



International Journal of Agriculture Innovations and Cutting-Edge Research



Auxin-Induced Rooting and Seedling Quality Enhancement in Seedless Lemon (*Citrus limon* L.) under Nursery Conditions

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Abstract

Seedless lemons (*Citrus limon* L.) are valued at the global level for the character of seedless. However, these cultivars are often characterised by poor rooting capability and low survival rates. In order to resolve this issue, the present study was conducted during the spring season of 2024 at the Nursery of Sindh Agriculture University (SAU), Tandojam, to evaluate the influence of auxin treatments on the sprouting and seedling growth of seedless lemon cuttings. A factorial experiment in a Completely Randomised Design (CRD) was laid out with four replications, comprising two varieties (Persian lime and Malaysian lemon) and four treatments: IBA gel dip, NAA powder dip, IBA gel + NAA powder dip, and control. All the seedling-related parameters, such as sprouting percentage, number of sprouts, days to sprouting, rooting percentage, root depth, seedling quality index, sturdiness quotient, shoot biomass and root biomass, were significantly affected by the auxin treatments. However, varieties and their interactive effect with auxin treatments were only significant for a few sprouting and rooting-related parameters. The statistical results revealed that the maximum sprouting percentage, number of sprouts per cutting, rooting percentage and minimum days to sprouting were observed in Persian lemon with the NAA powder dip method. The Dickson Quality Index, Sturdiness quotient, and biomass of shoot and root were not significantly affected by the varieties or their interactive effect with auxin treatments. However, Auxin as an independent factor had significant effects on all these parameters. The highest DQI, SQ, and biomass of shoot and root were observed with NAA powder dip treatments. However, the Number of sprouts and root depth traits were significantly influenced by treatments alone, with IBA gel dip resulting in more sprouts and the deepest roots. The findings suggest that NAA powder dip is the most effective treatment for enhancing rooting and overall seedling vigour in seedless lemon cuttings, particularly in the Persian variety.

Keywords: Asexual propagation, Auxins, Seedless lemon

DOI: <https://zenodo.org/records/19454702>

Journal Link: <https://jai.bwo-researches.com/index.php/jwr/index>

Paper Link: <https://jai.bwo-researches.com/index.php/jwr/article/view/214>

Publication Process Received: 02 Feb 2026/ Revised: 26 Feb 2026/ Accepted: 28 March 2026/ Published: 07 April 2026

ISSN: Online [3007-0929], Print [3007-0910]

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Indexing:



Publisher:

BWO Research International (15162394 Canada Inc.) <https://www.bwo-researches.com>

Introduction

Citrus fruits are the evergreen shrubs that belong to the Rutaceae family. The taxonomy of Citrus species presents a complex scientific challenge, with classifications ranging from three primary taxa to as many as 156 taxa (Zhong et al., 2023). However, many of these species are believed to have originated through natural or artificial hybridisation among a limited number of true species (Wu et al., 2018). Citrus fruits are highly demanded in the world as a fresh product as well as processed juice. Among citrus fruits, lemon (*Citrus limon*) is the third most important citrus species after the orange and mandarin. It is more frequently used than other varieties of citrus; therefore, several research scientists are emphasising multiplying seedless lemon varieties and enhance quality of the seedlings (Yadav and Mate, 2023). Seeded citrus was consumed over multiple years by the customers. But, in the past few decades, consumer interest in seedless fruits has increased significantly; as a result, seedlessness has become a highly desirable trait in many fresh market fruits, including citrus (Ali et al., 2013). In response to this growing demand, the production of cultivars, such as *Citrus limon* cv. Seedless Lemon has gained considerable importance. The fruit is medium to large in size, long-elliptic to oval in shape, with a rounded base and a broad but low nipple. The rind is medium thick, firm, and very smooth with a shiny yellow colour. It typically has 9–12 segments, a hollow central axis, and crystal-white pulp vesicles (Lalramhluna et al., 2016). The juice is abundant and highly acidic. Key fruit characteristics include an average weight of 81.33 g, peel thickness of 1.73 mm, 10.67 segments, 0 to 1 seed per fruit, total soluble solids (TSS) of 7.33 °Brix, acidity of 7.90%, and good flavour.

