

Development of methods to improve the technology of reproduction of lemon (*Citrus limon* L.) by green cuttings

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Abstract. The paper studies the effect of the form of preparation (powder and alcohol solution) and concentrations of auxin class phytohormone - indolyl-3- butyric acid (IBA) on morphometric parameters of root system development in green lemon cuttings at rooting under conditions of fog. The results of the study showed 100% rooting of Meyer lemon (*C. meyeri*) in all variants, and also revealed the advantage of using rooting powder with a concentration of 0.75% IBA. At rooting of ‘Novogruzinsky’ lemon variety (*Citrus limon* L.) 100% rooting ability was detected in all variants except for alcohol solution with concentration of 1.0%. According to the indicators of root system development the advantage of rooting powder with IBA concentration 1.0% and alcohol solution with IBA concentration 0.75% was revealed.

1 Introduction

Citrus fruits are one of the most important fruit crops; they are grown commercially in more than 140 countries, and constitute a significant export and import item for many countries [1-4]. About 70% of the world's total commercial citrus fruit is grown in the Northern Hemisphere, particularly in China, Mediterranean countries and the USA. Among European countries, Spain is the leader, accounting for more than 55% of citrus fruit production [5, 6]. It is important to note that the Russian Federation is one of the largest importers of citrus fruits in the world, while domestic citrus production is severely limited due to unsuitable climatic conditions [1, 7, 8].

Citrus production is greatly influenced by its biological characteristics, such as its light and heat requirements, as well as its late onset of fruiting and long ripening period [9, 10].

One of the most precocious and valuable citrus fruits is the lemon (*Citrus limon* L.), which ranks third after the orange and mandarin as the most widely grown species. Lemon fruits have a high nutritional value, are used for flavoring drinks and foods, are used to obtain

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essential oils, ascorbic acid, and are also widely used in medicine. Due to the presence of alkaloid components in various parts of the plant, it exhibits antibacterial activity [11, 12].

The growth of lemon fruit consumption requires an increase in the production of the necessary amount of quality planting material for this crop. In the world practice of citrus fruit propagation, vegetative methods, such as green cuttings, butt grafting; grafting and tissue culture are the most common. These methods of propagation allow preserving the hereditary traits of the mother plant and at the same time significantly reducing the juvenile period characteristic of seedlings, accelerating the entry into fruiting [13].

At the same time, despite the widespread use of the grafting method in citrus propagation, as well as significant advances in clonal micropropagation, the most accessible and widespread method of lemon propagation is green cuttings [14, 15].

The success of plant propagation by cuttings depends largely not only on climate conditions, but also on the proper selection of growth regulators that induce root formation. The most commonly used auxin-type phytohormones as rooting agents are indolyl-3- butyric acid (IBA), 3-indolylacetic acid (IAA), alpha-naphthylacetic acid (NAA), and their salts. At the same time, the most common preparation is IBA, and the selection of the most physiologically active concentrations and preparative form are equally important conditions for successful rooting [16].

Therefore, the aim of our study was to select the best concentration of IBA and preparative form for rooting lemon cultivars.

2 Material and methods

The experiment was conducted in 2024 at the Russian State Agrarian University - MSHA, named after K.A. Timiryazev, in the Department of Biotechnology and Berry Crops of the V.I. Edelstein Educational, Research and Production Centre for Horticulture and Vegetable Production.

The objects of the study were ‘Meyer’ lemon (*C. meyeri*) and ‘Novogruzinsky’ lemon (*C. limon* var. Novogruzinsky).

Different preparative forms (growth powder and alcohol solution) of rooting stimulator IBA (indolyl-3- butyric acid) at concentrations of 0.5%; 0.75%; 1.0% were used for rooting green cuttings.

The rooting powder was prepared two days before the experiment by impregnating talc with alcoholic solutions of IBA with appropriate experimental concentrations, followed by drying and grinding to powder.

The alcoholic solution was prepared immediately before use by dissolving an appropriate weight of IBA in a 40% water-alcohol solution.

Before the experiment, matured green cuttings of the first spring growth wave were cut from the experimental plants. They were selected from the middle part of the shoot with two internodes and two leaves (the lower leaf and thorns were removed). The cuts were made straight, with the lower cut 1 cm below the bud and the upper cut 0.5 cm above the upper bud.

