Comparison of Temporary Immersion Bioreactor (SETISTM) and Classical Solid Culture in Micropropagation of ‘Grand Naine’
(Musa spp.) Banana Cultivar

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Abstract

Banana is an important nutritional source for millions of people because it contains protein, carbohydrates, vitamins and minerals. Therefore, the need for banana production is increasing day by day. Various methods are being developed to meet this need. Among these methods, biotechnological applications are becoming more prevalent over time. In micropropagation of in vitro plantlets, which forms the basis of banana production and is one of the most important stages, the methods used and banana varieties must be selected correctly. Therefore, it is very important to decide which protocol is suitable for which variety. In TIBs, in vitro micropropagation and rooting were compared with solid culture by adjusting the frequency of immersion of in vitro plantlets into the nutrient medium and the contact time of nutrients to the plantlets in the immersion medium. It was determined that the TIB application was more successful than the solid medium experiment in many aspects, especially the micropropagation rate (4.20) and rooting rate (84%).

Keywords: temporary immersion system (TIS), RITA®, Plantform, BIT®, in vitro rooting, acclimatization

1. Introduction

According to a study by El Barnossi et al. (2021), global banana production data for the year 2018 reached approximately 115.74 million tons. Among the top banana-producing countries, India emerged as the leader with a production of 30.80 million tons, followed by China with 11.22 million tons, Indonesia with 7.26 million tons, and Brazil with 6.75 million tons, as reported by Napoleã et al. (2021). The production rankings remained consistent in 2019, with India maintaining its top position by producing 30.4 million tons, followed by China with 11.6 million tons, Indonesia with 7.2 million tons, Brazil with 6.8 million tons, and Ecuador with 6.5 million tons (Alzate Acevedo et al., 2021). Although Turkey’s banana production is relatively lower compared to these leading countries, it has been observed to demonstrate a consistent growth trend. According to FAO (2022) data from 2020, India produced 31.5 million tons, whereas Turkey’s production stood at only 0.72 million tons.

1.1 Biotechnological Banana Production Techniques and Grand Naine as a Banana Variety

The production of the banana plant is conducted using different techniques around the world. Banana plants produce suckers with a solid vascular connection to the parent plant. These can be removed from the parents, planted separately, and propagated again. In production using suckers, the characteristics of the primary source are preserved (Heslop-Harrison & Schwarzacher, 2007). An average of 8-10 saplings are obtained from one plant yearly, which is insufficient for commercial production. In addition, plant tissue culture techniques are used in the propagation of banana plants in many countries because of their negative features, such as the high risk of disease and pest transmission. With this technique, it is possible to produce disease-free, fast, and commercially potentially proven products. In addition, it is an essential technique to ensure the conservation of gene resources and to carry out biotechnological studies. On the other hand, it is noteworthy that this technique is costly, and especially the hardener has a large share in this cost. Because of the high costs, production in the laboratories of small and medium-sized enterprises is insufficient in quantity and quality (Jekayinoluwa et al., 2019; Uma et al., 2021).

In vitro tissue culture and micropropagation techniques continue to be employed in commercial settings, and ongoing advancements in these methodologies are closely monitored. As biotechnological developments
Increased, more effective suspension cultures and *in vitro* micropropagation were directed. The first notable advantages of using liquid media in micropropagation are the cost per plantlet and the reduction of personnel load by evaluating the automation option (Aitken-Christie, 1991). In addition, some advantages exist, such as more homogeneous nutrient elements in liquid culture, easy renewal of nutrient media, and larger culture vessels (Etienne et al., 2006). On the other hand, it has some disadvantages depending on the shaking systems frequently used in suspension cultures. The high amount of electricity used for shaking, hyperhydricity, damage to the cells by shaking, and low level of ventilation are some of its negative features (Gupta & Prasad, 2006).

