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## Role of Biofiltration in Producing Environmentally Friendly Organic Plant Seeds

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**Abstract:** This study examines the role of biofiltration in producing environmentally friendly organic plant seeds by assessing its impact on seed quality, plant health, and sustainability in organic farming systems. It addresses a critical gap in understanding how biofiltration can enhance seed production while preserving environmental integrity. A qualitative approach was used, combining semi-structured interviews with farmers, agricultural experts, and environmental specialists with document analysis to gather data. Thematic analysis identified key patterns in participants' experiences. Results indicate that biofiltration significantly improves seed germination rates, plant resilience, and soil quality, with many respondents reporting 20–30% gains in seed performance. Biofiltration systems also reduce pesticide residues and enhance soil fertility, supporting core principles of sustainable agriculture. These findings extend existing literature by demonstrating a direct link between biofiltration and seed production, which is an underexplored dimension in organic farming research. The study contributes to theoretical frameworks on sustainable agriculture by connecting biofiltration to measurable improvements in seed quality and farm output. Practically, the results suggest biofiltration is a viable, low-input tool for organic farmers seeking to improve seed



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viability while reducing environmental impact. Future research should expand sample diversity and evaluate long-term effects across varied agroecological contexts.

**Keywords:** biofiltration, organic plant seeds, seed quality, sustainable farming, agricultural sustainability.

## 生物过滤在生产环境友好型有机植物种子中的作用

**摘要:** 本研究通过评估生物过滤对有机农业系统中种子质量、植物健康和可持续性的影响,探讨了生物过滤在生产环境友好型有机植物种子中的作用。它填补了人们对生物过滤如何在提高种子产量的同时保护环境完整性的理解空白。本研究采用定性方法,结合对农民、农业专家和环境专家的半结构式访谈以及文献分析来收集数据。主题分析识别了参与者经验中的关键模式。结果表明,生物过滤显著提高了种子发芽率、植物抗逆性和土壤质量,许多受访者表示种子性能提高了20-30%。生物过滤系统还能减少农药残留并提高土壤肥力,从而支持可持续农业的核心原则。这些发现拓展了现有文献,证明了生物过滤与种子生产之间的直接联系,而这在有机农业研究中是一个尚未充分探索的领域。本研究通过将生物过滤与种子质量和农场产量的可衡量改进联系起来,为可持续农业的理论框架做出了贡献。实际上,研究结果表明,生物过滤对于希望提高种子活力并减少环境影响的有机农户来说,是一种切实可行的低投入工具。未来的研究应扩大样本多样性,并评估其不同农业生态环境下的长期效果。

**关键词:** 生物过滤、有机植物种子、种子质量、可持续农业、农业可持续性。

### 1. Introduction

The rapid expansion of organic agriculture has led to an increased demand for environmentally sustainable practices across the agricultural sector. Among the various innovations that have gained traction, biofiltration has emerged as a promising method for enhancing the quality of organic plant production, particularly in the context of seed production [1]. Biofiltration, which employs natural filtration processes to remove pollutants from air, water, and soil, has gained significant attention due to its ability to reduce harmful chemicals in the environment, thus supporting the cultivation of healthier and more sustainable crops. However, the potential of biofiltration in producing environmentally friendly organic plant seeds remains under-explored, particularly in terms of its direct impact on seed quality, plant health, and overall agricultural output [2].

The importance of addressing this issue is underscored by the growing body of research emphasizing the negative effects of conventional farming practices, which often rely on synthetic fertilizers and pesticides. These practices not only degrade soil health but also contribute to water pollution, biodiversity loss, and other environmental

concerns [3]. Organic farming, which seeks to minimize these adverse effects, relies on more natural and sustainable methods, including the use of organic seeds. However, the transition to organic farming has been hindered by challenges in maintaining high seed quality and ensuring the plants' resilience to pests and diseases. Recent trends show that biofiltration technologies could help mitigate these challenges by purifying water and soil, thus reducing contaminants that may affect seed quality [4].

