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Comparative Study on Response of Rose Semi-Hardwood Cuttings to Root Induction and Establishment Using Different Rooting Hormones and Unconventional Organic Compounds

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Abstract

The present investigation evaluated the response of rose semi-hardwood cuttings to synthetic rooting hormones and unconventional organic compounds under Prayagraj agro-climatic conditions. The experiment was conducted at the Horticultural Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, India, from September 2025 to February 2026. A completely randomised design comprising 13 treatments, three replications, and 195 cuttings was used. Treatments included different concentrations of indole-3-butyric acid (IBA) and naphthalene acetic acid (NAA), together with *Aloe vera* gel, coconut water, and honey. IBA at 1000 ppm recorded 100% rooting, 52.33% sprouting, three sprouts per cutting, 100% survival, and 100% field establishment. NAA at 1000 ppm also achieved 100% rooting, survival, and field establishment and produced the longest roots (16.9 cm). Coconut water for 12 hours resulted in the earliest sprouting (8 days), the highest sprout length (23.7 cm), 13 leaves, and 10 roots per

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cutting, with 93.33% rooting and 96.67% survival. Coconut water for 24 hours produced the widest root spread (11.4 cm). *Aloe vera* gel applied for 2 minutes recorded the highest benefit-cost ratio (2.58). These findings indicate that both synthetic auxins and selected organic treatments can support effective rose cutting establishment under the conditions of this study.

Keywords: Aloe vera; coconut water; local honey; IBA; NAA; root induction; rose; semi-hardwood cuttings.

1. Introduction

Roses (*Rosa* spp.) are among the most extensively cultivated ornamental plants worldwide, valued for their aesthetic appeal, fragrance, and economic importance. They are indigenous to a wide geographic range encompassing the Himalayan regions, West Asia, China, Japan, Europe, and North America. Although approximately 150 species have been identified, only a limited number such as *Rosa gallica*, *R. damascena*, *R. chinensis*, *R. foetida*, *R. gigantea*, *R. moschata*, *R. multiflora*, and *R. wichuriana* have played a foundational role in the development of modern rose cultivars (Hussain & Khan, 2004). India is recognised as a major global producer of roses, contributing significantly to both domestic floriculture markets and international trade. States such as Karnataka (notably Bengaluru), Maharashtra, Tamil Nadu, West Bengal, and Rajasthan serve as principal centres of rose cultivation. The sector not only supports large-scale exports to countries including the United Arab Emirates, Japan, Australia, and various European nations but also provides substantial employment in rural areas through activities related to cultivation, processing, and marketing.

Propagation is a critical step in rose cultivation, directly influencing the efficiency and fidelity of varietal reproduction. While several propagation techniques are available, including seed propagation, budding, grafting, layering, and cuttings, vegetative propagation of rootstocks and stem cuttings is most widely used for maintaining genetic uniformity and desirable horticultural traits. In particular, semi-hardwood cuttings are preferred due to their optimal balance of maturity and flexibility, which favours root initiation and plant establishment (Dawa *et al.*, 2017). To enhance rooting success, synthetic auxins such as Indole-3-butyric acid (IBA) and Naphthalene acetic acid (NAA) are commonly employed. These compounds are known to stimulate root primordia development and accelerate the rooting process (Susaj *et al.*, 2012). In parallel, increasing attention has been directed towards natural rooting biostimulants such as coconut water, *Aloe vera* gel, and honey. These natural substances contain bioactive compounds, including plant hormones and antimicrobial agents, which may enhance root induction and reduce the risk of infection in cuttings (El-ahmir *et al.*, 2021; Mirihagalla & Fernando, 2020; Narula & Stokes, 2021). Investigating the efficacy of these natural alternatives is vital for developing sustainable and environmentally friendly propagation methods.

Recent research in rose has shown that the rooting and survival responses of semi-hardwood cuttings to IBA can vary with concentration and planting time, supporting treatment-specific optimisation in vegetative propagation (Gupta *et al.*, 2024). A recent stem-cutting study in another horticultural crop likewise reported differential rooting, shoot development, and survival responses to IBA and NAA concentrations, indicating the need to evaluate auxin treatments under crop-specific conditions (Patel *et al.*, 2026). Recent studies on rose cuttings also show that adventitious rooting responses vary with plant material and propagation treatment, reinforcing the value of comparative assessment of rooting strategies (Wamhoff *et al.*, 2024; Morales Orellana *et al.*, 2024; Sran *et al.*, 2025).