Temporary immersion bioreactor (TIB) or Temporary immersion system (TIS) is one of the most important technologies in today’s agricultural biotechnology as a promising method to prevent all these negativities. This method combines the advantages of solid and liquid culture (Jain & Ishii, 2012) and was first described by Steward et al. (1952) and reported as having been developed by Steward and Shantz (1956) (Preil, 2005). The RITA® system, introduced by Alvard et al. (1993), represents the initial instance of a temporary immersion system (TIS) with a single jar featuring upper and lower compartments (Posada-Pérez, 2017). This pioneering system was specifically employed in the study conducted by Alvard et al. (1993) concerning banana plants (Persson, 2012). Apart from this, the Twin-Flask system (BIT®) (Escalona et al., 1999), Plantform, Ebb-and-Flow, Rocker systems, and many more systems are explained in detail by Georgiev et al. (2014). Besides these systems, SETIS™ has been reported to be more advantageous than others, as it is relatively larger and easier to use (Hwang et al., 2022).

Temporary immersion systems are considered more economically viable in commercial settings due to several factors. Firstly, these systems eliminate the need for solidifying agar, resulting in cost savings. Additionally, the labor requirements are reduced compared to traditional methods. Moreover, temporary immersion systems effectively address the issue of vitrification, also known as hyperhydricity, which can occur when plants are directly immersed in liquid media. Studies by Etienne and Berthouly (2002) and Uma et al. (2021) have highlighted the ability of temporary immersion systems to mitigate vitrification problems. In addition to banana plants, temporary immersion systems have successfully reproduced various other plant species. For example, Topoonyanont et al. (2012) utilized these systems in sugarcane studies, Jiménez et al. (1999) in potato research, and Firoozabady and Gutterson (2003) as well as Daungban et al. (2017) in pineapple-related investigations. Temporary immersion systems have also proven useful in the reproduction studies of other species such as Abies nordmanniana (Steven) Spach (fir), *Eucalyptus grandis* × *E. urophylla* (eucalyptus), Betula pubescens Ehrh (hairy birch), and Betula pendula var. carelica (curly birch), as reported by Businge et al. (2017). Overall, temporary immersion systems offer economic advantages, alleviate vitrification concerns, and have demonstrated successful applications in the reproduction of various plant species, expanding their utility beyond banana plants. Temporary Immersion Bioreactor Systems (TIS) have been under investigation for the past three decades, resulting in the development of various prototypes. Notably, the RITA® (Recipient for Automated Temporary Immersion System) and BIT® (Twin Flasks) systems are widely utilized for clonal propagation in tissue culture. The initial version of the RITA® system was introduced by Alvard et al. (1993), while subsequent modifications were made by Pavlov and Bley (2006), and Zhu et al. (2015). On the other hand, the BIC (Bioreactor with Internal Cylinders) systems were developed by Escalona et al. (1999) and have been employed for diverse plant species, as demonstrated in studies by Escalona et al. (2003), and Welander et al. (2007). TIS bioreactors have proven effective in the mass propagation of strawberries (Takeyama and Akita, 1998), ornamental plants (Dewir et al., 2006), Vaccinium angustifolium (Debnath, 2009), potatoes (Piao et al., 2003), and various other plant species. However, the previous bioreactor designs encountered challenges due to their small size or excessive weight, rendering them impractical (Welander et al., 2007). The Plantform bioreactor is another novel temporary immersion system developed to overcome the limitations of previous temporary immersion bioreactors. This innovative system offers advancements in plant tissue culture and clonal propagation techniques. The Plantform bioreactor is designed to provide efficient and controlled immersion of plant tissue or explants in a nutrient medium. It features a well-engineered design that ensures optimal gas exchange, nutrient supply, and growth conditions for plant cultures. The essential advantage of the Plantform bioreactor lies in its practicality and scalability. Unlike earlier designs that were too small or heavy, the Plantform bioreactor strikes a balance, making it suitable for large-scale production. It enables the mass propagation of various plant species, including ornamental plants, fruits, and vegetables (Aka Kaçar et al., 2020; Umarusman et al., 2020).

