International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(12): 1054-1057
www.biochemjournal.com
Received: 01-10-2025
Accepted: 06-11-2025

Athawale Himmatrao Anand
School of Agricultural Sciences, GH Raisoni University, Saikheda, Pandhurna, Madhya Pradesh, India

Haldar A
School of Agricultural Sciences, GH Raisoni University, Saikheda, Pandhurna, Madhya Pradesh, India

Bondre M Chetan
School of Agricultural Sciences, GH Raisoni University, Saikheda, Pandhurna, Madhya Pradesh, India

Corresponding Author:
Athawale Himmatrao Anand
School of Agricultural Sciences, GH Raisoni University, Saikheda, Pandhurna, Madhya Pradesh, India

Effect of different concentration of rooting hormone (IBA) and rooting media on root parameters and economics of citrus-lemon cuttings

Athawale Himmatrao Anand, Haldar A and Bondre M Chetan

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i12Sm.6661

Abstract
The present experiment entitled, "Effect of different concentration of rooting hormone (IBA) and rooting media on root parameters and economics of Citrus-Lemon Cuttings" was designed with an objective to study the effect of different concentration of IBA on root growth and survival of cuttings in citrus. The experiment was conducted at the student instructional field and Shed-net House, Department of Horticulture, School of Agricultural Sciences, G. H. Raisoni University Saikheda, Dist.-Pandhurna (M.P.) during *Rainy* Season of Year 2023. The experiment consists in ten treatments with control and replicated three times, the experiment laid out under Randomized Block Design, the observation recorded under the treatments such as T_1-Control (Garden soil), T_2-500 ppm IBA + Garden soil + Sand (1:1), T_3-500 ppm IBA + Garden soil + Sand + FYM (1:1:1), T_4-500 ppm IBA +Garden soil + Sand + Leaf mould (1:1:1), T_5-1000 ppm IBA + Garden soil + Sand (1:1), T_6-1000 ppm IBA + Garden soil + Sand + FYM (1:1:1), T_7-1000 ppm IBA +Garden soil + Sand + Leaf mould (1:1:1), T_8-1500 ppm IBA + Garden soil + Sand (1:1), T_9-1500 ppm IBA + Garden soil + Sand + FYM (1:1:1) and T_{10}-1500 ppm IBA + Garden soil + Sand + Leaf mould (1:1:1). The observation was recorded under the experiments like days taken to 50 % sprouting, maximum total number of leaves per cutting, number of roots per cutting, length of roots cm), diameter of root (mm) and economics. The result revealed that the Treatment T_9 (1500 ppm IBA + Garden soil + Sand + FYM) was the fastest sprouting time (16.55 days), the highest number of leaves (33.35), the maximum number of roots (11.23), and the longest and thickest roots (11.89 cm and 1.16 mm, respectively). The control (T_1), which had no IBA, performed the worst across all metrics. It took the longest to sprout (28.58 days) and had the fewest leaves and roots, confirming the critical role of IBA as a rooting hormone. The economic analysis revealed a trade-off between high yields and cost-effectiveness. While Treatment T_9 produced the highest number of rooted cuttings and the greatest net return, its high cost resulted in a lower Benefit-Cost (B:C) ratio (2.29). In contrast, treatments with lower IBA concentrations, like T_3 (500 ppm IBA + Garden soil + Sand + FYM), offered a better balance, providing good rooting success with a more favorable B:C ratio (3.53).

Keywords: Rooting hormone, media, survival, success percentage and lemon cuttings

Introduction
Citrus, belonging to the family Rutaceae, includes commercially important species of the genera Citrus, Fortunella, and Poncirus. Originating in Southeast Asia, citrus fruits are among the oldest domesticated fruit crops and are now cultivated in more than 100 countries. India ranks sixth globally in citrus production (Swingle and Reese, 1967) [11]. These fruits are highly valued for their nutritional, medicinal, and socio-economic importance, with vitamin C being their most significant nutrient. Vitamin C plays a crucial role in healing wounds, strengthening blood vessels, bones, and gums, and protecting against common ailments such as cold and cough. Among citrus fruits, lemon is a particularly rich source of vitamin C, making it vital in combating deficiencies in developing countries like India (Katz and Weaver, 2003) [4].

Citrus fruits are consumed fresh or processed, contributing significantly to food security, trade, and the livelihood of growers. Their wide agro-climatic adaptability further enhances their role as a major fruit crop in subtropical regions. Quality planting material is essential for sustaining production, and vegetative propagation through cuttings offers an efficient, true-to-type, and early-bearing option compared to seedlings.

