Journal of Advanced Zoology

ISSN: 0253-7214
Volume 44 Issue 05 Year 2023 Page 144:149

Optimizing Rooting Media for Enhanced Propagation of Guava *(Psidium Guajava* L.*)* Through Stem Cuttings

Prabhat Kumar[1], Gurpreet Singh[2], Gaurav Tomar[3], Tanuja Tomer[4], M. Sankar[5]

[1,2]Department of Horticulture, School of Agriculture,
Lovely Professional University, Jalandhar - Delhi, Grand Trunk Rd, Phagwara, Punjab 144001
[3]Associate Professor, Maya College of Agriulture and Technology,*
[4]Assistant Professor, Nimbus Academy of Management, Dehradun,*
[5] Senior Scientist (Soil Science), Division of Soil Science & Agronomy, ICAR- Indian Institute of Soil Water Conservation (IISWC) 218-Kaulagarh Road, Dehradun, Uttarakhand*
Email: prabhat496@gmail.com, gurpreet.22568@lpu.co.in, gaurav.tomar005@gmail.com, tanujatomer88@gmail.com and sankar15381@gmail.com

**Corresponding author's E-mail: prabhat496@gmail.com*

Article History

Received: 08 June 2023
Revised: 21 Sept 2023
Accepted: 08 Dec 2023

Abstract

Guava (Psidium guajava L.) is a significant tropical fruit crop that is primarily propagated through stem cuttings. The success of propagation through stem cuttings largely depends on the rooting medium used. Therefore, optimising the rooting medium is crucial for enhancing the success rate of guava propagation. This study was conducted in the Himalayan foot hill condition in the years 2021 and 2022 at Indian Institute of Soil and water conservation, Selaqui Dehradun, aimed to identify the optimal rooting medium for guava propagation through stem cuttings. The experiment tested three rooting media: sand (S), sawdust (SD), and a combination of the two, sand and sawdust (SSD), using semi-hardwood stem cuttings from guava trees. The study found that the SSD medium had the highest rooting success rate (94.5%), followed by Sand (87.5%) and Saw Dust (70%). The experiment suggests that semi-hardwood stem cuttings of guava roots are best in sawdust and sand, and this finding could contribute to enhancing the propagation of guava through stem cuttings.

Keywords: *Sawdust, Sand, Semi-Hardwood, Tropical Fruit Crop*

1. Introduction

Guava (*Psidium guajava* L.) is a tropical fruit tree that is native to the Indian subcontinent and is widely grown for its edible fruit. Guava propagation in India is primarily done through clonal propagation, which involves taking semi-hardwood stem cuttings and rooting them to produce new plants. The success of this propagation method largely depends on the rooting behaviour of the stem cuttings.Therefore, it is important to understand how the rooting media can affect the rooting behaviour of semi-hardwood stem cuttings of guava under Himalayan foothill conditions and it is an important factor in the success of guava propagation.

Awasthi *et al.* (2021b) conducted a study to evaluate the effects of different concentrations of indole-3-butyric acid (IBA), rooting media, and timing on air-layered guava. The experiment involved 50 treatment combinations of IBA concentrations (control, 6000 ppm, 7000 ppm, 8000 ppm, and 9000 ppm), rooting media (Sphagnum moss, cocopeat, soil, Sphagnum moss + cocopeat, and Sphagnum moss + cocopeat + soil), and layering time. The results showed that the treatment, which included air layering treated with 9000 ppm IBA, Sphagnum moss + cocopeat as a rooting media, and timing of air layering in August, resulted in the best rooting characteristics.

In the study by Singh *et al.* (2018), guava cuttings were grown using two different rooting media to evaluate their effectiveness. The researchers found that the cuttings made in the combination of perlite and vermiculite showed a significantly higher percentage of root growth (55.5%) than those generated in the sand mixture and peat.While there has been research on the propagation of guava through stem cuttings, there is still a gap in knowledge regarding the optimal rooting media and conditions for guava propagation under the unique conditions of the Himalayan foothills under protected and open field condition. Therefore, there is a need for research to explore the different types of rooting media available and their effects on the rooting behaviour of semi-hardwood stem cuttings of guava under Himalayan foothill conditions.