TISs offer a combination of benefits derived from conventional semi-solid and liquid media used in tissue culture. When compared to classical tissue culture systems, TIS provides several advantages. These include enhanced and uniform contact between the culture media, plant material, and nutrient media, reducing
vitrification and asphyxiation. TIS also minimizes the presence of toxic compounds secreted by cultures, leading to decreased browning compared to liquid media. The periodic change of atmosphere within the culture plates in TIS prevents the accumulation of harmful gases such as CO₂ and ethylene, contributing to improved growth conditions. Additionally, using larger culture plates in TIS allows for longer sub-culture durations. TIS offers easier and more efficient culture performance than solid nutrient media, which requires greater attention, care, and labor. Another advantage of TIS is its ability to promote cell division with the assistance of bubbles generated through air circulation. These advantages collectively contribute to an increased propagation coefficient and improved shoot quality within the TIS. In summary, TIS brings together the positive attributes of both semi-solid and liquid media in tissue culture, resulting in a system that offers uniform contact, reduced vitrification and asphyxiation, decreased browning, improved gas exchange, longer sub-culture durations, easier handling, and enhanced cell division. These advantages ultimately contribute to higher propagation coefficients and improved shoot quality (Lambardi et al., 2015).

The objective of this study is to assess the efficacy of micropropagation and rooting of the commercially promising banana variety ‘Grand Naine’ using the innovative Temporary Immersion Bioreactor (TIB) system, SETISTM, in comparison to the conventional tissue culture method. The study also aims to investigate the impact of immersion frequency and duration in TIB systems on the reproduction process, with a view to comparing the outcomes. The primary focus is to determine the success rate of ‘Grand Naine’ banana variety in terms of micropropagation and rooting when utilizing the SETISTM TIB system. This novel system offers an alternative approach to the traditional tissue culture method. The immersion frequency and duration, which play crucial roles in TIB systems, will be closely examined to understand their influence on reproductive efficiency. By conducting a comparative analysis between the SETISTM TIB system and the classical tissue culture method, the study aims to provide insights into the effectiveness and potential advantages of employing the innovative TIB system for the micropropagation and rooting of ‘Grand Naine’ bananas. Understanding the impact of immersion frequency and duration on the reproduction process will contribute to further optimizing the TIB system for commercial banana propagation.

2. Method

Rhizomes of ‘Grand Naine’ banana cultivars were used as plant material from a greenhouse belonging to farmers in Alanya/Mersin/Türkiye. By cleaning the coarse dirt of the rhizomes, the root, leaf, and upper stem parts were removed and the meristematic shoot tips in the inner part of the rhizomes were used as an explant source. The rhizomes, which were selected and collected from the greenhouses, were brought to the laboratory and shrunk to a size that the tips of the shoots could be accessed with the help of a knife. The shrunken explants were subjected to surface sterilization. The shoot tips, which were cut and reduced, were first washed under running tap water for 20 min.

2.1 Surface Sterilization

The shoot tips, which were cleaned of coarse dirt by washing were taken into a laminar flow cabinet and kept in a mixture containing Tween 20 (Sigma-Aldrich) and 0.35% (v/v) sodium hypochlorite for 5 min then washed 3 times with sterile water.

2.2 Media and Culture Conditions

Murashige and Skoog (MS, 1962) medium supplemented with 30 g l⁻¹ sucrose and 2 mg l⁻¹ BAP was used as the culture medium. The pH of the culture medium was adjusted to 5.7-5.8 using 0.1N HCl and NaOH, and 2.4-2.6 g l⁻¹ Gelrite (Duchefa Biochemie, NL) was used as the gelling agent. The prepared culture medium was sterilized by autoclaving at 121°C and 1.05 kg cm⁻² for 30 minutes. Afterward, the media was poured into culture containers in a sterile cabinet and left to solidify.

