Effect of Planting Schemes and Timing of Green Cuttings on the Rooting Ability and Quality of Kiwi (Actinidia Deliciosa (a. Chev.) c.f. Liang ET a.r. Ferguson) Seedlings

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Abstract. This study was conducted to determine the effect of planting schemes and planting dates on the rooting ability and growth performance of green cuttings of *Actinidia deliciosa* (kiwi). The experiments were carried out under greenhouse conditions during 2022–2024 using the "Hayward" cultivar. The cuttings were planted at various spacings (ranging from 10×5 cm to 15×25 cm) and at different times (from early May to the end of June). The results showed that as the planting distance increased, both the rooting ability of the cuttings and the overall growth parameters of the plants improved. The best results were obtained with the 15×25 cm spacing: the rooting rate reached 90.6%, shoot formation 98.3%, root system volume 7.1 cm^3, and plant height 73.6 cm. However, in terms of the number of standard seedlings obtained per 1 m^2, the 10×20 cm and 15×15 cm planting schemes proved to be the most optimal (yielding 44–46 standard seedlings). The timing of planting also had a significant effect on the rooting process. The most active rhizogenesis occurred in cuttings planted during the last ten days of May: callus formation began after 14 days, and roots appeared after 18 days, with a rooting rate of 87.8%. In contrast, both earlier and later plantings resulted in weaker root development. In conclusion, when propagating kiwi *(Actinidia deliciosa)* by green cuttings, the most favorable results are achieved when cuttings are planted in the last ten days of May using a 10×20 cm or 15×15 cm planting scheme. This approach ensures the production of high-quality, standard seedlings.

Keywords: *Actinidia deliciosa*, kiwi, Hayward, plant, planting scheme, vegetation, callus, green cutting, rhizogenesis, root, planting time, rooting ability

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1 Introduction

According to researchers, the rooting ability of fruit crops propagated through green cuttings is influenced by numerous factors, including the planting scheme and timing, the physiological condition of the donor shoots and the part from which the cutting is taken, as well as the types and concentrations of growth stimulants used [3, 5, 6, 7]. Among these factors, the planting scheme plays a particularly important role. Excessively dense planting increases humidity and shading [3, 4, 5], which can cause cuttings to rot, while overly wide spacing reduces the number of seedlings obtained per unit area [3, 5]. The significant importance of planting schemes in the propagation of fruit crops by green cuttings has been emphasized by many foreign [6; pp. 56–62; 7; pp. 17–20] and national [1; pp. 67–85; 4; 2018; pp. 5–14; 2; pp. 57–73] researchers. However, most of these studies focused on rootstocks of fruit trees, grapevine, olive, and other plant species whose biological characteristics differ substantially from those of kiwi. Therefore, when propagating *Actinidia deliciosa* through green cuttings, selecting a planting scheme that aligns with the biological properties of the species is a crucial factor in ensuring its effective regeneration and vigorous growth [3, 5, 6].

2 Materials and methods

Experiment 5. *Effect of planting schemes and planting time on the rooting ability and seedling quality of kiwi (Actinidia deliciosa) green cuttings.*

This experiment was conducted following the general methodology described above [3, 4, 5]. In this case, however, green cuttings were collected from mother plants of the kiwi cultivar at different times and planted according to various spacing schemes. The experimental design was as follows:

By planting time (planting scheme: 10×10 cm)

1. Preparation and planting of cuttings in the first ten days of May;
2. As above, in the second ten days of May;
3. As above, in the third ten days of May;
4. As above, in the first ten days of June – control;
5. As above, in the second ten days of June;
6. As above, in the third ten days of June.

By planting scheme (cuttings prepared in the third ten days of May)

1. Planting cuttings at 10×10 cm spacing;
2. Planting cuttings at 10×10 cm spacing – control;
3. As above, at 10×15 cm spacing;
4. As above, at 10×20 cm spacing;
5. As above, at 10×25 cm spacing;
6. As above, at 15×15 cm spacing;
7. As above, at 15×20 cm spacing;
8. As above, at 15×25 cm spacing.

In all experimental variants, the following phenological observations and biometric measurements were carried out:

- Bud burst – the date when the majority of plants showed swollen buds with visible leaf tips was recorded. Observations were made every two days.

- Cessation of shoot growth – the date when the apical buds of most current-season shoots were fully formed was recorded.
- End of vegetation (leaf fall period) – recorded when up to 75% of the leaves had dried, fallen, or turned yellow.

