Comparison of the Effectiveness of Various Growing Media in Banana (*Musa accuminata*) Seed Germination

Vincent Vernando¹, Rashinta Diva Ardani¹, Resa Sri Rahayu², and Erwin Fajar Hasrianda³

¹Department of Food Science And Biotechnology, Faculty of Agricultural Technology, University of Brawijaya, Malang, East Java, Indonesia.
²Ecophysiology and Plant Symbiosis Research Group, Research Center for Applied Botany, Research Organization of Life Science and Environment, National Research and Innovation Agency (BRIN), Bogor, Indonesia
³Research Organization of Life Science and Environment, National Research and Innovation Agency (BRIN), Bogor, Indonesia

Abstract. Banana is a fruit plant with numerous benefits and is considered one of the significant agricultural commodities in the world and in Indonesia. Typically, banana propagation is carried out through vegetative means using offshoots. However, this method comes with certain limitations, including challenges in generating a large number of uniform seedlings and the risk of disease contamination. Propagating bananas through seeds could offer a potential solution to address these issues. Banana seeds play a critical role in the reproduction and formation of new plants. This research aims to assess the impact of various growing media and identify an effective and efficient method for banana seed germination. The selected growing media encompass rockwool, Charcoal Husk, sand, cocopeat, farmer's planting media, a 1:1 mixture of Manure Compost and Soil, and Moss Sphagnum media, all on a greenhouse scale. The results indicate that Rockwool achieved the highest germination rate at 71.0%, followed by Moss Sphagnum media (66.33%), and cocopeat (64.67%). Conversely, sand, charcoal husk, farmer's planting media, and manure compost + soil exhibited lower germination rates. Each of these media options, including compost + soil, has its unique advantages and drawbacks. Moss Sphagnum media, for instance, features numerous cavities that enable plant roots to grow freely and effectively absorb and retain water. This study offers valuable guidance to farmers in selecting appropriate growing media to enhance banana seed germination, potentially benefiting agricultural development.

1 Introduction

Banana (*Musa sp.*) stands as an ancient monocotyledonous plant grown across nearly 120 countries in tropical and subtropical zones globally [1]. Additionally, the Banana serves as a

* Corresponding author: erwi011@brin.go.id
staple sustenance and a primary nutritional source for over 500 million people [2]. After rice, maize, and wheat, banana ranks among the most crucial global food crops, and it claims the second spot as the most popular fruit. Impressively, worldwide banana (Musa sp.) production reached 113.9 million metric tons in 2017 [3], underlining its indispensable role in both diets and commercial trade.

Bananas originate from Southeast Asia, bananas [4] and it is a region boasting the highest diversity of wild Musa species today, encompassing Musa accuminata AA and Musa balbisiana BB. Southeast Asia is also the earliest site of banana domestication [5] [6]. Among Southeast Asian nations, Indonesia shares a notable affinity for bananas [7]. According to Indonesia's Central Bureau of Statistics (BPS) data for 2019, banana production surged from 8.13 million tons in 2015 to 8.18 million tons in 2016 [8] [9]. A remarkable trend is the continuous growth in banana consumption across Indonesia. Commonly, banana plants are propagated vegetatively through suckers that sprout from the corm. However, sucker-type banana seedlings raise the risk of disease transmission in banana plantations. This is due to the fact that the parent banana used for propagation may not always be disease-free [10]. As an alternative, in the future, bananas could also have the potential to be propagated using their seeds. Seeds offer numerous advantages as a source of agricultural propagation. Firstly, seeds have a longer storage life, enabling them to be stored for extended periods compared to other propagation materials like cuttings, suckers, or bulbs. This advantage facilitates more efficient transportation and storage of seeds for future use. Furthermore, seeds also save space as they require less room compared to other propagation materials. Lastly, is disease prevention, as using seeds for propagation can reduce the risk of disease transmission compared to other propagation materials.