Rose cultivation holds significant agronomic, economic, and aesthetic importance globally and in India, with the country emerging as a major producer and exporter. This growth has intensified the demand for efficient, sustainable, and cost-effective propagation techniques. While synthetic auxins such as IBA and NAA are widely used to promote root development, concerns regarding their accessibility, cost, environmental impact, and residual toxicity pose challenges, particularly for smallholder and organic farmers. In light of the global shift toward sustainable agriculture, there is a growing need to explore natural alternatives such as coconut water, natural *Aloe vera* gel and local honey, which are rich in phytohormones, antioxidants, and antimicrobial compounds that aid in root induction and disease resistance (Ibironke, 2017; Wagan *et al.*, 2023). However, research on these natural substances remains limited and often lacks comprehensive comparisons across species and cutting types. Therefore, investigating their efficacy in promoting root initiation in rose semi-hardwood cuttings is both scientifically and practically significant. Such a study could lead to the development of low-cost, eco-friendly propagation protocols that support organic floriculture, reduce reliance on synthetic agrochemicals, and empower marginal farmers.

1.1 Objective

The objective of the present study was to compare the effects of different concentrations of IBA and NAA, as well as selected unconventional organic compounds (Aloe vera gel, coconut water, and local honey) on root induction, sprouting, survival, and field establishment of rose semi-hardwood cuttings under Prayagraj agro-climatic conditions.

2. Materials and Methods

The experimental trial was conducted from September 2025 to February 2026 at the Horticulture Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), located in Prayagraj, Uttar Pradesh, India. The experimental site is situated at 25.41° North latitude and 81.84° East longitude, with an altitude of 98 metres above mean sea level (MSL). The region experiences a humid subtropical climate characterised by warm, humid monsoons, hot, dry summers, and cold, dry winters. The annual mean temperature is 26.1°C, while monthly mean temperatures range from 18–29°C. The daily average maximum temperature is approximately 22°C, and the minimum temperature is 9°C. The average annual rainfall is 1042.2 mm. During the experimental period, maximum temperatures ranged from 33.3°C to 25.6°C, while minimum temperatures ranged from 22.5°C to 7.5°C. Relative humidity varied between 73.6% and 87.9%, with total rainfall of 24 mm recorded during September 2025.

A total of 195 semi-hardwood stem cuttings of uniform thickness and length (approximately 15-20 cm) were procured from the Indian Agricultural Research Institute (IARI), New Delhi, India. Each cutting retained 3-4 nodes, and the basal end was given a slant cut to facilitate hormone uptake. The rooting medium comprised a thoroughly mixed combination of sand and soil in a 1:1 ratio (v/v), which was placed in black 8 × 12-inch polythene bags.

Chart 1. Experimental details

Name of the crop	:	Rose
Botanical name	:	*Rosa indica*
Family	:	Rosaceae
Planting material	:	Semi-hardwood stem cuttings
Design of experiment	:	Completely Randomized Design (CRD)
Number of treatments	:	13
Number of replications	:	3
Number of cuttings per polybag	:	5
Total number of cuttings	:	195
Rooting media	:	Sand + soil (1:1 v/v)
Container	:	8-inch polybags

Chart 2. Treatments details

Notation	Treatment details
T_0	Control
T_1	IBA @ 1000 ppm
T_2	IBA @ 2000 ppm
T_3	IBA @ 3000 ppm
T_4	NAA @ 500 ppm
T_5	NAA @ 1000 ppm
T_6	NAA @ 1500 ppm
T_7	Aloe vera gel dip for 2 minutes
T_8	Aloe vera gel dip for 5 minutes
T_9	Coconut water dip for 12 hrs
T_{10}	Coconut water dip for 24 hrs
T_{11}	Honey dip for 2 minutes
T_{12}	Honey dip for 5 minutes

2.1 Preparation of Synthetic Hormone Solution (IBA & NAA)

The synthetic hormones, IBA and NAA, were of analytical grade. These were not very soluble in water; therefore, an accurately weighed quantity of the hormone powder was dissolved in a minimum quantity (10 ml) of 95% ethanol. The alcoholic solution so prepared was diluted with distilled water in a 1L flask, and the final volume was made up to 1000 ml with distilled water.