Although usually seedless, the fruit may occasionally contain a few seeds. This cultivar, known for its nearly seedless nature, is now widely cultivated in the sub-continent region (Rathour et al., 2021).

The seedless lemon is not common to cultivate in our locality, but at an International level, seedless fruits are in more demand. As a seedless cultivar, commercial sexual propagation of lemon is a challenge; therefore, vegetative propagation methods, especially budding and grafting, are more commonly used to produce true-to-type plants (Gnawali et al., 2022). Due to the high intensity of polyembryony (90–100%) and the low risk of viral contamination in lemon, stem cutting is considered an appropriate method for regeneration (Kour et al., 2022). Multiplication by cutting is the easiest and cheapest method of multiplication. However, the propagation ability of cuttings is influenced by various internal and external factors, including the age and vigour of the plant, rooting tendency, environmental conditions, nutrient availability, and the genetic makeup of the genotype, where rooting potential is the most important factor (Gnawali et al., 2022). In the present study, more emphasis was given on the sprouting, rooting and quality of the seedlings as lemons are commercially multiplied by budding. To introduce seedless lemon varieties via cuttings, it is very necessary to treat cuttings with regulating hormones before planting to induce adventitious roots.

Plant growth regulators (PGRs) are naturally occurring or synthetic substances that influence plant development by modifying physiological processes and enhancing the overall rooting behaviour of the cuttings (Harshita and Singh, 2022). Among the plant growth regulators, auxins play a fundamental role in regulating key growth responses

(Guilfoyle, 2015), particularly in root development (Roychoudhry and Kepinski, 2022). Auxins facilitate the accumulation of osmotic solutes by enhancing plasma membrane permeability and decreasing cell wall pressure. They also contribute to cell wall expansion and synthesis, while regulating cell division processes that collectively support root initiation and development (Jaiswal et al., 2023). Naphthalene acetic acid (NAA) and Indole-3-butyric acid (IBA) are the most commonly applied auxins for promoting root initiation and development (Gautam et al., 2022). These compounds significantly enhance rooting success, making it an essential factor in vegetative propagation.

Previous studies enlighten that the highest root formation, along with increased root length, root diameter, and shoot sprouting, was observed at a 500 ppm concentration of IBA (Bhatt and Tomar, 2011). In sweet orange, the maximum rooting and shoot growth parameters were recorded at a concentration of 5000 ppm IBA (Singh and Singh, 2016; Rathour et al., 2021). In seedless lemon, IBA at 3000 to 4000 ppm recorded the best for hardwood cuttings (Mishra et al., 2025a). While Naphthalene acetic acid (NAA) is also a synthetic auxin (Flasiński et al., 2014). NAA increases the formation of cellulose fibres in plants. In addition to that, it is commonly used to prevent premature fruit drop and for fruit thinning, particularly after flowering. NAA is effective on a variety of fruit-bearing plants such as apples, olives, oranges, and other citrus fruits. For optimal results, it is typically applied at concentrations ranging from 20 to 100 mg L⁻¹ (Ahmed et al., 2017).

Several researches are done, yet it remains unknown which auxin formulation is more effective for

regulating rooting in seedless lemon cuttings. Therefore, this study aims to evaluate Sprouting and seedling growth responses of seedless lemon (*Citrus limon* L.) cuttings to different auxin treatments.

Research Objectives and Questions:

1. To compare treated and untreated cuttings for better sprouting of lemon seedlings.
2. To evaluate the growth and quality of the seedlings in response to different auxin treatments.

The research was done to evaluate how auxin treatments improve sprouting percentage and reduce the time to sprouting as compared to the control. The objective was to identify the best auxin treatment for lemon cuttings.