The explants, whose surface sterilization was completed, were shrunk to appropriate sizes in a sterile cabinet, transferred to the nutrient medium, and cultured under a 16/8-h (light/dark) photoperiod at 25±2 °C. Enough plants were reproduced by subculturing in the same environment and culture conditions every 4 weeks. The desired amount was reached in the 4th subculture and TIB trials were established after this stage.

2.3 TIBs Trials

2.3.1 Micropropagation

Five brand bioreactors were used for TIB trials. For each TIB, 1 liter of the nutrient medium was prepared without Gelrite. Two separate trials were set up at different times, and each trial was compared with plantlets propagated in solid media. 50 plants were transferred to the TIB system and 10 plants were transferred to a solid medium. Three different trials were set up with different immersion periods and contact times in TIB trials. The
system was connected to an electronic socket with a timer, and the 24-hour day was adjusted by dividing it into hours and operated in this way for 6 weeks. TIB 1: daily application periods for immersion hours and times 04:00-04:05 (5 min), 09:30-09:40 (10 min), 14:30-14:40 (10 min), 20:00-20:05 (5 min). TIB 2: daily application periods for immersion hours and times; 01:00-01:05 (5 min), 04:00-04:05 (5 min), 07:00-07:05 (5 min), 10:00-10:05 (5 min), 13:00-13:05 (5 min), 16:00-16:05 (5 min), 19:00-19:05 (5 min), 22:00-22:05 (5 min). At the end of 6 weeks, the system was emptied and subcultured under the same conditions. Growth coefficients and growth observations were taken during the subculture stages.

SETIS™ bioreactor system consists of two parts, culture (5.6 l) and media container (4 l). Sealing is provided with gasket and screw caps (50 and 80 mm in diameter). It enables optimal plant production with its 432 cm² flat-bottomed area of the culture container. Assembled dimensions are 308 × 180 × 250 mm. A production capacity of 300 to 1200 plants per bioreactor has been reported, although it varies by plant species (Vervit, 2021). Having a high production capacity has been one criterion for preference in this study. The working mechanism of the system is given in Figure 1.

![Figure 1. The working mechanism of SETIS™ Bioreactor systems. A Stationary phase: no compressed air is applied, B immersion phase: pressurized air is supplied to the medium vessel and it passes into the upper culture vessel of the medium, and C discharge phase: the medium returns to the medium vessel by the force of gravity (Ramírez-Mosquera and Bello-Bello 2021)](image)

2.3.2 Rooting Trials

As in micropropagation experiments, solid media and TIB were established simultaneously and comparatively in rooting trials. MS medium supplemented with 5 mg/mL IBA and 7 g/L Agar (agar was not used for TIB) was used as the medium. Evaluations were made after a total culture period of 6-8 weeks in a growth chamber with 16/8 hours of light/dark conditions at 24 °C. For immersion, the conditions of TIB 2 were used in the TIB system.

Acclimatization of plantlets: The plantlets rooted in the TIB were removed from the system after 6-8 weeks, completely cleaned of media residues, and washed several times with distilled water. The cleaned plantlets were transferred to plastic 42-well vials containing a 1/1 mixture of peat and perlite. The plants were kept in high humidity (85%) greenhouses by transferring them to vials.

2.3.3 Data Analysis

The studies were carried out according to the randomized plot design with 3 replications and ‘Grand Naine’ plants each in replication. For each replication in the solid culture 10 shoot tips and 50 in the Plantform system were used. The data were analyzed using the SAS-JMP statistical program and analysis of variance was performed. The differences between them were compared with the LSD (least significant difference) multiple comparison test. Angle transformation was performed for percent values.
3. Results and Discussion

The TIB bioreactor system, which is a sustainable and innovative technology, was used in the in vitro propagation of the commercially important ‘Grand Naine’ banana cultivar. In this study, the classical method and the TIB bioreactor system were compared to obtain more plantlets per unit area for commercial production of the desired quality (Figure 2) Separate trials were set up for both micropropagation and rooting studies and compared with conventional solid media.