2.2 Preparation of Organic Compound Treatments

***Aloe vera* gel (T_7 and T_8):** Fresh leaves of *Aloe vera* were harvested. The thick epidermis was carefully peeled off, and the translucent, mucilaginous gel was scooped out. The gel was homogenized into a uniform, viscous paste. This fresh, undiluted gel was used directly as a dip treatment for the specified durations (2 and 5 minutes).

Coconut water (T_9 and T_{10}): The coconut water was freshly extracted by draining the liquid endosperm after making a clean cut at the top of the nut. The extracted water was filtered. The fresh, tender coconut water was used undiluted as a soaking medium for the basal ends of cuttings for 12 and 24 hours.

Honey (T_{11} and T_{12}): Local honey was procured from a certified local source. Pure, undiluted honey was used directly as a dip for the basal portions of the cuttings for 2 and 5 minutes.

Treated cuttings were planted individually in polybags containing the rooting medium, and the medium around each cutting was pressed firmly to eliminate air pockets. All polybags were placed in a shaded area to provide favourable conditions for root initiation. Light irrigation was provided immediately after planting and repeated as needed to keep the medium moist but not waterlogged.

2.3 Field Establishment

The main field was ploughed twice to achieve a fine tilth, and weeds and residues were removed. Pits 30 cm deep were dug at the recommended spacing and filled with a mixture of soil and well-decomposed vermicompost (500 g/plant) along with neem cake (100 g/plant) and fungicide before transplanting. The rooted cuttings from each treatment were carefully removed from polybags without disturbing the root ball and transplanted into the prepared pits on 15th November 2025. After each plant was placed, the pit was filled with soil and pressed gently to ensure good root-soil contact. Regular hand weeding and hoeing were carried out at intervals of 20-25 days from the day of transplanting.

2.4 Observations Recorded

Five cuttings were randomly selected and tagged in each treatment for recording various observations.

Vegetative Parameters:

- Days to first sprouting – recorded from date of planting
- Sprouting percentage (%) – recorded at 30 days after planting
- Survival percentage (%) – recorded at 90 days after planting
- Number of leaves per cutting – recorded at 15 and 30 days after planting
- Length of first sprout (cm) – recorded at 30, 60, and 90 days after planting
- Number of sprouts per cutting – recorded at 90 days after planting
- Field establishment percentage (%) – recorded at 30 days after transplanting

Propagation Parameters:

- Rooting percentage (%) – recorded at 60 days after planting
- Number of roots per cutting – recorded at 60 days after planting
- Root length (cm) – recorded at 60 days after planting
- Root spread (cm) – recorded at 60 days after planting

2.5 Statistical Analysis

The data were statistically analysed using a completely randomised design (CRD). The significance of differences among treatment means was tested using an F-test. Wherever the F-test was found to be significant, the critical difference (C.D.) at the 5 percent level of significance was calculated. The results are presented in the form of graphs and tables for interpretation.

3. Results and Discussion

The data for the different parameters of rose semi-hardwood cuttings are presented in Table 1.

Table 1. Different parameters of rose semi-hardwood cuttings

Treatment	Treatment Details	Days to Sprouting	Sprouting Percentage (%)	Rooting Percentage (%)	No. of Roots per Cutting	Root Length (cm)	Root Spread (cm)	Field Establishment (%)
T_0	Control	9	28.33	83.33	6	15.43	8.13	95
T_1	IBA @ 1000 ppm	10	52.33	100	8	13.9	8.17	100
T_2	IBA @ 2000 ppm	10	47	93.33	8	13.66	7.87	96.67
T_3	IBA @ 3000 ppm	10	43.33	90	8	14.26	10.23	95
T_4	NAA @ 500 ppm	10	31.67	86.66	7	15.56	9.03	86.67
T_5	NAA @ 1000 ppm	11	33.33	100	7	16.93	8.43	100
T_6	NAA @ 1500 ppm	10	38.33	90	7	10.83	10.27	95
T_7	Aloe vera gel (2 min dip)	10	43	76.66	7	9.63	10.57	100
T_8	Aloe vera gel (5 min dip)	11	34.67	100	6	14.33	9.5	95
T_9	Coconut water (12 hrs dip)	8	41.33	93.33	10	16.43	10.57	95
T_{10}	Coconut water (24 hrs dip)	10	28.33	93.33	9	15.1	11.4	91.67
T_{11}	Honey solution (2 min dip)	9	34	76.66	8	13.36	8.23	86.67
T_{12}	Honey solution (5 min dip)	9	24.33	63.33	5	10.76	7.53	83.33
SE(d)+		0.678	6.642	5.847	0.62	1.831	0.857	4.75
CD0.05		1.401	13.729	12.085	1.27	3.784	1.771	9.85
CV (%)		8.477	22.033	8.119	10.16	16.171	11.375	6.12