Material and methods

Experimental location

The experiment was conducted during the **spring season of 2024** at the SAU Nursery, Department of Horticulture, Sindh Agriculture University, Tandojam. The trial was laid out to study the sprouting and seedling growth responses of seedless lemon cuttings under different auxin treatments.

Experimental Design

The experiment was arranged in a Completely Randomised Design (CRD) with factorial arrangements to evaluate the interaction between varieties and auxin treatments. The study included four replications for each treatment.

Research details

The experiment included the four treatments of auxin application on two varieties of seedless lemon study viz; **Persian lime and Malaysian lemon**. Healthy and uniform semi-hardwood cuttings of both varieties were taken from the **local farm of Tando Allahyar**. The cuttings were selected based on uniformity in size, vigour, and maturity. Only disease and pest-free cuttings of approximately

15–20 cm in length and pencil-thickness diameter were chosen for experimentation. **A 45° slant cut at the basal end of each cutting was made with a sharp knife**, which increased the surface area for hormone absorption and root initiation. After trimming, the cuttings were treated for surface disinfection using a **Thiophanate methyl solution** before applying growth regulator treatments.

Auxins Application

The IBA (Indole-3-butyric acid) was applied in gel form by dipping the basal end (2–3 cm) of each cutting for 5 minutes. While NAA (Naphthalene acetic acid) was applied as a powder dip at the basal end of the cuttings. For combined treatment, the cuttings were first dipped in IBA gel and then rolled in NAA powder. Control cuttings were left untreated.

Growing Medium

All treated and control cuttings were planted in standard-sized polybags filled with a uniform rooting medium composed of soil and farmyard manure (FYM) in a ratio of 2:1, respectively. The mixture ensured adequate aeration, moisture retention, and nutrient availability for root development. To maintain high humidity and promote early rooting, all polybags were initially covered for 30 days with transparent plastic shoppers (polyethene sheets). This helped in conserving moisture. The bags were kept covered until visible sprouting was observed, after which covers were carefully removed to allow ventilation and prevent fungal growth. The polybags were kept under a 50% shade net structure to protect the cuttings from direct sunlight and excessive temperature. The average temperature inside the net shade house was recorded as 35–38 °C. Regular light irrigation was applied to keep the medium moist but not waterlogged. Routine intercultural

operations were performed as required to maintain ideal nursery conditions.

Data collection

The collected data was statistically analysed by using the computer-based Software Statistics version 8.1. The significance of the treatments was evaluated by using Analysis of Variance at a probability level of 0.05, and means were compared by using the Least Significant Difference Test. The parameters were measured by their standard procedures. Sprouting percentage (%) was calculated for each treatment by selecting samples randomly from each replication, using the formula: $(\text{Number of sprouted cuttings} / \text{Total number of planted cuttings}) \times 100$. The number of sprouts per cutting was recorded from 50% randomly selected cuttings per replication, and the average was calculated. Days to sprouting were recorded by daily observation, counting the number of days from planting until the first sprouting appeared. Rooting percentage was similarly calculated by counting the number of rooted cuttings per treatment using the formula: $(\text{Number of rooted cuttings} / \text{Total number of planted cuttings}) \times 100$. Root depth was measured from 50% randomly selected rooted cuttings using a measuring scale, with results expressed in centimetres per seedling. Seedling quality was evaluated using the Dickson Quality Index (DQI), calculated by the formula: $\text{DQI} = \text{TSDW} / (\text{H}/\text{D} + \text{SDW}/\text{RDW})$, where TSDW is the total seedling dry weight (shoot + root dry weight in grams), H is seedling height (cm), D is collar diameter (mm), SDW is shoot dry weight (g), and RDW is root dry weight (g), as described by [Dickson et al. \(1960\)](#). The sturdiness quotient (SQ), indicating seedling robustness, was calculated by dividing shoot height (cm) by collar diameter (mm), following the method of [Roller \(1977\)](#) and [Luna and](#)

Chamoli (2006). Fresh biomass of shoot and root was determined by weighing 50% randomly selected samples from each treatment using an electronic weighing balance, and values were expressed in grams per seedling.