Seeds are one of the generative organs of plants resulting from fertilization between egg cells and sperm cells in flowers. They serve the purpose of reproduction and new plant formation [11]. On the other hand, while seeds are used as a propagation material for banana plants, there are specific challenges that need to be addressed. Seeds possess protective layers designed to shield the banana embryo from unfavorable environmental conditions. When the environment becomes challenging, seeds enter a dormant phase to conserve their nutritional resources. The thick seed coat of bananas can restrict the flow of air and water into the seed, resulting in reduced germination capability and inducing dormancy. This dormancy trait can lead to delayed or even non-germination of the seeds [12]. This dormancy mechanism is one of the reasons seeds struggle to germinate. Furthermore, the typically low germination rate of banana seeds can impact seed availability and hinder banana farming. Nonetheless, research on determining the optimum characteristics of a growing medium to support banana seed germination has been relatively limited so far. With this in mind, this study aims to ascertain the influence of different growing media with the same humidity level and to find an effective and efficient method for banana seed germination.

2 Materials and Methods

The seed germination method utilized in this study was conducted to examine the impact of growing media on the germination of wild banana seeds, Musa accuminata. This testing took place on a greenhouse scale. Initially, seeds were collected from ripe wild bananas that had reached a mature stage, indicated by their yellowing and being free from pest and disease attacks. Subsequently, seeds were extracted from the mature bananas and cleaned of their pulp and fruit flesh to eliminate the risk of pest and disease hindrance to germination. Cleaned banana seeds were then air-dried overnight before being planted in various growing media under uniform humidity conditions.

A variety of growing media types examined in this study were chosen due to their high diversity, encompassing varying water absorption and retention capabilities. Furthermore,
the selected media exhibited distinct differences in their chemical, biological, and physical characteristics. The growing media employed in this research comprised rockwool, husk, sand, cocopeat, farmer's planting media, a 1:1 mixture of compost and soil, and Moss Sphagnum media, all placed in plastic germination trays. Each treatment was replicated three times. The media were misted daily and maintained to ensure optimal water conditions.

The experimental design employed in this study was a Randomized Complete Block Design. The treatments tested involved different growing media, each replicated three times with 100 seeds per replication, resulting in a total of 100 buried seeds per growing medium. The media were moistened to around 50-60% humidity, labeled on trays and boxes, and watered every 3 days or when the media were deemed dry. Lastly, the samples were kept in the greenhouse at room temperature and observations were conducted for up to two months until no further new germinations emerged. The growth progress of banana seed germination was recorded every 3 days. The observed parameters in this method included the number of germinated seeds, which could be calculated using the formula:

$$Seed\ Germination\ (%) = \frac{number\ of\ germinated\ seeds}{total\ number\ of\ seeds\ planted} \times 100\%$$

Once the observation data was collected, it was subjected to F-test (analysis of variance) using R software. If significant differences were identified through the F-test, and the Duncan's Multiple Range Test (DMRT) to identify these differences.

3 Result and Discussion

Large-scale propagation of banana plants can also be achieved using seeds. However, challenges exist in germinating banana seeds. Determining the optimal growing medium is essential to achieve optimal germination of banana seeds. An experiment employing various types of growing media for germinating banana seeds was conducted to address this issue.

Based on the experiment carried out across all growing media, seeds began to germinate on the eighth day after planting and continued up to the 53rd day after sowing. Subsequently, the rate of seed germination began to plateau. In this study, rockwool as a growing medium yielded the highest germination rate of banana seeds, significantly differing from other germination media treatments. Conversely, the lowest germination rate was observed in the manure compost + soil media treatment (Figure 1).
From the graph presented above, it is evident that Rockwool is the most effective medium for seed germination, with a germination rate of 71%. This is indicated by its significantly higher germination rate compared to other growing media. Following rockwool, the subsequent alternatives in descending order were Moss Sphagnum (66.33%), cocopeat (64.66%), farmer’s planting media (64.66%), charcoal husk (60.66%), sand (54.66%), and lastly, manure compost + soil (25.66%).