3.1 Days Taken to First Sprouting

Significantly fewer days were required for first sprouting (8 days) in T9 (Coconut water dip for 12 hours), followed by T0 (control, 9 days). Significantly more time to first sprouting (11 days) was observed in T_5 (NAA @ 1000 ppm) and T_8 (*Aloe vera* gel 5-minute dip, also 11 days). The significantly earlier sprouting observed with coconut water (12-hour dip) can be attributed to its rich content of cytokinins, gibberellins, amino acids, vitamins, and natural sugars, which collectively stimulate metabolic activity, promote cell division in the nodal buds, and provide an immediate energy source for bud break, thereby accelerating the emergence of new shoots (Ibironke, 2017; Wagan *et al.*, 2023).

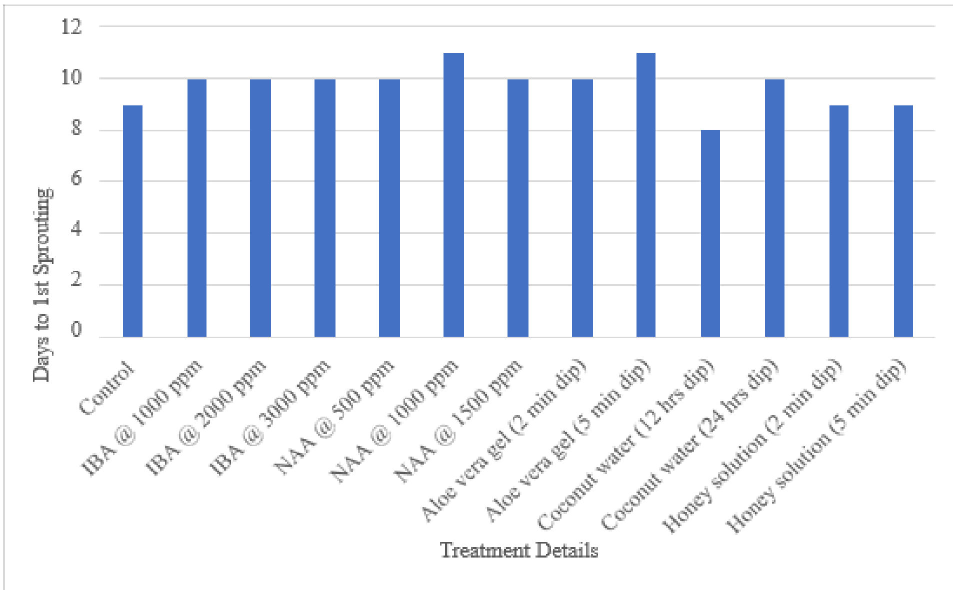

Fig. 1. Graph showing Effect of different rooting hormones and organic compounds on days to first sprouting in rose

3.2 Sprouting Percentage

Significantly higher sprouting percentage (52.33%) was recorded in T_1 (IBA @ 1000 ppm), followed by T_2 (IBA @ 2000 ppm) with 47.00%. Significantly lower sprouting percentage (24.33%) was recorded in T_{12} (Honey solution dip for 5 minutes). The significantly higher sprouting percentage observed with IBA at 1000 ppm can be attributed to its optimal auxin concentration that provides an appropriate balance between root and shoot initiation, whereby IBA promotes cell division and differentiation in both the cambial region (for roots) and the nodal buds (for shoots) without causing phytotoxicity, while its resistance to enzymatic degradation ensures sustained hormonal activity during the critical sprouting period (Abbas *et al.*, 2015; Hussain & Khan, 2004).