The duration of the vegetation period was calculated from the date of bud burst until the onset of stable frost that completely halted plant growth.

Formation of callus and root primordia on green cuttings was monitored every two days from the date of planting in the substrate, and the timing was recorded in days.

Root formation on green cuttings was studied dynamically—from the appearance of the first roots until autumn excavation—by measuring root growth in meters. Observations were made at 10-day intervals.

The volume of the root system was determined at the end of the vegetation period using a cylindrical measuring device. The volume of water displaced by the root system was measured and recorded in cubic centimeters (cm^3).

The total average root length was determined by measuring the lengths of all primary roots of the plant, summing them, and expressing the result in meters.

The rooting capacity of green cuttings was assessed at autumn excavation by calculating the proportion of rooted cuttings relative to the total number of cuttings planted, expressed as a percentage (%).

Shoot length (plant height) was measured every 15 days throughout the vegetation period—from the time of bud burst to the end of shoot growth—by measuring the height of the central shoot from the root collar to the apical bud, expressed in centimeters (cm).

The percentage of standard-quality seedlings was determined at the end of the vegetation period by sorting according to standard requirements and calculating their share in relation to the total number of seedlings (%).

The experimental methodology and evaluation criteria were developed based on the works of:

- Ermakov, *"*Propagation of woody and shrubby plants by green cuttings*"* [6; pp. 21–38];
- M.T. Tarasenko, "Green cutting of garden and forest crops (theory and practice)*"* [8; pp. 8–15; 112–118];
- F.Ya. Polikarpova, *"*Green cuttings in conditions of automatically regulated artificial fog formation*"* [7; pp. 78–83].

3 Results

Experiments conducted on the propagation of Actinidia deliciosa (kiwi) through green cuttings at different planting schemes revealed that the rooting ability of the cuttings varied across treatments [6, 7]. It was observed that as the planting spacing increased, the rooting percentage of the cuttings also improved [3, 5, 6].

As expected, the highest rooting rate was recorded in the treatment with a 15×25 cm planting scheme, where the proportion of rooted cuttings reached up to 90.6% of the total planted cuttings. Conversely, the lowest rooting ability was observed in the 10×5 cm spacing, where the rooting percentage of kiwi green cuttings did not exceed 79.3% (Figure 1).

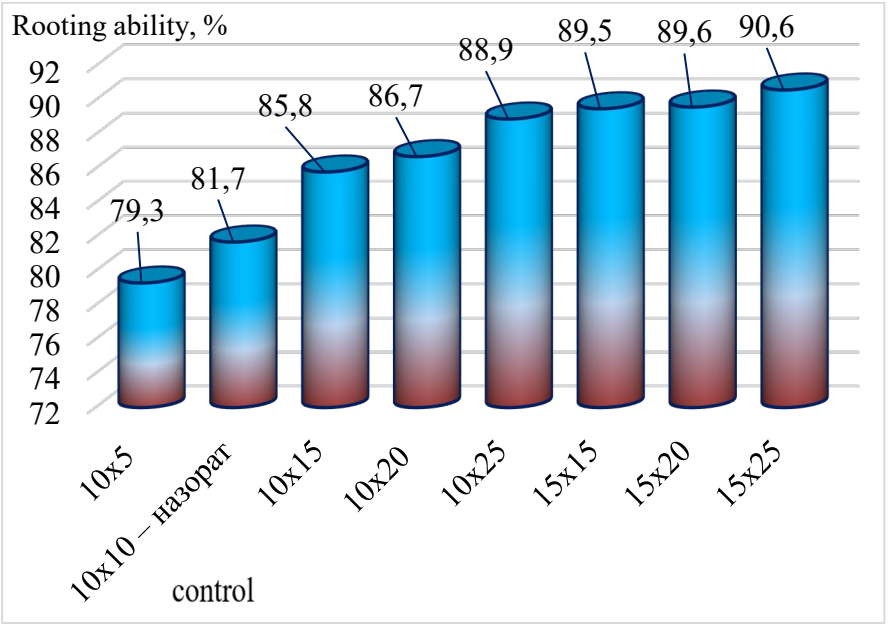

Figure 1. Rooting ability of green cuttings of the Actinidia deliciosa ‘Hayward’ cultivar under different planting schemes, 2022–2024.

It is noteworthy that although the differences in rooting percentages among the experimental treatments were not very large, the parameters of root system development showed a clear advantage in cuttings planted at wider spacings. The most well-developed root systems were observed in cuttings planted under 10×15–25 cm and 15×15–25 cm spacing schemes (Figure 2).