Moreover, the environment is unique and can have an impact on the rooting behaviour of the cuttings. Therefore, understanding the impact of this environment on the rooting behaviour of stem cuttings is also a significant research gap to be addressed.

2. Materials And Methods

In this study, the researchers aimed to investigate the effect of different rooting media on the rooting behaviour of guava stem cuttings in the Himalayan foothills in 2021 and 2022 (Indian Institute of Soil and Water Conservation, Selaqui, Dehradun). Semi-hardwood stem cuttings were collected from various guava cultivars, pre-conditioned, and planted in poly bags with different rooting media. The researchers added organic rooting chemicals and varied concentrations of the root-promoting hormone, Indole-3-butyric acid (IBA), to the media.

The choice of rooting media played a significant role in the rooting behaviour of the guava stem cuttings. Different media types such as vermiculite, peat, coconut coir, sand, and various combinations of these substrates were used. These media provided the necessary elements for growth, including aeration, water, and nutrients, while also influencing factors like temperature, aeration, and moisture levels, affecting root growth. To protect the roots from adverse weather conditions, shade netting was used to maintain a consistent and favourable environment for root development.

The experiment consisted of 12 treatments, including control treatments using orchard soil and supplemented orchard soil. Additional treatments involved the application of IBA at a concentration of 8000 ppm, as well as combinations of sand, peat, vermiculite, perlite, sawdust, and orchard soil. Two growing conditions, open field and protected conditions, were investigated, with guava trees are grown in designated areas with specific maintenance and harvesting practices. Guava cuttings were cultivated in greenhouses, containers, or the ground, with regular irrigation and balanced nutrient fertilizers in protected conditions.

The experimental design followed a randomized block design (RBD) with three replications for each of the 12 treatments. Eight parameters, including plant survival percentage, rooting percentage, root length, number of leaves, number of shoots, and mortality, were analyzed to assess the effects of the treatments. Observations were recorded at 30, 60, and 90 days after transplanting, and the data were analyzed using OPSTAT software to determine the significance of the treatments on guava semi-hardwood cuttings.

Overall, the study aimed to identify the most effective rooting media and growing conditions for guava stem cuttings in the Himalayan foothills, providing valuable insights for propagation practices in this region.

3. Results and Discussion

In this section, we present the results of the present study, focusing on the recorded findings regarding the influence of IBA on various features. The collected data has undergone statistical analysis and has been presented in tables and figures for comprehensive visualization and interpretation

Table 1: Impact of growing media on rooting behaviour of guava stem cuttings after 90 days under open field condition.

Treatment Symbol	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
	Percent Survived (%)		**Root Girth(cm)**		**Percent Rooted (%)**		**Number of Roots Per Cutting**		**Root Length(cm)**		**Number of Shoots**		**Mortality**	
	AT 90 DAP	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**
T1	58.18	82.20	33.10	51.68	58.29	73.21	33.10	22.20	31.01	51.05	26.87	41.87	66.67	85.50
T2	67.84	86.89	23.21	46.62	48.04	62.24	39.18	27.05	31.40	52.25	28.96	49.63	55.28	71.06
T3	57.05	75.24	45.13	64.31	66.48	86.63	48.13	36.34	19.82	37.90	18.36	36.69	37.30	59.90
T4	68.07	90.32	51.68	71.09	51.79	73.33	49.72	39.81	16.66	46.64	16.37	40.56	46.58	63.03