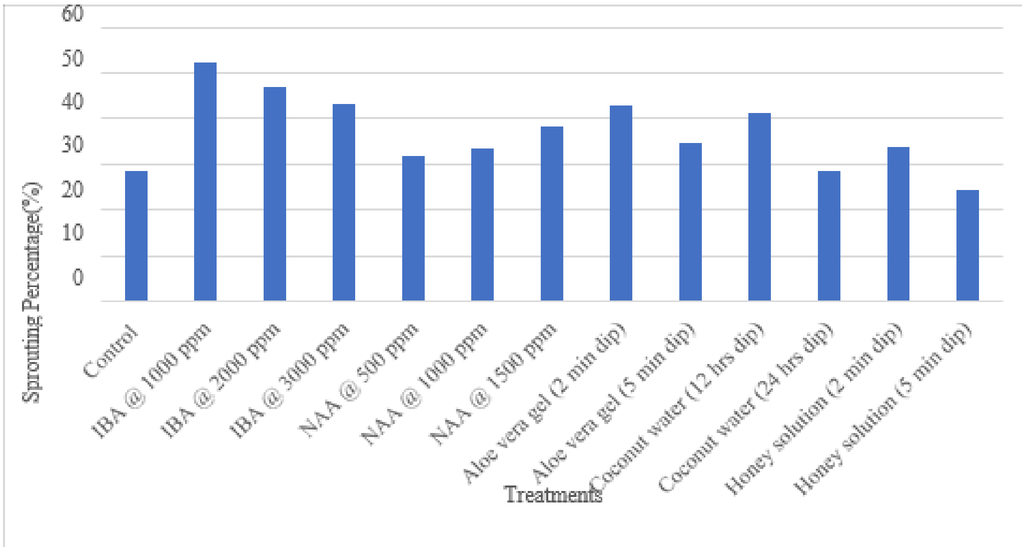

Fig. 2. Graph showing Effect of different rooting hormones and organic compounds on sprouting percentage in rose cuttings

3.3 Rooting Percentage (%)

Among all the treatments, a significantly higher rooting percentage (100%) was recorded in T_1 (IBA @ 1000 ppm), T_5 (NAA @ 1000 ppm) and T_8 (Aloe vera gel dip for 5 minutes), and these treatments were superior to all other treatments. These were followed by T_2 (IBA @ 2000 ppm), T_9 (Coconut water dip for 12 hours) and T_{10} (Coconut water dip for 24 hours), each recording 93.33% rooting. Significantly lower rooting percentage (63.33%) was observed in T_{12} (Honey solution dip for 5 minutes). The rooting percentage with IBA at 1000 ppm can be attributed to its role as a stable synthetic auxin that resists enzymatic degradation, activates auxin-responsive genes, and triggers dedifferentiation of cambial cells into root primordia at the cut base (Hussain & Khan, 2004). Similarly, NAA at 1000 ppm is a highly persistent synthetic auxin that binds strongly to auxin receptors, promoting rapid cell division and cambial activity without causing phytotoxicity at this optimal concentration (Dawa *et al.*, 2017; Susaj *et al.*, 2012).

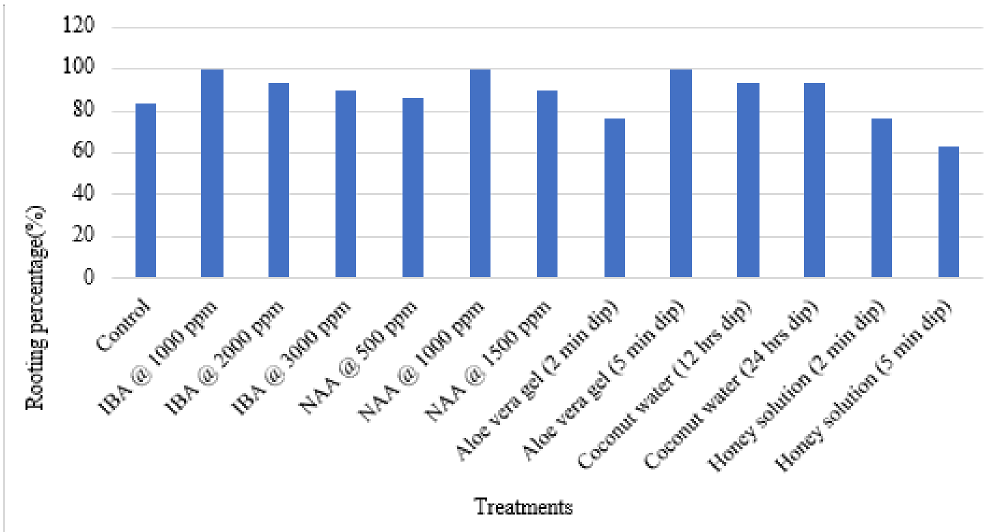

Fig. 3. Graph showing Effect of different rooting hormones and organic compounds on rooting percentage of rose cuttings