Statistical analysis

All collected data were subjected to statistical analysis using Statistics 8.1 software (Statistics, 2006), and the least significant difference (LSD) test was employed to compare treatment means where necessary.

Results

This experiment examined the combined and individual effects of different seedless lemon varieties and auxin treatments on rooting performance and related growth traits. The statistical analysis of the data exhibits significant effects of the auxin application on the sprouting, rooting, biomass and seedling quality related parameters. However, varieties had only significant differences for sprouting and rooting-related parameters. The interactive effect of the varieties and auxin treatments also had significant differences for sprouting and rooting-related parameters. It means auxin treatments had a significant difference for all the recorded parameters.

The highest sprouting percentage (80.66%) was observed in the interaction between the Persian variety and NAA powder dip treatment, whereas the lowest percentage (33.77%) occurred in the untreated Malaysian variety (Table 1). Contrastingly, the maximum sprout count (2.33) resulted from the interaction of IBA gel dip with the Persian variety, while all other treatment x variety combinations produced a uniform sprout count of 1.00. Regarding days to sprouting, the longest sprouting period (18.66 days) was recorded for the combined IBA gel dip + NAA powder dip treatment on the Persian

variety. Conversely, the shortest sprouting time (4.33 days) was observed under NAA powder dip treatment across both varieties.

Auxin Treatments	Sprouting percentage (%)			Number of sprouts			Days to sprouting		
	Varieties		Mean	Varieties		Mean	Varieties		Mean
	Malaysian	Persian		Malaysian	Persian		Malaysian	Persian	
T1 (Control)	33.77	34.00	34.18	1.00	1.00	1.00	16.00	14.33	15.16
T2 IBA gel dip	42.85	64.30	53.57	1.33	2.33	1.83	8.00	9.66	8.83
T3 NAA powder dip	78.33	80.66	79.50	1.00	1.00	1.00	4.33	4.33	4.33
T4 IBA gel dip + NAA powder	69.33	69.33	69.33	1.00	1.00	1.00	11.66	18.66	15.66

di P									
M ea n	56 .0 5	62 .2 2		1. 33 A	1. 08 B		10 .0 0	11 .7 5	
	V ar ie ti es	A ux in tr ea t m en ts	V x T	V ar ie ti es	A ux in Tr ea tm en ts	V x T	V ar ie ti es	A ux in Tr ea tm en ts	V x T
SE	2. 28 55	3. 23 21	4 .5 7 0 9	0. 11 79	0. 16 67	0 .2 3 5 7	1. 05 08	1. 48 60	2 .1 0 1 6
LS D 0.0 5	4. 84 50	6. 85 18	9 .6 8 9 9	0. 24 98	0. 35 33	0 .4 9 9 7	2. 22 76	3. 15 03	4 .4 5 5 2
P- va lu e	0. 01 58	0. 00 00	0 .0 1 1 9	0. 04 00	0. 00 00	0 .0 1	N S	0. 00 00	0 .0 5

Table 1: Effect of various Auxin treatments on the sprouting potential of stem cuttings of the seedless lemon.

Table 2 indicates the results of the rooting percentage and root depth. The highest rooting percentage (79.66%) was obtained from the interaction between the NAA powder dip. In contrast, the lowest rooting percentages were recorded in untreated cuttings of Persian (31.00%) and Malaysian (34.00%) varieties.