Figure 2. Development of the root system in green cuttings of *Actinidia deliciosa* 'Hayward' under different planting schemes (as of September 1): 1 – 10×5 cm; 2 – 10×10 cm; 3 – 10×15 cm; 4 – 10×20 cm; 5 – 10×25 cm; 6 – 15×15 cm; 7 – 15×20 cm; 8 – 15×25 cm.

The planting scheme also had a significant influence on the development parameters of the above-ground parts of the green cuttings. The highest shoot formation rate was recorded in the treatment with a 15×25 cm planting scheme, where the proportion of cuttings that produced new shoots reached approximately 98.3% of the total planted cuttings.

As planting density increased, the rate of shoot formation decreased proportionally. As expected, the lowest shoot development was observed in the 10×5 cm spacing, where only 51.6% of the planted green cuttings produced shoots.

The remaining treatments showed intermediate results, with the proportion of green cuttings forming new shoots ranging between 79.8% and 97.8%, following a gradual upward trend corresponding to the widening of the planting spacing.

The number of leaves formed on plants grown from green cuttings also varied depending on their shoot formation rate. Regarding this biometric parameter, the best performance was observed in the treatment with the 15×25 cm planting scheme. In this variant, the shoots developed from the green cuttings formed an average of up to 19 leaves per plant, which is 11 more leaves than in the control treatment.

The lowest number of leaves was recorded in cuttings planted at the 10×5 cm spacing, where the average number of leaves per shoot reached only 6.3, which is two leaves fewer than the control (8.3 leaves). The remaining treatments occupied intermediate

positions between these two extremes, with the average number of leaves ranging from 9.6 to 18.7, or 1.3 to 10.4 leaves more than the control. The smallest recorded difference among treatments was 0.4.

Experimental data also demonstrated that the planting scheme had a significant effect on the development of the conditional stem (main shoot thickness) of one-year-old seedlings. Similar to the trend observed for leaf number, plants grown from wider-spaced green cuttings showed thicker and better-developed stems (Table 1).

Accordingly, the thickest and most vigorous stems were observed in plants grown under the 15×25 cm planting scheme, where the average diameter of the conditional stem reached 15.1 mm, which is 6 mm thicker than that of the control treatment. The smallest difference recorded was 0.4 mm.

Conversely, the thinnest stems were found in plants from the 10×5 cm spacing, where the average stem diameter did not exceed 7.2 mm, being 1.9 mm thinner than that of the control plants (9.1 mm).

The plants in the remaining treatments showed intermediate results, with stem diameters ranging from 11.4 to 14.7 mm, which were 2.3–5.6 mm thicker than those of the control plants.

It is well known that in horticulture, the height of prepared seedlings is also an important agronomic indicator. Measurements of shoot length in plants developed from green cuttings planted under different spacing schemes showed that the tallest shoots were obtained in the variant planted at a 15×25 cm scheme. In this variant, the average shoot height reached about 73 cm, which is 32 cm higher than that of the control plants (41 cm).

Table 1. Development characteristics of 'Hayward' kiwi plants grown from green cuttings under different planting schemes, 2022–2024

Planting scheme (cm)	Root system volume (cm^3)	Cuttings that formed shoots (%)	Number of leaves (pcs)	Conditional stem diameter (mm)	Shoot length, (cm)
10x5 (cm)	2,1	51,6	6,3	7,2	36,5
10x10 (cm)– control	4,3	79,8	8,3	9,1	41,6
10x15 (cm)	5,1	85,7	9,6	11,4	45,4
10x20 (cm)	5,9	92,3	11,7	13,5	61,0
10x25 (cm)	6,5	95,8	15,7	13,7	66,2
15x15 (cm)	6,9	95,9	16,8	14,2	68,3
15x20 (cm)	7,0	97,8	18,7	14,7	69,7
15x25 (cm)	7,1	98,3	19,1	15,1	73,6
EKF_{05}	*0,3*	-	*0,4*	*0,4*	*0,8*
Sx	*0,04*	-	*0,06*	*0,05*	*0,11*

The shortest plants were observed in the variant where green cuttings were planted at a 10×5 cm spacing. In this treatment, the average shoot height did not exceed 36 cm, which is 5 cm shorter than that of the control plants. The remaining experimental variants occupied intermediate positions, with shoot lengths ranging from 45 to 69 cm, i.e., 4–28 cm longer than the control. The smallest difference recorded was 0.8 cm.