3.4 Number of Roots per Cutting

A significantly greater number of roots per cutting (10) was recorded in T9 (Coconut water dip for 12 hours), followed by T10 (Coconut water dip for 24 hours) with 9 roots per cutting. A significantly lower number of roots per cutting (5) was recorded in T_{12} (Honey solution dip for 5 minutes). The significantly higher number of roots per cutting observed with coconut water (12-hour dip) can be attributed to its rich composition of cytokinins (kinetin and zeatin), gibberellins, amino acids, vitamins, and minerals, which synergistically promote cell division in the cambial and pericycle cells, stimulate the formation of multiple root primordia, and enhance overall root proliferation (Ibironke, 2017; Wagan *et al.*, 2023).

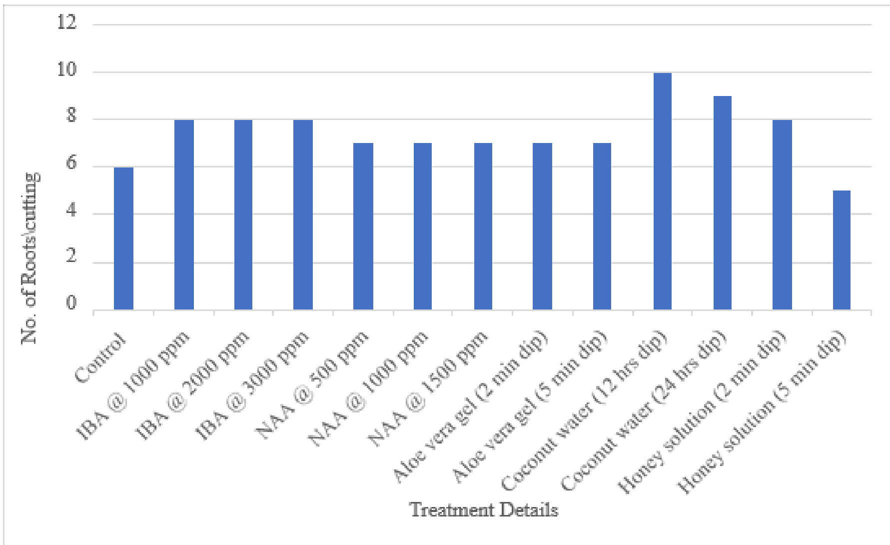

Fig. 4. Graph showing effect of different rooting hormones and organic compounds on number of roots in rose cuttings

3.5 Root Length (cm)

Significantly longer roots (16.9 cm) were recorded in T_5 (NAA @ 1000 ppm), which was at par with T_9 (Coconut water dip for 12 hours, 16.4 cm). Significantly shorter roots (9.6 cm) were recorded in T_7 (Aloe vera gel dip for 2 minutes). The significantly longer roots observed with NAA at 1000 ppm can be attributed to its auxin activity, which promotes cell production and elongation through polar auxin canalization, thereby enhancing root growth and elongation along the root axis through the acid growth hypothesis, in which NAA stimulates plasma membrane H^+-ATPase, causing cell wall acidification and loosening, thereby facilitating extensive root elongation (Susaj *et al.*, 2012; Wagan *et al.*, 2023). The equally remarkable root elongation with coconut water (12-hour dip) is due to its rich composition of cytokinins, gibberellins, amino acids, vitamins, and minerals, which synergistically promote cell division and elongation, while the natural sugars present provide an energy source for sustained root growth (Wagan *et al.*, 2023).