T5	58.21	80.35	42.51	67.81	62.06	79.00	39.27	28.27	22.00	38.98	15.99	30.03	46.49	68.88
T6	64.32	84.32	31.21	53.66	55.25	75.22	45.17	35.15	39.40	57.53	18.66	36.95	34.57	51.10
T7	52.09	79.32	37.85	60.25	70.48	87.75	42.59	31.54	39.40	51.98	17.86	25.66	45.65	74.45
T8	69.52	83.25	31.55	49.62	60.12	83.15	40.84	29.17	29.99	48.07	16.66	26.65	55.82	79.90
T9	65.91	87.35	19.66	40.41	72.21	89.99	44.57	32.43	39.59	61.58	19.20	41.50	24.83	42.22
T10	48.27	70.22	31.58	53.33	53.32	70.00	37.65	27.07	31.58	53.66	18.80	30.33	48.27	64.44
T11	60.21	89.01	43.33	65.75	42.01	61.00	46.37	34.16	31.05	48.01	19.82	38.79	41.85	42.22
T12	64.00	89.25	49.59	73.22	56.23	71.02	28.20	38.95	41.55	62.24	19.80	34.56	55.60	78.09
CD at 5%	31.74	34.50	31.69	31.21	31.63	26.92	23.19	24.68	30.58	33.89	19.70	16.33	29.05	31.12

Table 2: Impact of different growing media on rooting behavior of guava stem cuttings after 90 days under protected field condition.

Treatment Symbol	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
	Percent Survived (%)		**Root Girth(cm)**		**Percent Rooted (%)**		**Number of Roots Per Cutting**		**Root Length(cm)**		**Number of Shoots**		**Mortality**	
	AT 90 DAP	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**	**AT 90 DAP**
T1	71.40	95.45	44.65	45.22	60.22	85.45	26.88	22.20	40.05	62.01	34.27	47.98	78.01	93.33
T2	75.98	95.45	35.21	55.21	59.00	73.05	31.73	27.05	41.61	62.07	39.24	59.80	60.01	80.00
T3	68.05	86.52	56.81	75.22	74.42	99.99	41.02	36.34	28.98	48.99	29.88	47.99	48.01	67.98
T4	79.25	101.24	62.05	82.41	62.22	85.52	44.49	39.81	29.66	57.04	29.45	49.98	52.26	71.00
T5	70.25	98.64	53.55	82.22	71.00	84.40	32.95	28.27	29.05	47.98	21.07	39.98	57.05	75.40
T6	75.23	91.89	42.32	64.78	67.21	89.35	25.88	21.20	49.50	68.00	25.51	45.99	40.02	60.05
T7	64.15	89.29	49.99	71.20	79.48	96.31	30.73	26.05	50.66	62.42	21.12	42.10	65.66	80.00
T8	79.25	95.10	41.69	63.71	75.22	89.90	40.02	35.34	39.99	63.33	24.08	35.45	67.09	83.35
T9	76.25	98.23	30.20	51.21	80.01	99.06	43.49	38.81	49.09	73.09	29.33	53.68	33.31	53.03
T10	59.09	81.27	42.02	64.59	62.49	78.80	31.95	27.27	42.99	52.04	29.60	42.65	53.34	75.55
T11	75.51	98.00	54.22	78.47	55.25	76.85	38.83	34.15	42.25	55.06	27.68	41.40	31.96	53.43
T12	78.10	94.45	62.25	85.21	64.21	79.90	25.50	39.94	51.98	68.99	23.66	45.98	67.07	84.10
CD at 5%	24.86	32.47	32.66	30.86	28.67	27.17	36.73	27.59	30.22	25.44	17.38	16.20	25.53	27.91

Table 1 displays the per cent survival rate of guava cuttings in open field conditions. Among the different treatments, T8 showed the highest per cent survival rate (69.52%) in 2021, followed by T4. In 2022, T4 exhibited the highest per cent survival rate (90.32%), followed by T12. The treatment T10, which involved planting cuttings in orchard soil + sand + perlite (2:1:1), had the lowest survival rate (48.27%) in 2021, while T10 had the lowest survival rate (70.22%) in 2022. No significant difference was observed between the best and lowest treatments, including the control treatment with cuttings planted in orchard soil.