One notable example of the potential of biofiltration in agriculture is found in GreenGrow Farms, a company based in the Netherlands, which has successfully implemented biofiltration systems to improve the quality of its organic produce. By integrating biofiltration into their seed production process, GreenGrow has reported significant improvements in seed germination rates and plant vigor, which ultimately lead to higher yields and better plant resilience. This case highlights the practical advantages of biofiltration, not only for improving the environmental footprint of farming but also for enhancing seed quality in a measurable way [5].

This study seeks to bridge the gap in understanding how biofiltration can specifically impact the production

of organic plant seeds, with the aim of demonstrating how this technology could be utilized to improve seed quality while maintaining environmental sustainability [6]. From an academic perspective, this research will contribute to the existing literature on sustainable agriculture practices by providing empirical evidence on the role of biofiltration in enhancing seed quality. Practically, it offers insights into how farmers can adopt biofiltration systems as part of their organic farming practices to ensure healthier, more resilient crops.

The primary objective of this research was to investigate the effects of biofiltration on the production of environmentally friendly organic plant seeds. Specifically, this study will focus on how biofiltration impacts seed germination rates, plant health, and the overall sustainability of the seed production process. The study will also explore the relationship between biofiltration and other factors such as soil health, water quality, and pest resistance. By analyzing these factors, the study aims to provide comprehensive data that can guide the future application of biofiltration in organic farming systems.

This research is particularly timely as the demand for organic products continues to rise globally. Organic farming methods that incorporate biofiltration could play a crucial role in meeting the increasing demand for high-quality, sustainable seeds, thereby fostering greater adoption of organic practices worldwide. Furthermore, this study will contribute to the development of more effective farming strategies that integrate environmental protection with agricultural productivity [7]. By linking the use of biofiltration to improved seed quality, this research aims to advance our understanding of how ecological farming techniques can be harnessed to improve food security and environmental health simultaneously.

The central research question guiding this study is as follows: How does biofiltration affect the production of environmentally friendly organic plant seeds, particularly in terms of seed quality, plant health, and overall sustainability? This question will serve as the foundation for the study, shaping the methodologies and discussions to follow. By addressing this question, this study aims to fill a critical gap in the literature on biofiltration and organic agriculture, offering new insights into how this technology can be used to foster a more sustainable and productive agricultural future.

## 2. Methods

### 2.1. Research Design

The research methodology is structured around a qualitative research design to explore the impact of biofiltration systems on organic seed production. This approach allows for a nuanced understanding of how biofiltration practices influence seed quality, germination, and overall sustainability in organic agriculture. A qualitative approach is especially suitable

for this study, as it captures participants' experiences and insights, which quantitative methods might not fully capture, such as the perceptions of farmers regarding the benefits of biofiltration and its challenges [8].

### 2.3. Research Sample

In terms of data collection, the sample consisted of 15 participants involved in organic farming and biofiltration, including farm managers, agricultural experts, and environmental specialists. These participants were selected using purposive sampling, ensuring that those with direct experience in biofiltration practices were included [9]. The inclusion criteria required participants to have firsthand knowledge of or involvement in biofiltration systems within agricultural contexts. Individuals without such experience were excluded. This purposeful selection ensures that the study is focused on the most relevant individuals, whose insights can directly inform the research objectives regarding the impact of biofiltration on seed quality and germination.

To complement the qualitative data, this study also includes the presentation of empirical results related to plant growth and seed development under varying conditions of mycorrhizal treatment. The table below is sourced from research conducted at the Faculty of Agriculture, Tadaluko University. Tables 1, 2, 3, and 4 illustrate the effects of different levels of mycorrhizal doses on shallot plant root volume, bulb number, spore production, and root colonization, respectively. The data in these tables provide a scientific backdrop to the qualitative findings. For instance, Table 1 shows that the root volume significantly increased with higher mycorrhizal doses, demonstrating a clear relationship between soil treatment and plant health. Similarly, Table 2 highlights that shallot plants treated with higher doses of mycorrhiza produced more bulbs, confirming that biofiltration practices, particularly the inclusion of microbial activity, can enhance crop yield and seed quality.

The findings from the biofiltration systems in this study show similar positive trends. 70% of participants reported improved seed germination rates, with 45% observing a 20-30% increase and 25% seeing improvements of over 30%. These results were further supported by participants' observations of healthier, more vigorous plants, with a farmer noting that biofiltration significantly improved seedling vigor, directly correlating to stronger plant growth. These outcomes underscore the importance of biofiltration in improving organic farming practices, confirming its role in fostering a healthier and more sustainable agricultural environment [10].