The success of cuttings depends on factors such as the age and type of plant material, season, humidity, temperature, rooting media, and aftercare.
Root initiation can be improved through mechanical practices like ringing and girdling, which alter carbohydrate and hormone movement, enhancing root formation. The application of rooting hormones, particularly Indole-3-butyric acid (IBA), has been widely used to promote adventitious root development by influencing physiological processes like protein synthesis, enzyme activity, and membrane function. In addition, rooting media plays a critical role in root establishment. Ideal media should be porous, well-drained, and capable of retaining moisture while allowing aeration. Mixtures of soil, sand, farmyard manure (FYM), vermicompost, or leaf mould have been found effective, as they provide essential nutrients and encourage healthy, branched root systems compared to coarse and brittle roots developed in pure sand.
Thus, citrus not only holds immense nutritional and socio-economic value but also requires focused propagation practices, particularly the use of IBA and balanced rooting media, to ensure successful multiplication of quality planting material for sustainable production.

Materials and Methods

The Present experiment entitled, "Effect of different concentration of rooting hormone (IBA) and rooting media on root parameters and economics of Citrus-Lemon Cuttings" was designed with an objective to study the effect of different concentration of IBA on root growth and survival of cuttings in citrus. The experiment was conducted at the student instructional field and Shed-net House, Department of Horticulture, School of Agricultural Sciences, G. H. Raisoni University Saikheda, Dist.-Pandhurna (M.P.) during *Rainy* Season of Year 2023. The experiment consists in ten treatments with control and replicated three times, the experiment laid out under Randomized Block Design, the observation recorded under the treatments such as T_1-Control (Garden soil), T_2-500 ppm IBA + Garden soil + Sand (1:1), T_3-500 ppm IBA + Garden soil + Sand + FYM (1:1:1), T_4-500 ppm IBA +Garden soil + Sand + Leaf mould (1:1:1), T_5-1000 ppm IBA + Garden soil + Sand (1:1), T_6-1000 ppm IBA + Garden soil + Sand + FYM (1:1:1), T_7-1000 ppm IBA +Garden soil + Sand + Leaf mould (1:1:1), T_8-1500 ppm IBA + Garden soil + Sand (1:1), T_9-1500 ppm IBA + Garden soil + Sand + FYM (1:1:1) and T_{10}-1500 ppm IBA + Garden soil + Sand + Leaf mould (1:1:1). The observation was recorded under the experiments like days taken to 50 % sprouting, maximum total number of leaves per cutting, number of roots per cutting, length of roots cm), diameter of root (mm) and economics.

Results and Discussion

Days taken to 50 % sprouting

Treatment T_9 (1500 ppm IBA + Garden soil + Sand + FYM) demonstrated the highest efficiency in plant establishment, achieving 50% sprouting in just 16.55 days. This was significantly faster than the control group (T_1), which required 28.58 days to reach the same milestone. The data indicates a clear correlation between increased IBA concentrations and reduced sprouting time. This rapid development is likely a result of the lemon cuttings efficiently absorbing macro and micro-nutrients from the enriched media, which fuels metabolic processes and accelerates vegetative growth. These results are consistent with the findings of Kamble *et al.*, (2007) [3] and Awasthi *et al.*, (2008) [2].

Total number of leaves per cutting

The highest total leaf count per cutting (33.35) was achieved in treatment T_9 (1500 ppm IBA + Garden soil + Sand + FYM), followed by T_{10} (30.61) and T_7 (29.90). In contrast, the control produced the fewest leaves, averaging only 14.56 per cutting. This substantial increase in leaf production is attributed to the application of IBA, which activates growth processes in the vegetative segments of the plant. Additionally, the nutrient-rich rooting media—containing essential macro and micronutrients—provides the necessary resources to support an increased number of shoots and leaves. These observations align with research conducted by Kumar *et al.*, (2004) [5] and Murkute *et al.*, (2009) [7], which highlights how combining growth regulators with fertile media optimizes canopy development.

Number of roots per cutting

Treatment T_9 (1500 ppm IBA + Garden soil + Sand + FYM) achieved the highest root density, producing an average of 11.23 roots per cutting. This was followed by treatments T_{10} (10.31) and T_7 (10.19), while the control group produced the fewest roots at 5.29. The superior performance of the T_9 group is attributed to the synergistic effect of a moderate Indole-3-butyric acid (IBA) concentration and a nutrient-rich medium containing Farm Yard Manure (FYM). IBA facilitates the hydrolysis and downward translocation of carbohydrates and nitrogenous substances to the base of the cutting. In a favorable environment, these biochemical shifts accelerate cell division and elongation, leading to a more prolific root system. These findings align with previous research by Singh *et al.*, (2017) [10], Patel *et al.*, (2018) [8], and Malakar (2019) [6].

Length of roots (cm)

In this final segment, we look at root length and the physical properties of the medium. The maximum root length (11.89 cm) was achieved in treatment T_9 (1500 ppm IBA + Garden Soil + Sand + FYM), significantly exceeding the control group (6.93 cm).
This increased length is attributed to the friable and porous nature of the T_9 medium, which allows for effortless root penetration. The inclusion of Farm Yard Manure (FYM) is particularly beneficial, as it not only provides a steady supply of plant-available nutrients but also enhances the substrate's aeration and moisture retention. When combined with the high hydrolytic activity triggered by IBA, these factors create an ideal environment for rapid root elongation and overall survival. These findings are supported by the work of Abdullah and Khateeb (2004) [1], Singh *et al.*, (2017) [10], and Malakar (2019) [6].

