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Response of IBA on rooting behaviour of Rough lemon (*Citrus × jambhiri* Lush) under various growing conditions

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Abstract
An Experiment was conducted to know the effect of rooting hormones and different growing conditions on the rooting properties of Rough lemoncuttings in the Doab a region of Punjab. The impact of varying Indolebutyric acid (IBA) concentrations and varied growth conditions on adventitious root production in rough lemon stem cutting was investigated. In June, Cuttings of around 20-22cm in length were treated with varying doses of IBA (500, 1000, 1500 ppm) before being planted in three conditions, i.e. Open sunlight area (G1), Partial shade of big tree throughout the day (G2), and Polyhouse conditions (G3).Cuttings were treated dip method for 5-7 seconds: Cuttings treated with 500ppmIBA showed the best root growth, root length, root thickness, and leaf sprouting results. In addition, the open area growth environment was shown to boost root development. Under the polyhouse situation, the performance of all rooting parameters was at its maximum. Overall, the IBA 500ppm treatment in a polyhouse combination was the most effective for the economic productivity of rough lemon rootstock.

Keywords: Rough lemon, rooting, low-cost poly house, economic productivity

Introduction
The Rutaceae family includes citrus fruits, which are very rich in Vitamin C and organic acid content (Akhter. *et al.*, 2021) [2]. It is growing all over the world (Tandon *et al.* 2019) [19]. It is farmed in the Indian states of Andhra Pradesh, Karnataka, Maharashtra, Punjab, Rajasthan, and Uttarakhand. In addition, lime is produced in Punjab in some areas of the Jalandhar districts. Rough lemon can be found in many parts of the state, growing wild. This is a citrus hybrid whose fruit and trees are commonly known as rough lemons(*Citrus × jambhiri* Lush.) A hybrid of oranges and citrons, just like the rangpur. These trees can reach large sizes and are cold-hardy. However, Inrough lemons, 90 percent of the rind is present, making them almost inedible. Numerous cultivars of rough lemon can serve as a citrus rootstock, like 'Florida', 'Schaub', and 'Vangassay' rough lemon. These varieties of rootstock should be propagated through the clonal method of propagation. Otherwise, rough lemon is usually used as seedling rootstock into orange or grapefruit trees through shield budding, also known as T budding.

Apart from its nutritional value and utility as a table vegetable, rough lemon is often used as a rootstock for malta and mandarin. Regeneration of rough lemon is primarily carried out by seeds, which has the disadvantage of non-uniform progeny and risk of contamination with viral diseases. (Sidhu *et al.* 2014) [17]. For increasing natural regeneration and large-scale growing programmes, vegetative multiplication by cutting is the sole practical and extensively utilized approach for solving this difficulty. Because of the high intensity of polyembryony (90-100%) and low risk of viral illness contamination in rough lemon, stem cutting is appropriate for regeneration. It is low-cost, quick, and easy to execute, and it does not need the use of any particular processes as other vegetative approaches do. Auxins have been shown to encourage adventitious roots in stem cuttings.

Furthermore, combining it with other chemicals has improved root development (Otiende *et al.*, 2021) [16]. It was also discovered to work with IBA in citrus species (Bowman & Albrecht, 2017) [4]. However, despite much research on several aspects of citrus fruit propagation, the impacts of IBA on cutting rooted under various growth circumstances remain unknown.

With this information in mind, the current study examines the application of IBA with different growth conditions for rooting parameters and success percentage in rough lemon stem cuttings to establish a low-cost, simple clonal multiplication technology package.