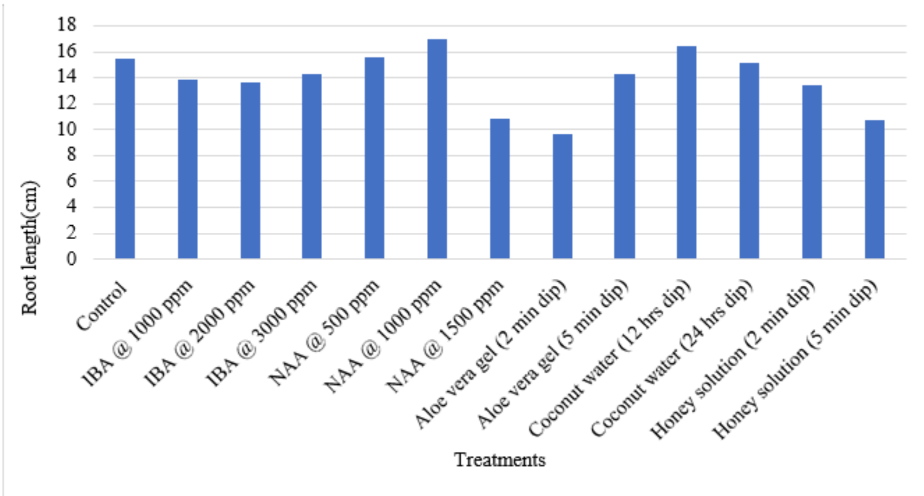

Fig. 5. Graph showing Effect of different rooting hormones and organic compounds on root length of rose cuttings

3.6 Root Spread (cm)

Significantly wider root spread (11.4 cm) was recorded in T_{10} (Coconut water dip for 24 hours), followed by T_7 (Aloe vera gel dip for 2 minutes) at 10.5 cm. A significantly narrower root spread (7.5 cm) was observed in T_{12} (Honey solution dip for 5 minutes). The significantly wider root spread observed with coconut water (24-hour dip) can be attributed to the cumulative effect of its rich phytohormone profile, particularly cytokinins and gibberellins, which promote lateral root formation and horizontal expansion by stimulating cell division in the pericycle cells, while the prolonged 24-hour soaking allowed greater absorption and sustained availability of these bioactive compounds (Wagan *et al.*, 2023). The excellent root spread with Aloe vera gel (2-minute dip) is due to its endogenous auxins, polysaccharides, and other growth-promoting substances that enhance lateral root initiation and branching, while its gel matrix provides a protective coating that maintains hydration and promotes uniform root development (Mirihagalla & Fernando, 2020; Wagan *et al.*, 2023).

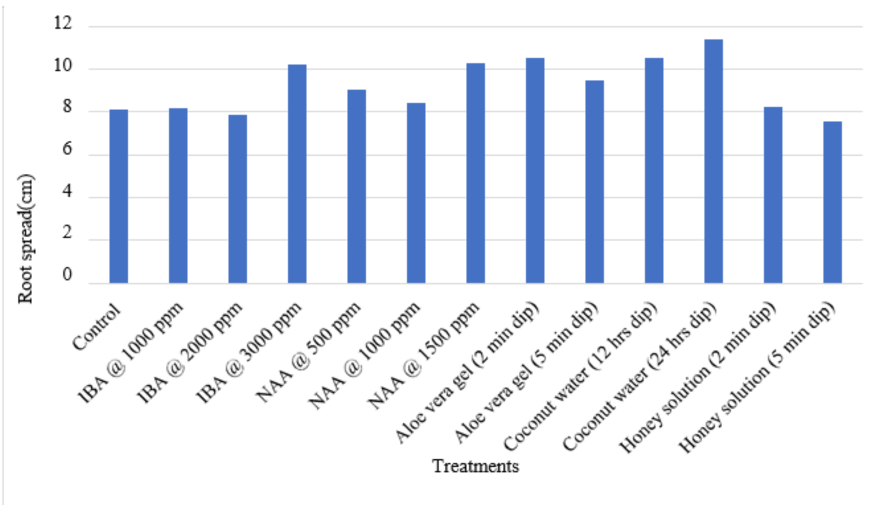

Fig. 6. Graph showing Effect of different rooting hormones and organic compounds on root spread of rose cuttings