It should be noted that although wider planting schemes resulted in higher regeneration rates and more vigorous plants, selecting an optimal spacing scheme is crucial in terms of the number of marketable seedlings obtained per unit area.

Calculations showed that the number of standard seedlings (with main shoot length exceeding 60 cm) was highest in the 10×20 cm and 15×15 cm spacing variants — 46 and 44 plants per m², respectively. Although denser planting schemes produced a higher total number of rooted and developed plants, 75–80% of them had to be left for the next growing season since their shoots did not even reach 50 cm. Conversely, in the wider planting variants, although 95–98% of the plants formed shoots and grew strongly, the total number of seedlings per unit area was lower due to fewer cuttings planted (Figure 3).

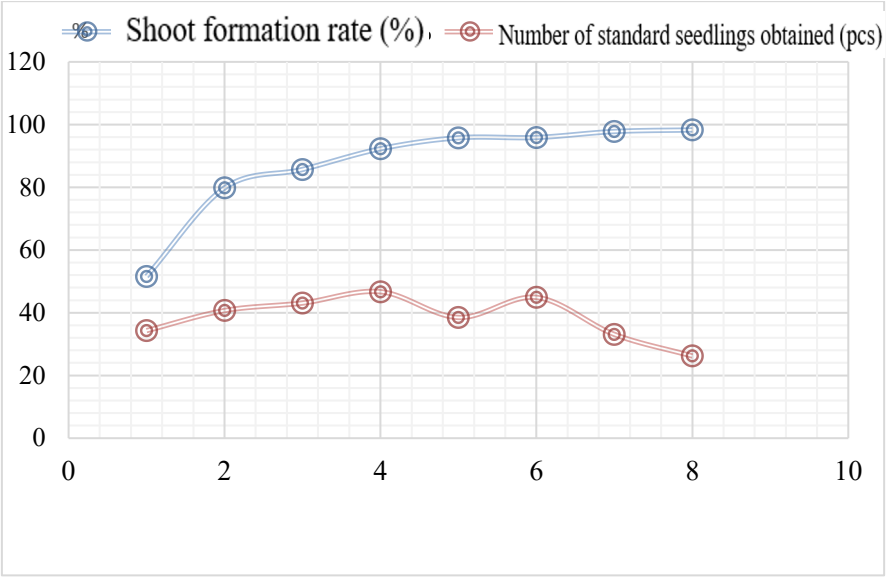

Figure 3. Effect of different planting schemes on the yield of 'Hayward' kiwi seedlings propagated from green cuttings, 2022–2024.

Based on the results obtained from the experiment, it can be concluded that the rooting ability of *Actinidia deliciosa* (cv. 'Hayward') green cuttings increases as the planting distance widens, reaching up to approximately 95% under the most favorable spacing. However, from the perspective of seedling yield per unit area, the 10×20 cm and 15×15 cm planting schemes were found to be the most optimal for production purposes. Under these conditions, up to 44–46 standard-sized seedlings per 1 m² can be obtained [3; 54–57].

Propagation of fruit crops through green cuttings significantly increases the multiplication coefficient of planting materials. However, the rooting ability of such cuttings is affected by a variety of factors, among which the planting time plays a decisive role. Depending on the growth phase of the plant, the intensity of physiological processes occurring in the shoots and their regenerative capacity vary considerably.

Our experiments conducted to determine the influence of planting time on the propagation of kiwi plants from green cuttings revealed that the rate of callus formation differed significantly depending on the planting period. The earliest callus formation was observed in the variant where cuttings were prepared and planted during the last ten days of May. In this treatment, callus tissue appeared on average within 14 days, which is two days earlier than in the control.

In contrast, the latest callus formation was recorded in the variants where green cuttings were prepared and planted either in the first ten days of May or in the last ten days of June. In these variants, callus tissue appeared only 19 days after planting, which was three days later than the control treatment (16 days).

This phenomenon can be explained as follows: in the early-planted variant, the shoots had not yet undergone sufficient lignification, and both the cambium and xylem tissues were still immature, resulting in a slower initiation of regenerative activity. Conversely, in the very late planting period, the shoots were overly lignified, which led to a reduction in their regenerative potential compared to younger shoots.

In the remaining experimental variants, callus formation occurred at intermediate rates, ranging from 16 to 18 days, depending on the planting period (Table 2).

