained these components equally. This difference indicates that the proportion of individual constituents can markedly alter the resulting physical environment as suggested by Oğuztürk *et al.* (2025) [19].

Cocopeat:vermicompost medium with intermediate bulk density (0.36 g cc⁻¹) and MWHC (210.60%), produced the poorest root development, recording only 7.00 primary roots, 26.17 secondary roots and root fresh and dry weights of 2.54 and 0.64 g, respectively. The comparatively poor rooting observed in this media may be associated with the high proportion of vermicompost, which could have altered the physical and chemical environment around the cutting base. Although the medium had moderate bulk density and water-holding capacity, its pore characteristics and possible accumulation of soluble nutrients may not have provided an optimum environment for adventitious root initiation. Bhusari *et al.* (2025) [16, 3] similarly reported poorer rooting of guava softwood cuttings in a soil:vermicompost medium than in a soil:perlite mixture.

The growing media differed considerably in their nutrient composition, indicating substantial variation in the nutritional environment available to guava cuttings. Media containing organic components such as FYM, vermicompost and cocopeat generally contained greater concentrations of macro- and micronutrients than sand. However, the rooting response did not correspond directly with nutri

ent concentration, suggesting that nutrient abundance alone was not sufficient to promote adventitious root formation. Cocopeat:vermicompost (1:1) medium was comparatively nutrient rich, recording high levels of N (0.49%), P (0.26%), K (0.75%), Ca (6.34%), Mg (0.97%), Zn (41.88 ppm), Mn (103 ppm) and Cu (58.50 ppm). Despite this, this medium produced the least-developed root system, with only 7.00 primary and 26.17 secondary roots and the lowest root fresh (2.54 g) and dry weight (0.64 g). This response indicates that greater nutrient availability in the rooting medium does not necessarily favour the early stages of adventitious rooting. Druege *et al.* (2019)^[20] explained that freshly excised cuttings initially depend largely on nutrients already stored within their tissues, with nutrient acquisition from the external medium becoming increasingly important as functional adventitious roots develop.

On the other side, sand contained negligible amounts of most nutrients but supported vigorous root formation, producing the highest number of secondary roots (59.83) and maximum root fresh (5.53 g) and dry weight (1.25 g). This further suggests that the nutritional status of the substrate was less critical during initial root induction than the overall conditions surrounding the cutting base. Nevertheless, survival in sand was only 55.00%, indicating that nutrient availability may become increasingly important for maintaining plantlets after root formation. Mineral nutrition has been shown to influence root-system development and subsequent establishment, although its effects depend on individual nutrients and the physiological stage of rooting (Shilpa Shree *et al.*, 2021)^[4].

Cocopeat showed a more balanced nutritional and biological response. It contained appreciable N (0.44%), K (0.50%), S (0.24%), Fe (50.56 ppm) and Cu (53.95 ppm) and produced the highest primary-root number (15.50), substantial secondary-root development (56.83) and 72.50% survival. Its superior establishment therefore appears to have resulted from the combined influence of substrate nutrition and its physical characteristics rather than from high nutrient concentration alone. A similar interaction between substrate characteristics and nutrient availability was demonstrated by Rymbai *et al.* (2025)^[21] in dragon fruit cuttings. Their soil:cocopeat:vermicompost (1:1:1) medium promoted superior rooting and survival together with enhanced N, P and K accumulation in roots and shoots. The contrasting performance of the present cocopeat:vermicompost (1:1) treatment indicates that the proportion and combination of substrate constituents can markedly modify their effects on rooting. Similarly, Saini *et al.* (2022)^[22] found that cocopeat:perlite:vermicompost (4:1:1) increased foliar N, P and K in rooted pomegranate plantlets compared with sand, demonstrating the importance of substrate composition in subsequent nutrient acquisition.

Overall, the present findings indicate that a nutrient-rich medium was not necessarily the most favourable medium for root induction in guava cuttings. The strong rooting observed in nutrient-poor sand and the weak rooting in nutrient-rich cocopeat:vermicompost clearly demonstrate this distinction. During the initial rooting phase, endogenous reserves and suitable root-zone conditions may be particularly important, whereas external nutrient supply assumes greater significance following the development of functional roots (Druege *et al.*, 2019)^[20].

The growing media markedly influenced the mineral nutrient status of rooted guava cuttings, with each medium exhibiting a distinct pattern of nutrient accumulation. Sand:soil:FYM favoured N accumulation, recording the highest tissue N (1.89%) and Mg (0.63%), along with comparatively high Ca. The presence of FYM together with soil may have provided a sustained nutrient source during plantlet establishment. In contrast, sand media which contained negligible quantities of most nutrients, resulted in the lowest tissue N (1.30%) and P (0.17%). Although sand supported excellent root proliferation, its relatively poor nutrient supply may have restricted subsequent accumulation of major nutrients. This finding is supported with Druege *et al.* (2019)^[20], who indicated that nutrient uptake from the rooting environment becomes increasingly important after functional adventitious roots are established.

The soilless mixture cocopeat:vermiculite:perlite maintained comparatively balanced plant nutrient concentrations, including N (1.63%), K (2.86%), Mg (0.52%) and S (1.21%). This suggests that a mixed substrate can provide conditions conducive to nutrient acquisition even when its inherent nutrient concentration is moderate. Similarly, Kapczyńska *et al.* (2020)^[23] demonstrated that propagation substrates containing porous components such as perlite influenced both root development and subsequent mineral composition of propagated plants. Arka fermented cocopeat enriched with AMC was particularly associated with micronutrient accumulation, especially Fe, which reached 1113.49 ppm, the highest among all media. In contrast, cocopeat:soil favoured P (0.27%), S (1.09%) and Mn (148.50 ppm) content in plants, indicating that combining cocopeat with soil modified the availability and uptake of several nutrients. Cocopeat alone was particularly favourable for K accumulation (2.77%) and simultaneously supported superior primary-root production and high survival. Thus, cocopeat provided a comparatively favourable combination of rooting performance and plant nutrient status. Overall, the results demonstrate that the composition of the growing medium determined the pattern of mineral accumulation in guava plantlets rather than uniformly increasing all nutrients. Similar media-dependent changes in nutrient uptake have been observed in chrysanthemum (Shilpa Shree *et al.*, 2021)^[4], pomegranate (Saini *et al.*, 2022)^[22] and dragon fruit cuttings (Rymbai *et al.*, 2025)^[21].

Conclusion

The findings highlighted the importance of rooting substrate characteristics in determining root development, plant survival, vegetative growth and nutrient uptake in guava softwood cuttings. Cocopeat favoured primary root production and plant survival, whereas sand enhanced secondary root formation and root biomass. The sand:soil:FYM (1:1:1) mixture facilitated better nutrient accumulation and plant establishment. Thus, cocopeat and sand:soil:FYM (1:1:1) offer promising options for improving the propagation efficiency of guava through softwood cuttings. Future research should focus on refining substrate combinations to optimize rooting and nutrient availability, along with evaluating their effectiveness under commercial nursery conditions and subsequent field establishment.

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