In terms of root depth, the IBA gel dip treatment independently led to the greatest mean root depth (18.50 cm), which was markedly higher than other treatments, ranging from 7.88 to 11.50 cm. The Persian variety exhibited superior root elongation compared to the Malaysian, with average

depths of 14.45 cm and 10.15 cm, respectively. These findings indicate that while both treatment type and varietal characteristics independently influenced root depth, their interaction did not play a substantial role in determining root depth. A similar trend of the results was observed for the seedling quality parameters like Dickson quality and sturdiness quotient (Tables 2 and 3). For the quality index, the NAA powder dip treatment produced the highest value (0.11), reflecting its effectiveness in enhancing overall plant vigour, likely due to improved rooting performance. In contrast, both the control and IBA gel dip treatments recorded substantially lower and statistically similar quality index values (0.03), highlighting the superior role of NAA in promoting plant quality through physiological and morphological improvements. Similarly, the sturdiness quotient was significantly affected by treatments alone. When SQ is above 6.0, it is considered poor quality seedlings. Here, the control treatment exhibited the highest mean sturdiness quotient (17.88) mean not good quality seedlings. Conversely, the NAA powder dip recorded the robustness of seedlings with SQ at the lowest value (5.05).

Table 3 presents the fresh shoot biomass and root biomass data. The interactive effect of the varieties and auxin treatments was non-significant. However, auxin as an independent factor had significant differences for the biomass of the shoot and roots. The results indicate that among the treatments, NAA powder dip produced the highest shoot and root biomass, exhibiting 36.14 and 2.81 g, respectively. In contrast, the control treatment resulted in the lowest results for both traits, exhibiting 2.31 g shoot biomass and 1.05 g root biomass, reflecting minimal growth promotion.

Auxin Treatments	Rooting percentage (%)			Root Depth			Dickson Quality Index		
	Varieties		Mean	Varieties		Mean	Varieties		Mean
	Malaysian	Persian		Malaysian	Persian		Malaysian	Persian	
T1 (Control)	31.00	34.00	32.50	6.93	8.83	7.88	0.03	0.03	0.03
T2 IB Age dip	39.30	62.00	50.66	14.66	22.33	18.50	0.03	0.04	0.04
T3 NAA powder dip	78.30	79.60	79.00	9.00	13.66	11.33	0.12	0.11	0.11
T4 IB Age dip + NAA powder dip	68.30	69.00	68.66	10.00	13.00	11.50	0.08	0.08	0.08
Mean	54.25	61.16	57.70	10.15	14.45	12.30	0.06	0.06	0.06

	Varieties	Auxin treatments	VxT	Varieties	Auxin Treatments	VxT	Varieties	Auxin Treatments	VxT
SE	2.4552	3.4721	4.9103	1.6030	2.2670	3.2061	6.5622	9.2800	0.0131
LS D 0.05	5.2047	7.3605	1.4099	3.3983	4.8059	6.7966	0.0139	0.0197	0.0278
P-value	0.0124	0.0000	0.0165	0.0162	0.0000	N.S	N.S	0.0000	N.S

Table 2: Effect of various Auxin treatments on rooting potential and quality of stem cuttings of Seedless lemon.

Auxin Treatments	Sturdiness quotient			Biomass of the shoot		Biomass of the root			
	Varieties		Mean	Varieties		Varieties		Mean	
	Malaysian	Persian		Malaysian	Persian	Malaysian	Persian		
T1 (Control)	16.91	18.86	17.88	2.17	2.45	2.31	0.94	1.16	1.05
T2 IB Age dip	15.02	15.20	15.11	21.16	20.14	20.65	1.83	2.03	1.93

T3	4.	5.	5	35	36	3	2.	2.	2
N	45	66	.0	.49	.80	6	89	73	.81
A			5			.1			A
pow			D			4			
der						A			
dip									
T4	10	9.	1	24	23	2	1.	2.	2
IB	.36	96	0	.06	.80	3	89	26	.08
A			.1			.9			B
ge			6			3			
l			C			B			
dip									
+ N									
A									
pow									
der									
dip									
Mean	11.68	12.42		20.72	20.80		1.89	0.05	
	Varieties	Auxin treatments	VxT	Varieties	Auxin treatments	VxT	Varieties	Auxin treatments	VxT
SE	0.7666	1.0841	1.0532	1.1963	1.1969	2.0392	0.2283	0.3228	0.4566
LS	1.6251	2.2982	3.0250	2.5361	3.5866	5.0722	0.4839	0.6844	0.9679
P-value	N.S	0.0000	N.S	N.S	0.0000	N.S	N.S	0.0000	N.S

Table. 3 Effect of various Auxin treatments on quality and biomass of stem cuttings of Seedless lemon.