Material and Methods

Cuttings were obtained from the tree's young branches at the end of June 2021.This research work used cuttings with a 20-22cm length and a 6-8cm diameter. The centre and basal sections of the branch were formed with a diameter of 0.6 - 1.2 cm. Defoliated cuttings were used to reduce transpiration. Stem cuttings were divided into four bundles containing about 80stem cuttings. Three bundles of cuttings were handled with IBA at three different concentrations, *viz*. 500 ppm, 1000 ppm, and 1500 ppm. At a room temperature of 20 C, the basal sections (2-3 cm) of each cutting were dipped for 2 minutes in varying concentrations of IBA (Campbell *et al*., 2021) [5]. The fourth bundle of clippings wereserved as a control (it was merely dipped in water for 2minuteswith regular tap water).Six gunny bags of Sandy loam soil in the LPU farm was exposed to soil solarisation to kill insects, disease spores, and weeds. Stones and gravel were physically removed. In June, after one day of drying, 1 part of FYM was mixed with two parts of sandy loam soil combined to provide good drainage. It was then placed in perforated polythene bags with a capacity of around 1 kg (20-22cm height x 8-10cm diameter). IBA solutions concentrations of 1500, 1000, and 500ppm were made and stored in a 1 L glass beaker. The treated cuttings were planted in three distinct growth settings: open sunlight area (G1), partial shade from a large tree during the day (G2), and polyhouse conditions (G3) with areas of 3m (l) × 2m (b) x 2m (h).The observations on root properties were recorded using standard procedures (Bardini *et al.*, 2021). Each treatment combination had three replications, each with nine stem cutting, in a factorial randomized block design (FRBD).The data were analyzed using standard statistical methodologies (White *et al.*, 2020) [22].

Results and Discussions

The rooting response of *Citrus* × *jambhiri* Lushcuttings were treated with various concentrations of IBA and growth conditions. The mean data show that after 130 days, the treatment C1 (500 ppm IBA) had the highest number of sprouted cuttings with 72.16 percent and 51.00 percent, followed by C2 (1000 ppm).The C0 treatment had the least number of sprouted cuttings (37%) of all the treatments. The current findings are consistent with a few earlier studies that have been reported in the literature.(Kaczmarek *et al.*,2020) [10], although they contradict that the highest proportion of sprouting at higher concentrations (1500 ppm of IBA). The treatment G1 (open area) had the highest mean sprouting percentage (61.05%), followed by the treatment G2 (partial shade) with 48.54 percent, and the G3 (polyhouse) condition had the lowest (48.54 percent). However, with 83.33 percent of sprouted cuttings, C1G3 (500ppm IBA with polyhouse condition) was the optimum treatment combination. These observations might be attributed to favourable environmental circumstances for cutting survival in polyhouses and the influence of reduced concentrations of rooting hormones. Table 1 also shows that the C2 (1000 ppm IBA) treatment yielded the most primary roots (8.76 cm), followed by C1 (500ppm IBA) with 7.54 cm. The current results of the experiment are backed and enhanced by the work of Essa *et al.* (2021) [8]. They discovered a total of 13.55cuttings with the most primary roots. According to the findings of Kaczmarek *et al.*, (2020) [10]. Cuttings treated to 1000ppm extract generated more roots per cutting (Francavilla *et al.*, 2021) [9]. Cuttings grown in the G3 (polyhouse) treatment generated the most primary roots (11.66cm), followed by G1 (open area) with 11.00, while cuttings grown in the G2 (partial shade) condition produced the fewest primary roots (4.06) of all the growth environments. It also demonstrated a strong link between various IBA concentrations and varied growth conditions. The C2G3 (1000 ppm of IBA with polyhouse condition) treatment combination produced the most primary roots (18.66), followed by the C3G3 (1500 ppm of IBA with polyhouse) treatment with 11.66. The C1G2 and C2G2 combinations had the same number of primary roots (2.62 cm). Improved root and growth (500 ppm IBA to polyhouse) may be connected to improved metabolic activity and maximum sugar and starch utilization.C1 (500 ppm IBA) therapy resulted in the longest root length (14.00 cm), followed by C0 (control) treatment with 13.44 cm. Verma *et al.* (2005) showed a maximum root length (15.27 cm).The findings of citrus cuttings support this study's conclusions. In terms of generating the longest root with the greatest length (20.33 cm), combination treatments C1G3 (500 ppm of IBA with polyhouse grown) and C2G3 (1000 ppm IBA with polyhouse grown) were found to be equally good, while C2G1 (1000 ppm of IBA with open area grown) treatment combination produced the shortest root (4.66 cm). Furthermore, Table 1Treatment C1 treatments have the largest effect on root density (0.26 cm). Zheng *et al.* (2022) [23] confirmed the current findings, noting that IBA had the greatest influence on root diameter (1.93 mm) among other growth regulators such as IAA and NAA. Growing cuttings in various environments indicated that the G3 (to polyhouse) condition yielded the biggest diameter of thick roots (0.26 cm). A G1 (open area) environment yielded the least diameter of the strongest root (0.18 cm). (0.21 cm). C2G3 (1000 ppm IBA with polyhouse) and C3G3 (1500 ppm IBA with polyhouse). Recent studies have suggested that strong root growth, fewer brittle roots, more fibrous roots and a higher fresh and dry weight are possible explanations for plant survival, root number and diameter (Tyagi and Patel, 2004) [21]. Regardless of the concentrations of IBAs, the plantlets survive, sprout, and produce the maximum number of leaves in poly houses because they provide controlled environments that are more conducive to growth than the uncontrolled environments of open areas. This finding strongly agrees with the results obtained by Ahmad *et al*. (2007) in patch budding of walnut, Akhter *et al*. (2021) [2]. The application of IBA led to a significant increase in rooting, rooting characteristics, sprouting and leaf count of guava plants. In stem cuttings, 500 ppm of IBA was the most successful in establishing the roots, establishing the roots, and establishing the growth characteristics. Regardless of IBA concentrations, polyhouses always proved to be more successful in terms of stem cutting survival and growth.