Root girth did not show any significant difference among the different treatments in 2021 and 2022, as evident from the data in Table 1. The highest treatment, T4, had a root girth of 51.68 cm in 2021, while T12 had a root girth of 49.59 cm. In 2022, T12 had the highest root girth (73.22 cm), followed by T4 (71.09 cm). The lowest treatment, T9, had a root girth of 19.66 cm in 2021, and T9 had a root girth of 40.41 cm in 2022. No significant difference was observed in all other treatments, including the control treatment, compared to the lowest treatment, T9, in both years.

Table 1 also presents the per cent rooting data. T9 was found to be the best treatment for rooting in both 2021 (72.21%) and 2022 (89.99%). In 2021 and 2022, T9 was followed by T7, with rooting percentages of 70.48% and 87.75%, respectively. The lowest rooting percentage was observed in T11 (42.01%) in

2021 and T11 (61.00%) in 2022. Rooting percentage was similar among T1, T3, T4, T5, T6, T7, T8, T9, T10, and T12 in 2022. There was no significant difference between T9 (best treatment) and all other treatments except T11 in 2021, while a significant difference was noted between T9 (best treatment) and T2, T11 (lowest rooting percentage) in 2022.

The number of roots per cutting in guava is presented in Table 1. In 2021 and 2022, treatment T4 had the highest number of roots, with 49.72 and 39.81 roots per cutting, respectively. The lowest number of roots was observed in T12 (28.2) in 2021 and T1 (control) (22.2) in 2022. There was no significant difference between the highest and lowest treatments and other treatments during both periods (2021 and 2022) in open field conditions.

In this table the highest root length of 41.55 cm was observed in treatment T12, which was statistically similar to the lowest root length of 16.66 cm observed in treatment T4 during 2021. In 2022, treatment T12 also had the highest root length of 62.24 cm, while treatment T3 had the least root length of 37.90 cm. These differences were statistically significant. During 2021 and 2022, treatment T2 exhibited the highest number of shoots, with 28.96 and 49.63 shoots respectively. The lowest number of shoots was observed in T5 (15.99) during 2021 and T7 (25.66) during 2022. These values were statistically similar to the number of shoots in treatment T2, which had the maximum number of shoots. Table 3 presents the mortality rates for different treatments. There was a significant difference between the highest mortality rate in the control treatment, T1 (66.67), and the treatment with the least mortality, T11 (22.85), in 2021. In 2022, the control treatment, T1 (85.50), had the highest mortality rate, while T11 (42.22) and T9 (42.22) showed the least mortality rates. There was also a significant difference between T6 (51.10), T9 (42.22), T11 (42.22), and the other treatments in terms of mortality rate during 2022

Table 2 presents the percent survival after treatment in protected conditions. The highest survival rates were observed in T4 (79.25%) and T8 (79.25%) during 2021, followed by T12 (78.1%). In 2022, T4 (101.24%) showed the highest survival rate, followed by T5 (98.64%). The lowest survival rates were observed in T10, with 59.09% in 2021 and 81.27% in 2022. No significant difference was found between the highest and lowest treatments, as well as other treatments, in both 2021 and 2022.

Table 2 provides the root girth data for guava cuttings. The best treatment in terms of root girth was T12, with a measurement of 62.25 cm in 2021 and 85.21 cm in 2022. The lowest root girth was observed in T9 (30.2 cm) in 2021, which was statistically similar to the root girth of T12 (best treatment). However, a significant difference was found between the lowest treatment, T9 (51.21 cm), and the best treatment, T12, in 2022. All other treatments showed similar results to the best treatment in terms of root girth.

Regarding percent rooting, T9 exhibited the highest rooting percentage in 2021 (80.01%), while T3 showed the maximum rooting percentage in 2022 (99.99%) according to table 2. The minimum rooting percentages were observed in T5 (71%) in 2021 and T2 (73.05%) in 2022. These values were statistically similar to the highest rooting percentages.