After treating the basal part of green cuttings with experimental concentrations of rooting powder (1 second exposure) and alcohol solution (3 seconds exposure), they were planted in plastic cassettes (40 cells, cell volume 110 ml) with peat substrate consisting of a 5:1 mixture of top peat and perlite. Rooting of cuttings was performed in a plastic-clad greenhouse with a fogging system.

Repetition of experiments was threefold, 10 cuttings in one repetition. Morphometric parameters of root system development were measured on 40 days of rooting and the following were taken into account: % of rooted cuttings, number of roots, root length, total root length, root system volume.

Statistical processing was performed using the method of two-factor variance analysis using Microsoft Excel 2016 and PAST 4.03 computer programs and according to the method of Isachkin A.V. [17]. The data are presented as mean values and standard error of the mean ($M \pm SEM$).

3 Results and Discussion

According to the results of research on ‘Meyer’ lemon cuttings, rooting rate was 100% on the 40th day in all experimental variants.

Analysis of the effect of preparative forms (factor B) and concentrations of IBA (factor A) on morphometric indices of root system development (Table 1) showed the advantage of using the basal part of green ‘Meyer’ lemon cuttings treated with rooting powder (Figure 1) compared to the alcohol solution (Figure 2).

There was also a significant advantage of 0.75% concentration of IBA, at which the total root length was 57.3 ± 5.63 cm vs. 40.8 ± 3.64 cm in the control.

Table 1. Morphometric indices of the development of the root system of the Mayer lemon variety

IBA concentration (Factor A)	Preparative form of IBA (Factor B)		Average for factor A
	Rooting powder	Alcohol solution	
	Number of roots, pcs.		$LSD_{05} a = F_e < F_t$
IBA 0.5% (control)	7.1 ± 0.69^b	5.4 ± 0.75	6.3
IBA 0.75%	8.9 ± 0.74^b	7.2 ± 0.77	8.1
IBA 1.0%	6.3 ± 0.50	6.3 ± 0.63	6.3
Average for factor B $LSD_{05} b = 1.12$	7.4	6.3	×
$LSD_{05} ab = F_e < F_t$ for comparison of individual cases			
	Root length, cm		$LSD_{05} a = F_e < F_t$
IBA 0.5% (control)	5.5 ± 0.47	7.8 ± 0.68	6.7
IBA 0.75%	5.9 ± 0.24	6.1 ± 0.41	6.0
IBA 1.0%	6.4 ± 0.52	5.7 ± 0.54	6.1
Average for factor B $LSD_{05} b = F_e < F_t$	5.9	6.5	×
$LSD_{05} ab = F_e < F_t$ for comparison of individual cases			
	Total root length, cm		$LSD_{05} a = 9.85$
IBA 0.5% (control)	40.8 ± 3.64	38.0 ± 2.20	39.4
IBA 0.75%	$57.3 \pm 5.63^{a,b}$	44.1 ± 5.47	50.7
IBA 1.0%	47.6 ± 2.19^b	35.0 ± 4.04	41.3
Average for factor B $LSD_{05} b = 6,70$	48,6	39,0	×
$LSD_{05} ab = F_e < F_t$ for comparison of individual cases			
	Root system volume, cm^3		$LSD_{05} a = F_e < F_t$
IBA 0.5% (control)	3.2 ± 0.35	3.1 ± 0.21	3.2
IBA 0.75%	4.7 ± 0.37^b	3.7 ± 0.41	4.2
IBA 1.0%	4.4 ± 0.36^b	3.5 ± 0.28	4.0
Average for factor B $LSD_{05} b = 0.55$	4.1	3.4	×
$LSD_{05} ab = F_e < F_t$ for comparison of individual cases			



Fig. 1. ‘Meyer’ lemon (*C. meyeri*) cuttings at 40 days (rooting powder with IBA 5%; 7.5%; 10%)



Fig. 2. ‘Meyer’ lemon (*C. meyeri*) cuttings at 40 days (alcohol solution with IBA 5%; 7.5%; 10%)

According to the results of research of lemon cuttings of ‘Novogruzinsky’ variety, on the 40th day rooting rate was 100% in all variants of the experiment except for the alcohol solution with IBA concentration of 1.0%. In this variant there was a sharp decrease in rooting capacity, which amounted to 40%.