![Image](https://example.com/image.png)

Figure 2. Micropropagation of banana with solid media and SETIS™. A: solid medium, B-C: SETIS™

When the micropropagation coefficient was examined, it was determined that TIB 2 had the highest rate of 4.20. It was followed by TIB 2 with 3.52 and solid media with a micropropagation coefficient of 2.65, respectively. It has been determined that there is a visible improvement in the micropropagation rate of TIB systems. When the data on the number of leaves was observed, it was found that TIB 2 was 5.67, TIB 2 was 3.67, and solid medium was 2.67. When the length of the plants grown under in vitro conditions were compared, it was determined that TIB 2 (14.16 cm) grew to almost twice the length of those in solid media (7.56 cm). In TIB 1, a plant length of 10.73 cm was measured (Table 1).

<table>
<thead>
<tr>
<th>System</th>
<th>Micropropagation rate</th>
<th>Number of leaves</th>
<th>Plant length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid medium</td>
<td>2.65b</td>
<td>2.67b</td>
<td>7.56b</td>
</tr>
<tr>
<td>TIB 1</td>
<td>3.52ab</td>
<td>3.67b</td>
<td>10.73b</td>
</tr>
<tr>
<td>TIB 2</td>
<td>4.20a</td>
<td>5.67a</td>
<td>14.16a</td>
</tr>
</tbody>
</table>

*Note. LSD value was calculated according to the angle conversion value. Different letters (a-b) indicate significant differences according to the LSD test (p ≤ 0.05). LSDMicropropagationrate: 0.988, LSDNumberofleaves: 1.631, LSDPlantlength: 3.390.*

It has been concluded that TIB is better than solid media results in the trials established for rooting plantlets developed in vitro (Figure 3). The longest root length was observed in TIB 2 (10.83 cm), followed by TIB 1 (8.76 cm) and solid medium (7.12 cm), respectively. The root number was determined as 8 for TIB 2, 7 for TIB 1, and 6 for solid media. The highest plant length was observed in TIB 2 with 18.16 cm, followed by TIB 2 and solid media with 15.50 cm and 12.16 cm. When the number of leaves per plantlet was compared, it was determined that TIB 2 (6) and TIB 1 (5) had relatively higher leaf numbers, while solid media (3.66) was lower. While the leaf blade width was determined at most with 3.90 cm in TIB 2, no statistically significant difference was detected in TIB 1 (2.83 cm) and solid media. When rooting rates were examined as a percentage, a similar result was found, and it was determined that TIB 2 (84%) and TIB 1 (74%) gave better results than solid media (61%) (Table 2).
Table 2. Comparison of rooting performance of grand nine banana cultivar in solid media and TIB systems

<table>
<thead>
<tr>
<th></th>
<th>Root Length (cm)</th>
<th>Number of roots</th>
<th>Plant length (cm)</th>
<th>Number of leaves</th>
<th>Leaf Feet Width (cm)</th>
<th>Rooting Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid medium</td>
<td>7.13b</td>
<td>8b</td>
<td>12.16b</td>
<td>3.66b</td>
<td>2.20b</td>
<td>61c (51.36)</td>
</tr>
<tr>
<td>TIB 1</td>
<td>8.76ab</td>
<td>7ab</td>
<td>15.50ab</td>
<td>5ab</td>
<td>2.83b</td>
<td>74b (59.36)</td>
</tr>
<tr>
<td>TIB 2</td>
<td>10.83a</td>
<td>6a</td>
<td>18.16a</td>
<td>6a</td>
<td>3.90a</td>
<td>84a (66.48)</td>
</tr>
</tbody>
</table>

Note. LSD value was calculated according to the angle conversion value. Different letters (a-b) indicate significant differences according to the LSD test (p ≤ 0.05). LSD_{RootLength}: 2.717, LSD_{Numberofroots}: 1.997, LSD_{Plantlength}: 4.225, LSD_{Numberofleaves}: 1.761, LSD_{LeafFeetWidth}: 0.655, LSD_{RootingRate}: 4.334*** (p ≤ 0.001).