Further analysis, based on the ANOVA results presented in Table 1, indicates that the treatments significantly affect the germination of banana seeds. Subsequently, the highest average germination rate of banana seeds was observed in the rockwool medium treatment with an average germination rate of 71%. The lowest germination was in the manure compost + soil medium treatment. The result of the experiment indicated a significant difference in germination rates. The results of the statistical analysis of banana seed germination in various growing media are provided in the table below:
From the graph presented above, it is evident that Rockwool is the most effective medium for seed germination, with a germination rate of 71%. This is indicated by its significantly higher germination rate compared to other growing media. Following rockwool, the subsequent alternatives in descending order were Moss Sphagnum (66.33%), cocopeat (64.66%), farmer's planting media (64.66%), charcoal husk (60.66%), sand (54.66%), and lastly, manure compost + soil (25.66%).

Further analysis, based on the ANOVA results presented in Table 1, indicates that the treatments significantly affect the germination of banana seeds. Subsequently, the highest average germination rate of banana seeds was observed in the rockwool medium treatment with an average germination rate of 71%. The lowest germination was in the manure compost + soil medium treatment. The result of the experiment indicated a significant difference in germination rates. The results of the statistical analysis of banana seed germination in various growing media are provided in the table below:

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>Sum Sq</th>
<th>Mean Sq</th>
<th>F value</th>
<th>Pr (&gt;F)</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>123.5</td>
<td>61.76</td>
<td>0.9424</td>
<td>0.4167399</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>6</td>
<td>4717.8</td>
<td>695.30</td>
<td>10.6089</td>
<td>0.0003331</td>
<td>***</td>
</tr>
<tr>
<td>Residuals</td>
<td>12</td>
<td>786.5</td>
<td>65.54</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 2. DMRT Results of Various Growing Medium on Banana Seed Germination.

<table>
<thead>
<tr>
<th>Growing Medium</th>
<th>Data</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockwool</td>
<td>71.00000</td>
<td>a</td>
</tr>
<tr>
<td>Moss Sphagnum</td>
<td>66.33333</td>
<td>ab</td>
</tr>
<tr>
<td>Cocopeat</td>
<td>64.66667</td>
<td>ab</td>
</tr>
<tr>
<td>Pak Tani™ medium</td>
<td>64.66667</td>
<td>ab</td>
</tr>
<tr>
<td>Charcoal Husk</td>
<td>60.66667</td>
<td>ab</td>
</tr>
<tr>
<td>Sand</td>
<td>54.66667</td>
<td>b</td>
</tr>
<tr>
<td>Manure Compost + Soil</td>
<td>25.66667</td>
<td>c</td>
</tr>
</tbody>
</table>

Table 3. The impact of various growing medium on banana seed germination.

<table>
<thead>
<tr>
<th>Growing Medium</th>
<th>Rockwool</th>
<th>Moss Sphagnum</th>
<th>Cocopeat</th>
<th>Pak Tani™ medium</th>
<th>Charcoal Husk</th>
<th>Sand</th>
<th>Manure Compost + Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germination Rate</td>
<td>71.0±6,0a</td>
<td>66.0±6,5ab</td>
<td>64.0±5,9ab</td>
<td>64.0±11,0ab</td>
<td>60.0±1,5ab</td>
<td>54.0±4,6b</td>
<td>25.0±14,0c</td>
</tr>
</tbody>
</table>

Notes: Values in each column followed by differing superscripts indicate significant differences (p<0.05) between treatments with the Duncan Multiple Range Test. Values are presented as mean ± SE (n=6).
In this study, the germination medium of rockwool yielded the highest germination rate, reaching 71%. Rockwool is a medium frequently employed by hydroponic farmers and is considered one of the best mediums for plant growth due to its porous and lightweight nature, resistance to decomposition, and absence of seed-borne pests and diseases. Rockwool possesses a favorable water-holding capacity and excellent air porosity, supporting plant development. The choice of rockwool as a germination medium is based on several advantages as explained by [13]. Firstly, rockwool has exceptional water-retaining capabilities, holding water up to 14 times better than soil, along with good resistance to decomposition. Moreover, optimal aeration is another hallmark of rockwool. With uniform pores in its fibers, this medium retains essential oxygen for root growth and provides optimal aeration for plant development. Eventually, this condition may affect the microclimate around the plant and influence the structure and the chlorophyll content of the plant [14].