The data presented in Table 2 also indicate that, similar to the rate of callus formation, the overall root initiation of green cuttings varied according to the time of planting. The most rapid root development was recorded in cuttings prepared and planted during the last ten days of May.

Table 2. Influence of planting time on the intensity of rhizogenesis in green cuttings of kiwi (Actinidia deliciosa Hayward cultivar), 2022–2024

Experimental option	Dynamics of rhizogenesis, (days):			Cuttings that formed roots, (%)
	Initial callus formation	Beginning of mass rooting	Initiation of shoot growth in cuttings	
1-10/V	19	24	29	55,3
11-20/V	16	20	27	75,9
21-30/V	14	18	22	87,8
1-10/VI – control	16	20	24	85,3
11-20/VI	18	23	27	77,8
21-30/VI	19	26	31	65,5

Starting the preparation and planting of green cuttings either too early or, conversely, delaying it beyond the optimal period led to a slowdown in the initiation of mass root formation. Specifically, the rooting process in cuttings prepared in the first and second halves of May was delayed by four days compared to the control, while in those prepared toward the end of June, this physiological process was delayed by three to six days.

The initiation of new shoot growth in green cuttings followed a similar trend to that of root formation. Accordingly, in the variant where cuttings were planted during the last ten days of May, new shoots appeared the earliest—on the 22nd day after planting—

which was two days earlier than in the control variant. In contrast, when planting was carried out either earlier or later than this period, shoot emergence was delayed by three to five and three to six days, respectively, compared to the control.

It is particularly noteworthy that the timing of cutting preparation and planting had a significant effect on the quality of root formation. The highest percentage of rooted cuttings was observed in the variant where cuttings were prepared and planted during the last ten days of May. In this case, approximately 87.8% of cuttings formed roots, which was 2.5% higher than the control. Planting cuttings too early, however, resulted in a sharp decline in rooting ability. For instance, in cuttings prepared and planted during the first ten days of May, the proportion of rooted cuttings did not exceed 55.3%, and in those planted during the second ten days of May, it reached only 75.9%.

Delaying the cutting period also had a negative effect on their rooting ability. Thus, when cuttings were planted in the second ten days of June, 77.8% of the total planted cuttings developed roots, while further delaying the planting (to the last ten days of June) led to a decrease in this physiological indicator down to 65.5%.

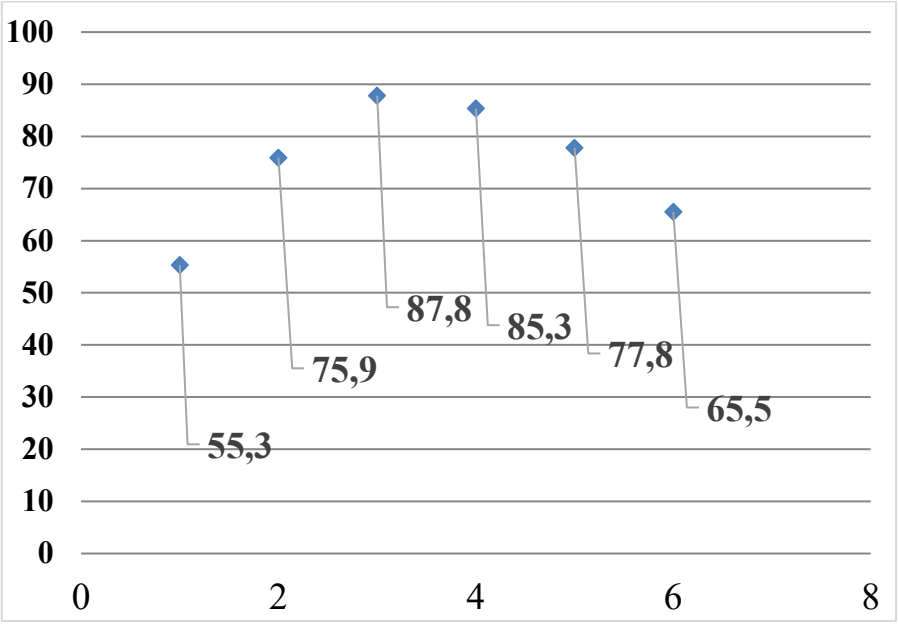

Figure 4. Rooting ability (%) of green cuttings of the Hayward kiwi variety depending on planting dates; 2022–2024

In general, it can be concluded that during the propagation of the kiwi plant (Actinidia deliciosa) by green cuttings at different times, the cuttings show a tendency to root (rhizogenesis). However, this tendency varies significantly depending on the physiological activity of the shoot. Beginning from the first ten days of May, the rooting ability of cuttings increases linearly until the end of May due to changes in the physiological activity of the shoots, after which a gradual decline in this physiological process is observed (Figure 4).