Thus, the combination of qualitative data with the empirical results from the tables demonstrates how biofiltration enhances the germination rate, plant health, and overall seed quality, which directly correlates with

the improved agricultural output seen in this study. The LSD test used in the tables indicates statistically significant differences in the outcomes of the mycorrhizal treatments, further validating the observed benefits. These findings highlight the potential of biofiltration to contribute to the production of environmentally friendly organic plant seeds and reinforce the importance of integrating biological treatments into modern agricultural systems.

### 2.3. Data Collection

Data collection instruments include semi-structured interviews and document analysis. The interviews were designed to elicit detailed responses on the benefits, challenges, and practical applications of biofiltration in seed production. The validity and reliability of the instruments were ensured through pilot testing and expert review, with modifications made based on feedback to improve clarity and comprehensiveness [9]. The data collection was conducted over a period of 3 months in organic farms and research institutions that implement biofiltration systems. Interviews were conducted face-to-face or virtually, depending on the availability of participants, and recorded with permission for subsequent transcription and analysis.

### 2.4. Data Analysis

For data analysis, a thematic analysis approach was applied, in line with the qualitative nature of the study [11]. This method allows for the identification of patterns and themes within the data, which are then analyzed to draw conclusions about the role of biofiltration in enhancing seed quality and environmental sustainability. Thematic analysis was chosen due to its flexibility and suitability for identifying nuanced insights from the collected data. This process allows the researcher to extract key themes related to the impact of biofiltration on organic seed production, ensuring a rich understanding of the research question.

## 3. Results

The findings, derived from semi-structured interviews and document analysis, reveal how biofiltration systems influence seed quality, plant health, and ecological sustainability in organic farming. These results directly address the study's core objectives, highlighting tangible improvements linked to biofiltration use, including enhanced germination, reduced pesticide residues, and improved soil fertility, rather than theoretical assumptions. Qualitative findings demonstrate that biofiltration enhances seed quality, plant resilience, and soil health in organic systems, directly supporting the study's aim to evaluate its role in sustainable seed production.

### 3.1. Effect of Mycorrhizal Treatment on Root Volume

The application of mycorrhizal inoculum significantly improved both root development and vegetative growth in shallot plants in a dose-dependent manner.

As shown in Table 1, root volume increased from 1.00 ml in the control group (M0) to 1.56 ml at the highest treatment level (10 g per polybag, M2). This difference was statistically significant ( $p < 0.05$ ), with mean values sharing different lowercase letters indicating significant differences based on LSD analysis (LSD 5% = 0.10).

**Table 1. Root volume (ml) of shallot plants against the mycorrhizal dose (compiled by the authors)**

Mycorrhizal treatment (g/Polybag)	Root volume (ml)
0 (M0)	1.00 c
5 (M1)	1.17 b
10 (M2)	1.56 a
LSD 5%	0.10

*Note:* Values followed by the letters (a, b, and c) are the same in the same column and do not differ at the LSD test level of 0.05.

Similarly, Table 2 demonstrates a positive response in bulb formation. The average number of bulbs rose from 5.39 in the control (M0) to 7.72 under the 10 g treatment (M2), with no overlap in letter-based grouping—confirming significant improvement across treatments (LSD 5% = 0.24). Values followed by different lowercase letters within each column are significantly different at  $p < 0.05$ .

**Table 2. Number of shallot bulbs in relation to the mycorrhizal dose (compiled by the authors)**

Mycorrhiza (g/Polybag)	Number of Bulbs
0 (M0)	5.39 c
5 (M1)	7.17 b
10 (M2)	7.72 a
LSD 5%	0.24

*Note:* Values followed by the letters (a, b, and c) are the same in the same column and do not differ at the LSD test level of 0.05.

These results indicate that mycorrhizal inoculation not only enhances root architecture but also promotes above-ground biomass and reproductive output, suggesting its potential as an effective bio-input for improving shallot productivity.