Analysis of the effects of preparative forms (factor B) and IBA concentrations (factor A) on morphometric parameters of root system development of green cuttings of Novogruzinsky lemon variety (Table 2) showed the advantage of treatment of the basal part of cuttings with rooting powder with IBA concentration of 1.0% (Figure 3). At the same time, reliable differences with the control were revealed in terms of total root length, which amounted to 34.3 ± 1.96 cm vs. 10.9 ± 3.75 cm when the alcohol solution was applied. The effect on the volume of root system was also noted, which amounted to 4.8 ± 0.24 cm³ vs. 1.3 ± 0.70 cm³ when alcohol solution was applied.

When using the preparative form in the form of alcohol solution (Figure 4), the advantage of IBA at a concentration of 0.75% (factor A) was noted, and a significant difference was found in root length, which amounted to 7.8 ± 0.68 cm vs. 6.0 ± 0.49 cm in the control.

Thus, for rooting green cuttings of Novogruzinsky lemon variety we can recommend rooting powder with IBA concentration of 1.0% and alcohol solution with IBA 0.75%.

Table 2. Morphometric indices of the development of the root system of the Novogruzinsky lemon variety

IBA concentration (Factor A)	Preparative form of IBA (Factor B)		Average for factor A
	Rooting powder	Alcohol solution	
Number of roots, pcs.			LSD ₀₅ a = F _e <F _t
IBA 0.5% (control)	3.3±0.33	8.8±1.18 ^b	6.1
IBA 0.75%	5.9±0.35	6.1±0.72	6.0
IBA 1.0%	4.9±0.35	4.3±0.48	4.6
Average for factor B LSD ₀₅ b = 1.13	4.7	6.4	×
LSD ₀₅ ab = 2.88 for comparison of individual cases			
Root length, cm			LSD _{05a} = 1.57
IBA 0.5% (control)	9.4±0.80^b	6.0±0.49	7.7
IBA 0.75%	6.4±0.68	7.8±0.68^{a,b}	7.1
IBA 1.0%	7.2±0.37^b	3.0±0.84	5.1
Average for factor B LSD ₀₅ b = 1.07	7.7	5.6	×
LSD ₀₅ ab = 2.71 for comparison of individual cases			
Total root length, cm			LSD ₀₅ a = F _e <F _t
IBA 0.5% (control)	40.5±4,67	46.3±5.54	43.4
IBA 0.75%	33.4±5,53	38.3±3.65	35.9
IBA 1.0%	34.3±1,96^b	10.9±3.75	22.6
Average for factor B LSD ₀₅ b = 7.54	36.1	31.8	×
LSD ₀₅ ab = 19.20 for comparison of individual cases			
Root system volume, cm ³			LSD ₀₅ a = F _e <F _t
IBA 0.5% (control)	4.5±0.42	4.6±0.37	4.6
IBA 0.75%	3.5±0.43	4.5±0.36^b	4.0
IBA 1.0%	4.8±0.24^b	1.3±0.70	3.1
Average for factor B LSD ₀₅ b = 0.64	4.3	3.5	×
LSD ₀₅ ab = 1.64 for comparison of individual cases			



Fig. 3. 'Novogruzinsky' lemon (*Citrus limon* L.) cuttings at 40 days (rooting powder with IBA 5%; 7.5%; 10%)



Fig. 4. 'Novogruzinsky' lemon (*Citrus limon* L.) cuttings at 40 days (alcohol solution with IBA 5%; 7.5%; 10%)

4 Conclusions

In the rooting of green cuttings of 'Meyer' lemon, 100% rooting ability was observed when using the prepared forms and concentrations of IBA studied. According to the morphometric indicators of the development of the root system, the advantage of using the growth powder with the IBA concentration of 0.75% was revealed.

Rooting of green cuttings of 'Novogruzinsky' lemon showed 100% rooting ability in all variants except alcohol solution with IBA concentration of 1.0%. According to morphometric indicators of root system development, the advantage of using growth powder with IBA concentration of 1.0% and alcohol solution with IBA concentration of 0.75% was revealed.

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