3.7 Field Establishment Percentage

Significantly higher establishment percentage (100%) was recorded in T_1 (IBA @ 1000 ppm), T_5 (NAA @ 1000 ppm) and T_7 (Aloe vera gel dip for 2 minutes) followed by T_2 (IBA @ 2000 ppm, 96.67%). A significantly lower establishment percentage (83.33%) was recorded in T_{12} (Honey solution dip for 5 minutes). The superior field establishment (100%) observed with IBA at 1000 ppm and NAA at 1000 ppm can be attributed to their strong auxin activity that promotes the development of a robust, well-branched root system during the propagation phase, enabling the rooted cuttings to effectively absorb nutrients and water from the soil after transplanting, while reducing transplant shock and ensuring rapid resumption of vegetative growth in the main field (Dawa *et al.,* 2017; Traversari *et al.,* 2022). The equally high establishment with Aloe vera gel (2-minute dip) is due to its synergistic combination of endogenous auxins, gibberellins, polysaccharides, and antimicrobial compounds, where the gel matrix provides a protective coating that prevents desiccation, promotes wound healing, and reduces the risk of soil-borne infections, while its natural growth-promoting substances support sustained root and shoot development during the critical transition from nursery to field conditions (Mirihagalla & Fernando, 2020; Wagan *et al.*, 2023).

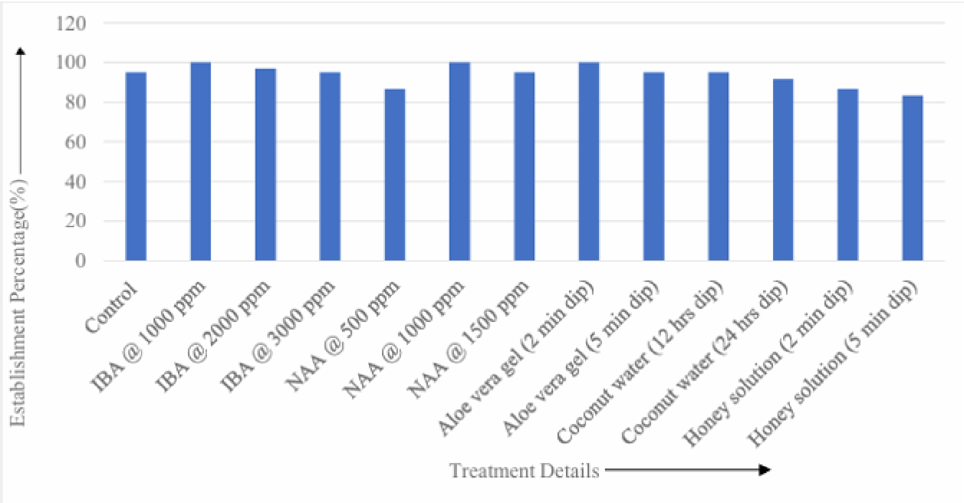

Fig. 7. Graph showing Effect of different rooting hormones and organic compounds on field establishment in rose

4. Conclusion

It is concluded from the present study that T_1 (IBA 1000 ppm), T_5 (NAA 1000 ppm), T_9 (Coconut water dip for 12 hours) and T_{10} (Coconut water dip for 24 hours) are the best treatments for rose propagation under Prayagraj agro-climatic conditions. Treatment T_1 recorded significantly higher rooting percentage (100%), sprouting percentage (52.33%), a greater number of sprouts per cutting (3), survival (100%) and field establishment (100%). Treatment T_5 recorded 100% rooting, survival, and field establishment, along with the longest roots (16.9 cm). Among the organic treatments, T_9 recorded the earliest sprouting (8 days), the highest sprout length (23.7 cm), 13 leaves, and a higher number of roots per cutting (10), along with 93.33% rooting and 96.67% survival. T_{10} recorded the widest root spread (11.40 cm) with 93.33% rooting and 96.67% survival. In terms of economics, T_7 (Aloe vera gel dip for 2 minutes) recorded the highest benefit-cost ratio of 2.58 with the lowest total cost of Rs. 1,935 per 100 cuttings, making it the most economically profitable treatment. Therefore, IBA 1000 ppm (T_1), NAA 1000 ppm (T_5), Coconut water dip for 12 hours (T_9) and Coconut water dip for 24 hours (T_{10}) are strongly recommended for commercial rose propagation, while Aloe vera gel dip for 2 minutes (T_7) offers a sustainable, low-cost alternative for organic farmers with the highest B:C ratio of 2.58.

5. Limitations

The study was conducted at a single location under Prayagraj agro-climatic conditions during one propagation period and evaluated a defined set of hormone concentrations and organic treatment durations in rose semi-hardwood cuttings. Consequently, the observed responses may be specific to the tested conditions and treatment combinations. Validation across additional seasons, locations, rose genotypes or cultivars, and propagation environments would strengthen the general applicability of the observed rooting, sprouting, survival, field establishment, and economic responses.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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