Percentages were subjected to angle transformation and these values were presented in parentheses.

The classical tissue culture method allows the reproduction of many virus-free plants and this method is still used commercially. It is widely used especially in the production of banana saplings. In this study, different immersion times and frequencies were evaluated using the commonly used solid culture system and SETIS™, an advanced TIB system. It has been determined that both micropropagation and rooting success of TIB are more successful than classical solid culture. Different suspension cultures could also be tried, but mostly the effects of immersion time and frequency on the growth and development of plantlets were evaluated. Farahani and Majd (2012), working in different systems, compared TIB with solid media and different liquid media in banana micropropagation. The highest weight gain and multiplication coefficient (7) were obtained from the TIB system. Then, the growth rate of 3.5 and 2.7 was determined from the cotton substrate liquid medium and solid medium, respectively.

In a study by Monja-Mio et al. (2020), the BioMINT II bioreactor was utilized to investigate the rooting of Agave tequilana, comparing it with the traditional culture system. The researchers examined various characteristics such as root number, root length, number of leaves, and shoot length increase. They found that the temporary immersion system (TIS) was more effective compared to the traditional system. Additionally, they highlighted that the frequency of immersion periods influenced the effectiveness of the TIS and suggested that it may vary depending on the species being evaluated. The study also observed that immersion duration and frequency influenced morphology, size, number of leaves, and root size. Roels et al. (2005) conducted a study on the optimization of the temporary immersion system for banana plant micropropagation. They tested three different cytokines at various concentrations and found that 4.4 μM meta-topolin had the highest micropropagation rate (8.1). Interestingly, they reported that immersion time and frequency had no effect on banana proliferation within the tested ranges. In contrast, our study revealed that different immersion times and frequencies could have positive or negative effects on banana micropropagation. Etienne and Berthouly (2002) also emphasized the importance of immersion time and frequency as crucial parameters that determine efficiency in these systems. The present study determined that immersion duration and frequency significantly affected micropropagation, plant height, rooting success, and other characteristics. It is predicted that reactor capacity and design will also play a crucial role in in vitro tissue culture studies. Supporting this prediction, Ramirez-Mosqueda and Iglesias-Andreu (2016) compared different temporary immersion systems for vanilla (Vanilla planifolia Jacks) micropropagation. They compared the Recipient for Automated Temporary Immersion

Figure 3. Comparisons of ‘Grand Naine’ banana plantlets rooted in SETIS™ and solid media
(RITA®), Temporary Immersion Bioreactors (BIT®), and Gravity Immersion Bioreactors (BIG). The BIT® system exhibited the highest shoot/explant ratio (18.06), followed by RITA® (12.77) and BIG (6.83). Similarly, the BIT® system showed greater success in rooting, while the BIG system exhibited the highest chlorophyll content. Corona et al. (2017) compared the SETIS™ and BIT® systems with semi-solid media for the micropropagation of the papaya hybrid ‘MSXJ’. The SETIS™ system demonstrated the highest number of shoots per explant (15.0), followed by BIT® (9.8) and the semi-solid medium (6.86). SETIS™ was generally found to be more successful across the evaluated parameters. Similarly, in our study, the SETIS™ system was compared with solid media, and it proved to be more successful for the ‘Grand Naine’ banana variety in all parameters. The SETIS™ system offers advantages such as automation suitability, reduced labor requirements, cost advantages in commercial production, a larger surface area, and reduced occurrence of hyperhydricity. Furthermore, the relatively large size of SETIS™ allows for increased plant production per unit area. Comparing different TISs, Bello-Bello et al. (2018) found that the sizes of various systems had an impact on shoot length and number. The limited size of RITA® resulted in lower shoot length and number, while SETIS™ exhibited higher shoot numbers (41). Considering the numerous features of the SETIS™ system, including its relatively large volume, we chose to utilize it in our study. The viability of the plantlets transferred to the greenhouse for acclimatization, which is the last part of the study, was evaluated. Although no significant differences were observed between their viability, it was determined that the plantlets in SETIS™ showed faster and healthier growth. It has been observed that TIB-based productions are quite successful in the acclimatization stage, which is one of the critical steps of in vitro production (Figure 4).