Diameter of root (mm)

In addition to root length and number, the structural thickness of the root system was also significantly influenced by the treatments. The maximum root diameter (1.16 mm) was observed in treatment T_9 (1500 ppm IBA + Garden soil + Sand + FYM), followed closely by T_{10} and T_7 (both at 1.13 mm). In contrast, the control group produced significantly thinner roots with a diameter of only 0.48 mm.

This increase in root and shoot thickness is likely caused by the elevation of endogenous auxins, phenols, and carbohydrates at the base of the cutting. These biochemical compounds act in unison to stimulate vigorous cell division and expansion. The use of an optimal IBA concentration combined with a nutrient-rich medium creates a reservoir of bio-compounds that fuels the development of a robust, thick root system, a finding supported by Singh *et al.*, (2017) [10], Patel *et al.*, (2018) [8], and Malakar (2019) [6].

Economics

The economic analysis of citrus cutting treatments per 1,000 cuttings clearly demonstrates that the use of Indole-3-butyric acid (IBA) as a rooting hormone significantly enhances rooting percentage, survival rate, and profitability compared to untreated controls. Although the control treatment (T_1) with only garden soil yielded a relatively high B:C ratio of 5.25, it resulted in fewer rooted cuttings (500) and a net return of ₹6,300, limiting total propagation potential.

The application of IBA at 500 ppm, especially when combined with a rooting medium like soil + sand + FYM (T_3), markedly improved rooting success (650 rooted cuttings) and net returns (₹7,600). Importantly, this combination maintained a B:C ratio of 3.53, showing that low-concentration IBA with organic media is a cost-effective and efficient approach for mass propagation. IBA at this concentration is known to enhance adventitious root formation by promoting cell differentiation in the basal region of the cutting. At higher concentrations (1000-1500 ppm IBA), the number of rooted cuttings increased substantially-up to 800 rooted cuttings in T_9 (1500 ppm IBA + Soil + Sand + FYM)-resulting in the highest gross return (₹12,000). However, this also increased input costs due to the higher price of IBA, lowering the B:C ratio to 2.29 despite maintaining a net return of ₹8,350. This diminishing economic efficiency at higher doses has also been observed in citrus and guava cuttings (Patel *et al.*, 2019) [13], where excessive auxin can lead to callus formation or root deformation, reducing overall propagation quality.

The results suggest that while higher IBA concentrations maximize output, treatments such as T_3 (500 ppm IBA + Soil + Sand + FYM) provide a better balance between cost and return, making them economically viable and sustainable for nursery-scale propagation.

Table 1: Effect of rooting hormone and rooting media on shoot, root characters and economics of citrus cuttings

Notation	Days taken to 50% sprouting	Total Number of leaves per cutting	Number of roots per cutting	Length of roots (cm)	Diameter of roots (mm)	Gross Return (20/cuttings)	Net Return (₹)	B:C Ratio
T_1	28.58	14.56	5.29	6.93	0.48	7500	6300	5.25
T_2	25.22	16.45	6.53	7.33	0.67	9000	6950	3.39
T_3	22.13	18.65	8.34	8.96	0.88	9750	7600	3.53
T_4	23.77	17.86	7.32	8.45	0.76	9300	7200	3.43
T_5	21.03	27.76	10.09	10.59	1.11	10500	7700	2.75
T_6	20.34	23.29	9.59	9.67	1.09	11250	8350	2.88
T_7	19.93	29.90	10.19	10.66	1.13	10800	7950	2.79
T_8	21.23	22.43	9.22	8.99	1.06	11700	8150	2.30
T_9	16.55	33.35	11.23	11.89	1.16	12000	8350	2.29
T_{10}	18.63	30.61	10.31	10.89	1.13	11550	7950	2.21
S.Em ±	0.099	0.191	0.070	0.046	0.007			
CD at 5 % Level	0.294	0.567	0.209	0.138	0.020			

Conclusion

Treatment T_9 (1500 ppm IBA + Garden soil + Sand + FYM) was the most effective in promoting plant growth. It led to the fastest sprouting time (16.55 days), the highest number of leaves (33.35), the maximum number of roots (11.23), and the longest and thickest roots (11.89 cm and 1.16 mm, respectively). This suggests that a high concentration of IBA combined with a nutrient-rich and well-aerated medium is ideal for vigorous root and shoot development. The control (T_1), which had no IBA, performed the worst across all metrics. It took the longest to sprout (28.58 days) and had the fewest leaves and roots, confirming the critical role of IBA as a rooting hormone. The economic analysis revealed a trade-off between high yields and cost-effectiveness. While Treatment T_9 produced the highest number of rooted cuttings and the greatest net return, its high cost resulted in a lower Benefit-Cost (B:C) ratio (2.29). In contrast, treatments with lower IBA concentrations, like T_3 (500 ppm IBA + Garden soil + Sand + FYM), offered a better balance, providing good rooting success with a more favorable B:C ratio (3.53).

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