Additionally, the flexibility in its form and texture is advantageous. This enables users to tailor it to the size and shape of planting containers. Its homogeneity and standardization allow for standardized experiments and data with minimal error. In addition, banana seeds have a fairly thick seed coat. Good water availability from the planting medium can allow the existing water to penetrate the thick banana seed coat layer and reach the endosperm and embryo (figure 2). As stated in previous research, germination marks the onset of embryonic growth activity characterized by the rupture of the seed coat and the emergence of the prospective new plant individual [15]. The mechanism of banana seed germination commences with the event of imbibition, the process of water absorption by the seed, causing the seed to swell, soften, or break the seed coat, and undergo hydration [16] [17]. The rate of water absorption is influenced by factors such as the thickness of the seed coat. The rate of water absorption is related to the speed of germination; the thicker the seed coat, the slower the water absorption, and the longer the time required for water to fill the cortex cavities of the seed, thereby slowing down seed germination.

Despite its numerous advantages, rockwool also has a few drawbacks. Firstly, its relatively high pH is a characteristic of rock wool, originating from broken glass, ceramics, and basalt rock. This necessitates soaking and rinsing before use to lower the pH to a suitable level. Secondly, its environmental friendliness is a concern, as rock wool is made of materials. 

**Figure 2.** Cross-Section of a Banana Seed. The thick seed coat of banana seeds poses challenges in breaking dormancy and inhibits germination.
that are slow to decompose and can leave behind chemical residues, potentially leading to soil pollution due to the difficulty of material decomposition [13].

On the other hand, the lowest germination rate was observed in the treatment involving a combination of soil and organic manure, yielding only 25.66%. Although the soil-manure mixture possesses high nutrient content, it tends to have a denser physical structure compared to other germination mediums used in this study. This compacted structure is presumed to hold the availability of water which is critical for the initial phase of seed germination. As a result, the germination rate of banana seeds in the soil-manure mixture exhibited the lowest significant outcome compared to other mediums. As stated by Tyas et al. (2019), organic manure is derived from animal waste, possessing natural properties and soil-enriching qualities. It contributes to improving the physical, chemical, and biological characteristics of soil, thereby enhancing soil fertility in agricultural fields. However, higher amounts of organic manure lead to greater available water content in the soil. This is due to the high organic matter content in the soil, which has the capacity to hold water effectively, thus maintaining water within the soil [18]. This condition causes the water in the manure compost media to be less available for seed germination when compared to other germination media used in this experiment. Consequently, the germination rate of banana seeds in this medium is not as good as in other media, even if the medium's nutrient content is not exceedingly high.

The Moss Sphagnum growth medium yields the second-best germination rate, trailing behind only the rockwool growth medium. Moss Sphagnum is obtained by drying moss and possesses numerous cavities that allow plant roots to grow freely. This medium is commonly used in cultivating orchids. Moss medium's advantages include its excellent water absorption and retention capabilities, maintaining both medium moisture and the plant's surrounding environment, as well as its ability to absorb and retain nutrients. Moss medium contains nitrogen and a small amount of phosphorus, with nitrogen stimulating plant growth and accelerating flowering [19] [20]. The substantial pores and water-holding capacity of this medium are believed to adequately support banana seed germination, resulting in a germination rate of 66.33%.

Using cocopeat as a growth medium provides the third-best germination rate in this study. Cocopeat is made from coconut coir powder and is an environmentally friendly growth medium. Cocopeat exhibits a high water absorption capacity, able to hold 6 to 9 times its volume, reducing the need for frequent nutrient solution irrigation. It maintains a favorable pH range for plant development. Moreover, cocopeat is easily decomposable organic material, rendering it eco-friendly [13], [21]. Cocopeat contains calcium, magnesium, potassium, nitrogen, and phosphorus, with these nutrients assisting plant growth across the root, leaf, chlorophyll content, and hormonal levels. However, cocopeat contains a significant amount of tannins, which hinder plant growth. It also has a low nutrient content, necessitating appropriate fertilization and a consistent nutrient supply to ensure optimal plant growth.