Discussion

Stem cutting success is broadly dependent on various internal and external factors that impact root formation. A range of external factors can influence rooting characteristics; for instance, auxin application has been shown to increase the rooting potential in many plant species (Hawramee et al., 2019). Consequently, auxins are commonly used in plant propagation. This study revolves around auxin application on seedless lemon cuttings, which exhibited significant results. The interactive effect of the varieties and Auxin treatments proved better for sprouting and rooting parameters, biomass of shoot/root and quality parameters, as DQI and SQ had no effect of interaction. NAA powder dip resulted in better performance for most of the parameters because NAA promotes various plant functions, including the expansion and division of cells, enhancement of photosynthetic activity, stimulation of RNA production, increased membrane permeability, shoot elongation, and improved water absorption (Alotaibi et al., 2024). Auxin (NAA or IBA) increases the transport of auxin and also supports metabolites and carbohydrate accumulation. Auxin also regulates gene expression, which is involved in the initiation and elongation of the roots (Cohen et al., 2024). In this study, sprouting percentage exhibited maximum results when the Persian variety was treated with NAA powder dip solely, similar to the results of Patel et al. (2021) in Kagzi lime, where plants treated with NAA at 3000 ppm showed a significantly higher sprouting rate, with 73.09% of the cuttings successfully sprouted. This increase in the sprouting percentage may be attributed to

the more efficient utilisation of stored carbohydrates, nitrogen, and other essential compounds regulated by PGR application (Sinha et al., 2014).

Root initiation occurs in the stem cutting by activating proton pumps and by gene induction, which are responsible for root primordia and cell division. The signalling pathways of auxins operate via molecular mechanisms that regulate responses of plant growth and gene expression. The application of auxins promotes the hydrolysis and movement of carbohydrate and nitrogenous reserves toward the basal ends of the cuttings, thereby stimulating rapid cell division and elongation (Singh et al., 2015; Liu et al., 2025). Moreover, auxin treatments have been reported to improve histological characteristics, such as enhanced callus formation, tissue regeneration, and the differentiation of vascular structures. Similar outcomes were also documented in earlier studies by Kurd et al. (2010) and Thota (2012). Along with sprouting percentage, the number of sprouts matters the most when observing the growth potential of a cutting. In this study, the IBA gel dip applied to the Malaysian variety showed the maximum number of sprouts. Ayaz et al. (2021) observed similar results in olive cuttings, where the maximum number of sprouts (3.33) cutting⁻¹ was observed at 3000 mgL⁻¹ IBA concentration. The enhanced number of sprouts per cutting may be attributed to the stimulated hydrolysis of stored nutrients and their frequent mobilisation towards active growth sites, regulating sprout initiation and development (Kondle et al., 2022). Loushambam et al. (2014) and Singh et al. (2014) observed similar results in mulberry cuttings. The early sprouting was seen in the NAA powder dip; similar results were observed in the study of Patel et al. (2021)

in Kagzi lime. The early sprouting is a result of more efficient utilisation of stored carbohydrates, nitrogen, and other essential reserves, facilitated by the action of growth regulators (Dhand et al., 2019).