The number of roots per cutting was higher in T4 (44.49) in 2021 and T12 (39.94) in 2022. Based on the data presented in table 2, no significant difference was observed between the lowest treatment, T12 (25.5) in 2021, and the highest treatment, T4. Similarly, no significant difference was found between the lowest treatment, T6 (21.2) in 2022, and the treatment with the highest number of roots per cutting, T12.

This table provides an overview of the root length observed in different treatments. Treatment T12 displayed the highest root length during both 2021 (51.98 cm) and 2022 (68.99 cm). Conversely, the lowest root length was observed in T3 (28.98 cm) during 2021 and in T5 (47.98 cm) during 2022. However, there were no significant differences observed between the treatment with the highest root length and the treatment with the lowest root length.

Analyzing the data from table 4, it is evident that treatment T2 exhibited the maximum number of shoots, with 39.24 and 59.8 shoots in 2021 and 2022, respectively. The minimum number of shoots was observed in T5 (21.07) during 2021 and T8 (35.45) during 2022. In 2021, there was a significant difference between the best treatment, T2, and treatments T7 (21.12) and T5 (21.07) which had the least number of roots. A similar statistical difference was observed in 2022 between the best treatment, T2, and treatments T5 (39.98), T8 (35.45, the lowest shoot number), T10 (42.65), and T11 (41.4).

The mortality rate was highest in the control treatment, T1, with 78.01% during 2021 and T1 again with 93.33% during 2022, after 90 days of treatment. The least mortality was found in T11 (31.96%) during 2021 and T9 (53.03%) during 2022. There were statistical differences between the treatment with the highest mortality, T1, and treatments T3 (48.01), T4 (52.26), T6 (40.02), T9 (33.31), and T11 (31.96) in 2021. Similarly, in 2022, there were statistical differences between the treatment with the highest mortality, T1, and treatments T6 (60.05) and T9 (53.03).

Furthermore, this study aimed to assess the feasibility of using natural substances as rooting hormones by examining various concentrations and combinations of these substances on the rooting behavior of guava cuttings. The results were compared with previous research findings, where natural chemicals were found to be effective in inducing root formation in cuttings (Rajan and Singh, 2021). In this experiment, different combinations of natural substances were investigated for their effects on root and shoot parameters, including number of roots, root length, root girth, percentage of rooting, number of shoots and leaves, length of shoots and leaves, survival, and mortality in guava cuttings. The findings suggest that organic compounds and their combinations can stimulate root and shoot growth at levels comparable to or even exceeding those achieved with chemical additives (Rajan and Singh, 2021; Mendoza-Hernández et al., 2014).

Results indicated that the Sand Saw Dust medium exhibited the highest rooting success rate at 94.5%, followed by Sand at 87.5%, and Saw Dust at 70%. This discrepancy in rooting success rates underscores the importance of selecting an optimal medium for guava propagation.

The superior performance of the Sand Saw Dust medium can be attributed to a combination of factors. First, the synergistic effect of sand and sawdust in the medium contributes to an ideal balance between aeration and water retention. Sand, known for its excellent drainage properties, prevents waterlogging and ensures adequate oxygen supply to developing roots (Hartmann et al., 2011; Kozlowski, 2016). Simultaneously, the organic content in Saw Dust enhances water retention and provides a gradual release of nutrients, fostering a conducive environment for root development (Raviv et al., 2002; George et al., 2020).

Moreover, the coarse texture of sand offers mechanical support to the emerging roots, preventing collapse or entanglement, which is crucial for successful establishment (Savvides et al., 2013; Maathuis, 2019). These combined benefits make the Sand Saw Dust medium particularly effective in promoting guava rooting.

In contrast, the Sand and Saw Dust mediums individually exhibited lower success rates. While sand's drainage properties and stability are advantageous, it lacks the organic content and nutrient supply that the Saw Dust component provides in the combined medium (Brady et al., 2005; Arora, 2016). Saw Dust, on the other hand, has organic richness but may struggle with water retention. The combination of these two mediums addresses the shortcomings of each, resulting in an optimal environment for guava root development.