Table 1: Rooting percentage and rooting properties of rough lemon cuttings are affected by different quantities of IBA and different growth environments

IBA Conc.	Sprouting percentage cuttings				Number of roots (cm)				Longest roots length (cm)				largest root's diameter (cm)			
	G_1	G_2	G_3	Mean	G_1	G_2	G_3	Mean	G_1	G_2	G_3	Mean	G_1	G_2	G_3	Mean
C_0	61.00	34.33	14.33	36.55	7.33	7.56	5.66	6.85	10.33	11.33	17.66	13.10	0.20	0.20	0.20	0.20
C_1	72.16	50.00	83.33	68.50	11.00	2.72	8.00	7.24	14.00	11.00	21.03	15.34	0.26	0.20	0.26	0.24
C_2	51.00	55.50	55.50	55.67	5.00	2.72	18.66	8.79	4.66	11.66	20.03	12.16	0.20	0.20	0.30	0.23
C_3	58.83	55.33	37.73	50.63	5.00	3.43	11.66	6.69	7.33	7.33	15.06	9.90	0.30	0.20	0.30	0.23
Mean	61.05	48.05	53..65		9.44	6.47	14.64		12.10	13.77	24.59		0.21	0.20	0.26	
CD0.05																
IBA Conc. (C)			4.07			1.87				2.76				0.056		
Conditions of growth (M)			2.66			1.18				1.85				0.038		
C x M			4.82			3.17				4.12				0.052		

G_1= Area with lots of sunlight, G_2= Partial shade of big tree throughout the day, G_3= Conditions in a polyhouse
C_0=control (Water), C_1= 500ppm (IBA), C_2= 1000ppm (IBA), C_3= 1500ppm (IBA)

Conclusion

The results demonstrate that IBA 500 ppm is most effective at encouraging plant root formation and root growth in *Citrus jhambhiri* cutting. It was astonishing that although open-air growing conditions alone produce satisfactory results, mixing IBA 500 ppm with polyhouse growth conditions has even better results. The outcomes of this study could pave the way for a significant increase in spontaneous clonal or pure to type replicating of citrus plants. Overall, the IBA 500ppm treatment in a polyhouse combination was the most effective for the economic propagation of the citrus fruit crop.

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