The rooting percentage reflects the proportion of cuttings that successfully developed roots. The highest rooting percentage was seen in the Persian variety upon NAA dip application. Patel and Patel (2018) found similar results in Fig where rooting percentage was higher with auxin application. This improvement in rooting percentage may be attributed to the positive influence of auxin, which likely enhanced the cellular activities essential for root initiation. These findings are consistent with the results reported by Reddy et al. (2008b) in fig. In this study, root depth greatly increased with IBA gel dip, similar trend of rooting depth was observed by Dhand et al. (2019) in pear. Available studies indicate that auxins have a significant role in increasing both root initiation and elongation, as the root elongation phase is particularly sensitive to auxin levels. Higher concentrations of auxins may contribute to improved root development, as suggested by Hartmann et al. (2002). Similar findings have been reported across various species, including *Camellia sinensis* (L.) O. Kuntze (Zenginbal et al., 2014), pomegranate (Melgarejo et al., 2008; Saroj et al., 2008; Polat and Caliskan, 2009), and peach (Kaur, 2017).

Dickson Quality Index was observed to be better with NAA application; it relies on destructive sampling to determine the dry biomass of both the shoot and root systems. DQI remains a valuable and widely accepted standard for evaluating seedling vigour and structural integrity, offering long-term productivity of fruit trees (Binotto et al., 2010). While the least SQ was observed in the NAA powder dip in this study. The sturdiness quotient is a key

indicator of seedling resilience, with lower values generally indicating higher survival potential under adverse environmental conditions. According to Edralin and Mercado (2010), SQ values above 6 suggest a disproportionate seedling height relative to collar diameter, resulting in weak, spindly seedlings prone to poor field performance. Budiman et al. (2015) further emphasised that SQ should closely correspond with stem diameter to reliably predict field performance.

The shoot biomass observed in this study was higher when the plants were treated with NAA; the outcomes are in line with (Mishra et al., 2025b). Similar findings have been reported in previous studies, where the application of auxins significantly influenced early physiological activity in plants. Enhanced shoot fresh weight was observed, which can be attributed to increased sprouting, greater leaf production, expanded leaf area, and improved accumulation of total sugars. These physiological enhancements, along with a higher C: N ratio, collectively contributed to increased biomass in the aerial parts of the cuttings. Such outcomes have been documented by Rymbai et al. (2010), Seiar (2016), and Ghosh et al. (2017) in Guava, Pomegranate and Jujube, respectively. The maximum root weight of seedless lemon was observed in NAA application, which might be attributed to the role of auxins in stimulating root initiation and promoting subsequent growth. Elevated auxin activity, coupled with slower degradation by auxin-degrading enzymes, is believed to enhance root vigour and development. Additionally, the stored carbohydrates within the cuttings might have contributed to increased root biomass (Singh et al., 2013). Notably, the fresh weight of roots showed a direct relationship with the number of roots produced per cutting. These findings

align with previous reports by Riaz et al. (2007) in kiwi and Singh & Tomar (2015) in Phalsa.

Innovation statement:

This study evaluates a novel auxin-mediated propagation technique specifically for the seedless lemon, which is a globally demanded fruit crop and provides efficient propagation techniques for the citrus growers. The seedless lemon is not commonly available in any region. Normally, growers multiply lemon varieties by seed or by budding.

Conclusion

The study demonstrated that different auxin treatments significantly influenced various growth parameters of the plant cuttings. Treatments involving auxins enhanced sprouting, rooting, and biomass production. Among the treatments, NAA powder dip consistently showed superior performance in improving rooting percentage, fresh biomass, and overall quality index, followed by IBA applied in the gel dip method, while among varieties, Persian resulted in better performance than the Malaysian variety.

Recommendation:

From the present study, it is recommended that NAA applied as a powder dip be used for improving sprouting, vegetative growth, and overall seedling quality of seedless lemon cuttings under nursery conditions. This treatment resulted in better sprouting response, enhanced root and shoot development, and improved seedling vigour compared to untreated cuttings and other auxin treatments. The use of NAA in powder form is therefore suggested as a practical and cost-effective approach for nursery propagation of seedless lemon. However, further evaluation under different environmental conditions and seasons is recommended to validate its wider applicability.

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