![Setis](image)

**Figure 4. Development of plantlets transferred from the laboratory to the greenhouse**

In a study conducted by Copetta et al. (2021) on improving plant conditioning through in vitro methods, a similar outcome was observed. The researchers determined that the acclimatization success of plants propagated in the temporary immersion system (TIS) known as Plantform was superior to those propagated in solid media. They also highlighted that the root systems developed better in the TIS, which aligns with the findings of our study. Our research also revealed the positive impact of TIS systems on mitigating hyperhydricity, a significant factor in acclimatization. This observation is consistent with the findings of Lotfi et al. (2020), who investigated the use of temporary immersion systems in the in vitro propagation of *Pyrus communis*. They reported that the immersion interval affected hyperhydricity, with a longer immersion period leading to a decrease in hyperhydricity. Overall, these studies provide further evidence of the benefits of TIS systems, including improved acclimatization success and reduced hyperhydricity, supporting the effectiveness of such methods in enhancing in vitro propagation and conditioning processes.

In this study, we conducted experiments using two different immersion numbers and durations. In the TIB1 application, we tested four immersion numbers with immersion times of 5 minutes, 10 minutes, 10 minutes, and 5 minutes. In the TIB2 application, we tested eight different immersion numbers, each for 5 minutes. Upon analyzing the results, we observed that TIB2, with a higher number of immersions, yielded more successful outcomes. This can be attributed to the fact that the plant parts were exposed to the nutrient medium for a longer duration as the number of immersions increased. Plant tissue culture studies are influenced by various factors,
including genotype, media content, and culture conditions (Zekai et al., 2022). Previous studies have shown diverse and sometimes conflicting results. Our study has contributed important insights and approaches to the production of banana seedlings, which hold significant importance in global agricultural production.

4. Conclusions

This study focused on exploring the potential of SETIS™, a temporary immersion bioreactor system, as an innovative and high-throughput method for tissue culture, especially in the context of banana production with the ‘Grand Naine’ variety. The aim is to compare SETIS™ with the traditional banana growing method and to examine the effect of different immersion periods and contact times in bioreactors on the efficiency of banana production. Data obtained as a result of experimental studies revealed that SETIS™ performed better than traditional solid banana growing medium in terms of micro-propagation, rooting and adaptation to greenhouse conditions. The results achieved highlight the significant advantages offered by SETIS™ in promoting the growth and development of the banana plant. However, this study emphasizes the importance of considering the frequency of immersion and contact time in SETIS™, as micropropagation, rooting and adaptation factors to greenhouse conditions have an impact on \textit{in vitro} tissue culture studies. Therefore, it is of great importance to optimize parameters such as dipping frequency and contact time to achieve positive results in production processes. SETIS™ exhibits many desirable properties, including user-friendliness, significant surface area for plant growth, relatively low cost, and compatibility with automation. These features further increase its appeal as a viable option for large-scale commercial \textit{in vitro} banana production. It is envisaged that by adopting SETIS™ and its associated benefits, the agricultural industry can unlock greater efficiency and productivity in growing banana seedlings. Overall, this study underlines the importance of using advanced techniques such as SETIS™ in \textit{in vitro} tissue culture studies. Through comprehensive optimization and strategic application of immersion frequency and contact time, researchers and practitioners can achieve more successful and sustainable production results in the field of plant tissue culture.

References


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Authors Contributions

Dr. Taner Bozkurt was responsible for designing the study, establishing and optimizing the bioreactor system, making statistics and writing the article. Sezen Inan and İljal Dündar were responsible for carrying out the experimental laboratory studies.

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Obtained.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data Sharing Statement

No additional data are available.

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