Almost all rooted cuttings of the Hayward kiwi variety developed a well-formed root system and aerial parts by the end of the growing season. However, in terms of growth parameters, plants propagated in May demonstrated superiority over those planted at other times.

Experimental data also showed that the volume of the root system of green cuttings varied depending on the planting period. The highest values were recorded in variants planted in the first half of May, ranging from 6.7 to 6.9 cm³, which is 0.8–1.0 cm³ higher than the control plants (5.9 cm³).

As the planting period of green cuttings of different kiwi cultivars was delayed, the volume of the formed root system decreased proportionally. According to the data, the smallest root system volume—3.2 cm³—was recorded in cuttings planted during the last ten days of June. The other experimental variants occupied intermediate positions between the above-discussed options, with the root system volume ranging between 4.5 and 6.1 cm³, and the smallest difference being 0.5 cm³ (Table 3).

The length of the plant shoots was also found to depend on the planting period. The tallest shoots were observed in the variants planted in the first half of May, where the average shoot length reached about 88.0 cm by the end of the growing season. This is 13.7 cm longer compared to the control variant. The smallest difference among the variants was 1.9 cm.

Table 3. Effect of planting dates on the rooting ability of green cuttings of the Hayward kiwi cultivar, 2022–2024

Experimental option	Rooting ability, (%)	Root system volume, (cm³)	Cuttings that formed shoots, (%)	Shoot length, (cm)
1-10/V	55,3	6,7	78,6	88,0
11-20/V	75,9	6,9	86,7	87,3
21-30/V	87,8	6,1	89,6	80,6
1-10/VI – naz.	85,3	5,9	81,3	74,3
11-20/VI	77,8	4,5	75,8	75,7
21-30/VI	65,5	3,2	65,9	40,8
EKF_{05}	-	*0,5*	-	*1,9*
Sx	-	*0,08*	-	*0,31*
r	-	-	-	*0,08*

The shortest plant shoots were observed in green cuttings planted during the last ten days of June. The stem length of plants developed from cuttings planted during this period did not exceed 40.8 cm, which is 33.5 cm shorter compared to the control variant. The shoot length of plants in other variants occupied an intermediate position between the analyzed options, ranging from 75.7 to 87.3 cm. The correlation coefficient between the root system volume and shoot height was 0.08 (Figure 5).

The data from Figure 5 clearly indicate that although green cuttings of Hayward kiwifruit showed high rooting ability at all planting dates, plants propagated from cuttings taken in the first half of May demonstrated superiority in terms of development parameters.

Figure 5. Effect of planting dates on the rooting ability of green cuttings of *Hayward* kiwifruit (as of September 1), cm:
1 – 1–10/V; 2 – 11–20/V; 3 – 21–30/V; 4 – 1–10/VI; 5 – 11–20/VI; 6 – 21–30/VI

The above experimental data allow us to conclude that Hayward kiwifruit is highly predisposed to propagation from green cuttings, with rooting ability reaching up to 87.8%. When propagating kiwifruit from green cuttings, treating the cuttings for 2 hours in an aqueous solution of indole-3-acetic acid (IAA) at a concentration of 50 mg/L before planting provides high efficiency. The most favorable period for propagating these plants from green cuttings is the third decade of May. Although cuttings taken in early May showed relatively high biometric parameters, their rooting ability was weaker, resulting in a lower number of seedlings per unit area. Cuttings taken in the last decade of May, however, allow obtaining the highest number of standard seedlings.

4 Conclusion

In plants propagated from green cuttings of “Hayward” kiwifruit, the highest number of standard seedlings with shoots longer than 60 cm per total grown plants was recorded under the 10x20 cm planting scheme, reaching 46 seedlings/m². Although densely planted variants produced a higher number of rooted and grown plants, most of them (75–80%) are left for next-year cultivation because their shoot length does not even reach 50 cm. Conversely, in sparsely planted variants, approximately 95–98% of the plants produce shoots and grow vigorously; however, due to fewer cuttings planted per unit area, the total seedling yield is correspondingly lower.

The most favorable period for propagating kiwifruit from green cuttings in a controlled microclimate facility is the third decade of May. Planting cuttings during this period allows obtaining the maximum number of standard seedlings.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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