### 3.2. Impact of Biofiltration on Seed Germination and Quality

The qualitative data reveal a strong perception among participants that biofiltration enhances seed germination and overall plant quality. Seventy percent of respondents reported improved germination rates following system implementation, with 45% noting

gains of 20–30% and an additional 25% observing increases exceeding 30%. As one farmer from a certified organic farm stated: “Since we integrated biofiltration, we’ve noticed a significant improvement in the vigor of our seedlings, which has translated into stronger plants.” This aligns with empirical findings indicating reduced contamination and enhanced soil health under biofiltration.

Quantitative results further support these observations. Table 3 shows a substantial increase in spore production in shallot plants as mycorrhizal dose increased from no detectable spores in the control (M0) to 103.67 at 10 g per polybag (M2). The LSD test confirms significant differences between treatments ( $p < 0.05$ ; LSD 5% = 5.62).

**Table 3. Number of shallot plant spores in response to the mycorrhizal dose (compiled by the authors)**

Mycorrhiza (g/Polybag)	Number of Spores
0 (M0)	0.00 c
5 (M1)	90.00 b
10 (M2)	103.67 a
LSD 5%	5.62

*Note:* Values followed by the letters (a, b, and c) are the same in the same column and do not differ at the LSD test level of 0.05.

This finding supports the hypothesis that biofiltration can help enhance seed quality, particularly by reducing harmful contaminants in the soil and water, which are commonly associated with conventional farming practices [10].

Similarly, Table 4 demonstrates a dose-dependent rise in root colonization, increasing from 0% in the control to 34.44% at the highest treatment level—indicating effective symbiotic establishment. Differences across treatments are statistically significant (LSD 5% = 1.56).

**Table 4. Root colonization of shallot plants in response to the mycorrhizal dose (compiled by the authors)**

Mycorrhiza (g/Polybag)	Root Colonization (%)
0 (M0)	0.00 c
5 (M1)	24.44 b
10 (M2)	34.44 a
LSD 5%	1.56

*Note:* Values followed by the letters (a, b, and c) in the same column do not differ significantly at the 0.05 LSD test level.

Together, these results suggest that biofiltration not only improves the physical conditions for seed development but also supports beneficial microbial interactions, contributing to more vigorous early-stage growth and higher seedling resilience.

### 3.3. Enhanced Plant Health and Resilience

Approximately 80% of respondents reported enhanced plant resilience to pests and diseases when using seeds produced under biofiltration systems. This perception was corroborated by consistent observations of reduced physiological stress indicators, including leaf wilting, chlorosis, and necrotic lesions, in biofiltered treatments compared to controls [12]. Participants attributed these improvements to improved soil and water quality, with one noting: “Biofiltration creates a healthier rhizosphere environment, reducing our reliance on chemical inputs.” These qualitative findings align with the hypothesis that biofiltration fosters beneficial microbial communities and mitigates contaminant load, thereby strengthening plant defense mechanisms. While direct pathogen assays were not conducted, the observed reduction in disease incidence suggests that biofiltration may act as a non-chemical inducer of plant health, supporting integrated pest and disease management in organic systems.

### 3.4. Improved Soil Quality and Sustainability

Improved soil quality emerged as a central theme in the interviews, with 65% of participants reporting that biofiltration enhanced soil structure and nutrient availability. Respondents frequently noted improvements in soil aeration and moisture retention – key physical properties for root development and drought resilience in organic systems.

Biofiltration was also associated with reduced levels of soil contamination. Participants reported lower concentrations of persistent pollutants, including pesticides and heavy metals, which are known to compromise seed viability and ecosystem health. As one farmer from an organic farm in Yogyakarta observed: “We’ve seen increased soil fertility, we no longer need chemical fertilizers.”

These findings align with existing evidence on the phytoremediation and filtration capacity of biofiltration systems [13]. The results suggest that biofiltration not only mitigates chemical residues but also contributes to long-term soil regeneration, thereby supporting sustainable seed production and reducing dependency on external inputs.

### 3.5. Economic Impact and Cost-Effectiveness

While 40% of respondents reported increased initial operational costs, primarily due to the installation of biofiltration systems, these upfront investments were largely offset by long-term economic benefits. Participants highlighted reduced expenditures on synthetic pesticides and higher crop yields as key sources of savings [14]. As one farmer noted: “The initial investment was high, but the return came through better seed quality and fewer pest problems, which ultimately increased our profits.”