In this research, the Pak Tani™ medium resulted in a banana seed germination rate of 64.66%, making it the fourth-best germination outcome after the use of the cocopeat growth medium. This medium is a commercially available option in the market, mainly intended for ornamental plants and those found in residential yards. According to the information on its packaging, this growth medium is composed of a balanced combination of topsoil, burned rice husk, organic manure, and beneficial bacteria. The composition of the Pak Tani™ medium allows for the availability of both macro and micronutrients for plants. Moreover, the mixed nature of this medium enables porosity, facilitating water retention and moisture crucial for plant growth.

The use of rice husk charcoal as a growth medium also did not yield the best results in this study. Rice husk charcoal is produced by partially burning rice husks until they turn into charcoal. This growth medium exhibits water retention capacity and aeration. This might be
due to the macro and micro pores available in the rice husk charcoal medium not aligning with the ideal characteristics for water availability and root growth of banana seeds. However, this medium is also organic and environmentally friendly. The advantage of charcoal husk lies in its ability to improve soil physical and chemical properties, as well as provide protection to plants. The charcoal used in this study is obtained from incomplete rice charcoal husk, resulting in black-colored rice husk charcoal, rather than white ash, which aids in aeration and drainage. Nonetheless, it still contains pathogens or organisms that can inhibit plant growth. Therefore, prior to using charcoal husk as a growth medium, it needs to be burned to eliminate these pathogens [22].

In addition, the sand growth medium in this study resulted in a germination rate of 54.66%, significantly lower than the Rockwool medium. This is presumed to be due to the excessively porous nature of this medium, causing rapid water loss and depletion. This condition leads to insufficient water availability in the growth medium, which is vital to support the imbibition process during the early germination phase. As a consequence, banana seed germination becomes suboptimal. However, there are advantages to using sand as a growth medium for initial seed germination. The rapid drying characteristic of sand facilitates the transplanting of seedlings to other media. Another advantage of sand as a growth medium is its ability to enhance drainage and aeration. Nevertheless, the disadvantages of sand as a medium include its relatively small cumulative surface area, very low water retention capacity resulting in quick drying, large-sized pores (macro pores) that easily become wet and dry quickly through evaporation, and the small cohesion and consistency of sand making it susceptible to erosion by water or wind. As stated by Yosias et al. sand is a highly porous medium, easily leaching nutrient solutions, with good aeration and drainage properties that promote root growth and development. Moreover, sand as a medium contains minimal nutrients and struggles to retain essential nutrients needed for plant growth [23].

4 Conclusion

In this study, banana seeds began to germinate significantly in the second week after planting and had fully germinated after two months. The use of rockwool as a growth medium resulted in the best banana seed germination. The sequence of best germination outcomes from the growth media used is as follows: Rockwool, Moss Sphagnum, Cocopeat, Pak Tani, Rice Husk Charcoal, Sand, Organic Manure + Soil.

The Rockwool growth medium excelled due to its porous nature, enabling root penetration and offering a high water content. These two factors are crucial during the early germination phase. On the other hand, the manure compost + soil growth medium yielded the lowest germination rate because of its relatively compact composition. This composition limits water availability and makes it challenging for seedling roots to penetrate during the initial germination phase, thus inhibiting germination. In conclusion, among the diverse growth media tested in this research, Rockwool is recommended as the best growth medium for the germination of Musa Accuminata banana seeds.

The authors would like to express their sincere gratitude to the Research Organization for Life Sciences and Environment, National Research and Innovation Agency (BRIN) Indonesia, and University of Brawijaya for their essential contribution to this research endeavor.

References


3. https://doi.org/10.1038/s41477-019-0452-6