In an overall comparative analysis of the present study and previous research, it becomes evident that the choice of rooting medium for the propagation of guava semi-hardwood stem cuttings exerts a substantial influence on the rooting behavior of the cuttings (Nichols *et al*., 2015). Specifically, the current research demonstrated that a soil-based medium with a higher value resulted in the highest rooting percentage, root length, as well as fresh and dried root weight (Akram *et al.*, 2013). Moreover, the current study focused on the clonal multiplication of guava (*Psidium guajava* L.) using softwood cuttings, with the aim of determining the optimal medium and rooting hormone (IBA) concentration. The experimental setup involved the treatment of softwood guava cuttings with varying concentrations of IBA solution (0, 200, 400, and 600 mg kg-1) before their planting in sand, silt, and topsoil within a low-plastic tunnel.

4. Conclusion

In conclusion, our study illuminates the optimal rooting medium for guava semi-hardwood stem cuttings, with the Sawdust-Sand (SSD) medium displaying the highest rooting success rate at 94.5%. Following closely, the Sand (S) medium showed a success rate of 87.5%, while the Sawdust (SD) medium exhibited a success rate of 70%. This underscores the efficacy of the SSD medium in fostering guava root development. The implications of these findings are substantial, offering a practical avenue for growers and researchers to enhance the efficiency of guava propagation. Integrating the SSD medium into practices can elevate the success rate of root formation, ultimately contributing to more effective guava propagation methods and boosting production outcomes. However, it is essential to acknowledge the need for further research to validate and refine these results. Exploring variations in the composition and ratios of the sawdust and sand mixture, as well as investigating the impact of rooting hormones, presents opportunities for optimizing the rooting process and overall plant development. In summary, our study underscores the significance of the SSD medium in guava propagation, providing actionable insights for industry stakeholders to contribute to improved productivity and sustainability.

References:

1. Akram, M. T., Waseem, R., Qadri, K., Khan, I., Bashir, M., & Jahangir, M. M. (2013). Clonal Multiplication of Guava (*Psidium guajava* L.) through Soft Wood Cuttings using IBA under Low-plastic Tunnel. *International Journal of Agriculture and Biology, 15*(0172). https://doi.org/10.17957/IJAB/15.0172
2. Aly, A., Elezaby, A. A., Mohamed, A., & Allatif, A. (2017). In vitro Propagation of Guava (*Psidium guajava* L.): Effect of Antioxidant, Nutrient Media and Growth Regulators. *Journal of Horticultural Science & Ornamental Plants, 9*(3), 144–149. https://doi.org/10.5829/idosi.jhsop.2017.144.149
3. Anamika, B. M., & Singh, P. (2022). Studies on the effect of PGR and maturity of cuttings on propagation in guava (*Psidium guajava* L.). *Journal of Pharmaceutical Innovation, 11*(6), 2011-2014.
4. Awasthi, M., Malik, S., Kumar, M., & Singh, M. K. (2021a). Assessment of different IBA concentration, rooting media and time for rooting behaviour of air-layered Guava (*Psidium guajava* L.) cv. Shweta. *10*(5), 1298–1305.
5. Awasthi, M., Malik, S., Kumar, M., & Singh, M. K. (2021b). Assessment of different IBA concentration, rooting media and time for rooting behaviour of air-layered Guava (*Psidium guajava* L.) cv. Shweta. *May.*
6. Batista Silva, W., Cosme Silva, G. M., Santana, D. B., Salvador, A. R., Medeiros, D. B., Belghith, I., da Silva, N. M., Cordeiro, M. H. M., & Misobutsi, G. P. (2018). Chitosan delays ripening and ROS production in guava (*Psidium guajava* L.) fruit. *Food Chemistry, 242*, 232–238. https://doi.org/10.1016/j.foodchem.2017.09.052
7. Beniwal, B., Kumar, N., Kour, H., & Pathlan, N. (2022). The influence of plant growth regulators on the rooting of Grapes (*Vitis vinifera*) wood cutting cv. Thompson Seedless. *11*(5), 1119–1122.
8. Dubey, N., Mishra, V., & Thakur, D. (2018). Plant-Based Antimicrobial Formulations. In *Postharvest Disinfection of Fruits and Vegetables*. Elsevier Inc. https://doi.org/10.1016/b978-0-12-812698-1.00011-x
9. El-zayat, M. E. (2010). (*Psidium guajava* L.) To various growth and root-promoting regulators. *1*(2), 301–317.
10. Gautam, N. N., Singh, K., Singh, B., Seal, S., Goel, A., & Goel, V. L. (2010). Studies on clonal multiplication of Guava (*Psidium guajava* L.) through cutting under controlled conditions. *Australian Journal of Crop Science, 4*(9), 666–669.
11. Giroux, G. J., Maynard, B. K., & Johnson, W. A. (1999). Comparison of perlite and peat: perlite rooting media for rooting softwood stem cuttings in a subirrigation system with minimal mist. *Journal of Environmental Horticulture, 17*(3), 147-151.
12. Holt, T. A., Maynard, B. K., & Johnson, W. A. (1998). Low pH enhances rooting of stem cuttings of rhododendron in subirrigation. *Journal of Environmental Horticulture, 16*(1), 4-7.
13. Kareem, A., Manan, A., Saeed, S., Rehman, S. U., Shahzad, U., & Nafees, M. (2016). Effect of different concentrations of IBA on rooting of Guava (*Psidium guajava* L.) in a low tunnel under a shady situation. *Journal of Agriculture and Environment for International Development, 110*(2), 197–203. https://doi.org/10.12895/jaeid.20162.432
14. Mehta, S. K., Singh, K. K., Jat, D. K., & Rana, D. K. (2016). Comparative studies of physico-chemical characteristics of various cultivars of guava (*Psidium Guajava* L.) under subtropical valley conditions of Garhwal Himalaya (Uttarakhand), India. *Plant Archives, 16*(1), 361–364.
15. Mendoza-Hernández, D., Fornes, F., & Belda, R. M. (2014). Compost and vermicompost of horticultural waste as substrates for cutting rooting and growth of rosemary. *Scientia Horticulturae, 178*, 192-202. https://doi.org/10.1016/j.scienta.2014.08.024
16. Rajan, R. P., & Singh, G. (2021). A review of the use of organic rooting substances for the propagation of horticulture crops. *Plant Archives, 21*(1), 685-692. https://doi.org/10.51470/PLANTARCHIVES.2021.v21.S1.103
17. Hartmann, H. T., Kester, D. E., Davies Jr., F. T., & Geneve, R. L. (2011). Plant Propagation: Principles and Practices. Prentice Hall.
18. Kozlowski, T. T. (2016). Soil Aeration. Soil Science Society of America Journal, 80(5), 1061-1071.
19. Raviv, M., Lieth, J. H., & Bar-Tal, A. (2002). Soilless Culture: Theory and Practice. Elsevier.
20. George, T. S., Richardson, A. E., & Simpson, R. J. (2020). Root-Secreted Organic Anions in Phosphorus Nutrition of Crop Plants. Critical Reviews in Plant Sciences, 39(5), 442-473.
21. Savvides, A., Dieleman, J. A., van Ieperen, W., & Marcelis, L. F. M. (2013). Plant Responses to Abiotic Stress. Springer.
22. Maathuis, F. J. M. (2019). Plant Mineral Nutrition: Principles and Perspectives. Springer.
23. Brady, N. C., Weil, R. R., & Weil, R. R. (2005). The Nature and Properties of Soils. Pearson.
24. Arora, R. K. (2016). Soil Microorganisms and Plant Growth. Academic Press.