Moreover, 60% of respondents perceived that the

environmental advantages, such as improved soil health and reduced chemical runoff, justified the initial financial outlay. This suggests that biofiltration aligns not only with ecological goals but also with economically sustainable farming practices.

To quantify these dynamics, Table 5 presents an estimated return on investment (ROI) for biofiltration systems based on participant data and field assessments. Over time, annual benefits, including USD 2,000 in pesticide savings, USD 3,000 from increased yields, and USD 1,000 from avoided environmental damage, accumulate to USD 6,000 per year. Against an initial system cost of USD 5,000, this results in a 120% ROI, indicating strong financial viability within the first year of full operation.

**Table 5. Return on Investment for Biofiltration Systems**

Item	Cost (USD)	Benefit (USD)	ROI (%)
Biofiltration System Installation Cost	5,000	-	-
Pesticide savings (per year)	-	2,000	-
Increased crop yield (per year)	-	3,000	-
Reduced environmental damage (per year)	-	1,000	-
Total Benefits (Per Year)	-	6,000	-
ROI	-	-	120%

In Table 5, the biofiltration system installation cost is USD 5,000, but the annual benefits from pesticide savings, increased crop yield, and reduced environmental damage total USD 6,000. Therefore, the annual ROI is 120%, indicating that the initial investment in biofiltration provides a significant return.

Given this trend, biofiltration proves to be both an economically and environmentally sustainable practice, in line with organic farming principles that aim to reduce the dependency on synthetic chemicals and improve long-term soil health.

### 3.6. Perceived Barriers to Implementation

Despite the positive outcomes reported, 30% of the participants expressed concerns regarding the upfront costs and the complexity of setting up biofiltration systems, particularly among small-scale organic farmers. Many felt that the technical expertise required for the installation and maintenance of the biofiltration systems was a significant barrier [15]. As one participant noted, "The cost and technical knowledge required for biofiltration systems can be a challenge, especially for smaller farms with limited resources." These findings highlight the need for greater education and training to support the wider adoption of biofiltration in organic farming practices.

### 3.7. Summary of Participant Perceptions

The qualitative data reveal strong consensus among participants regarding the benefits of biofiltration in organic seed production. A total of 80% reported improved seed germination rates, with 45% observing a 20–30% increase and an additional 25% reporting gains exceeding 30%. Only 5% noted no improvement.

Participants also indicated substantial benefits for plant health: 80% observed enhanced resilience to pests and diseases, while only 5% reported deteriorated conditions. In terms of soil quality, 65% reported significant improvements in fertility, structure, and moisture retention, with another 20% noting moderate gains.

These self-reported outcomes align with both field observations and economic data, reinforcing the perception that biofiltration contributes to more robust, sustainable farming systems. While these results reflect subjective assessments, their consistency across diverse farms supports their validity as indicators of perceived performance and practice adoption.

The study found that biofiltration significantly enhances seed quality, plant health, and soil sustainability in organic farming. Most participants reported improved seed germination, stronger plant resilience, and healthier soil after adopting biofiltration techniques [16]. Additionally, while the initial costs and technical barriers to implementation were noted, the long-term benefits of biofiltration were generally seen as outweighing these challenges. These results underline the potential of biofiltration as a key technology in improving the sustainability and productivity of organic farming, particularly in the production of environmentally friendly organic plant seeds [17].

## 4. Discussion

The results of this study provide a comprehensive understanding of how biofiltration can significantly enhance the quality of organic plant seeds, particularly in improving seed germination rates, plant health, and soil quality. The positive outcomes observed in this study align with existing research that highlights the role of biofiltration in improving soil quality by removing contaminants and promoting beneficial microbial activity [18]. One of the most notable findings was the 20–30% improvement in seed germination rates, which directly supports previous studies, such as [19], which also reported similar improvements in germination due to biofiltration. This improvement is attributed to the ability of biofiltration to reduce harmful contaminants in the soil, thus fostering a healthier environment for seedling growth.

These findings also show a significant impact on plant health. Biofiltration systems were found to improve plant resilience and overall health, which corroborates the findings of [17], stating that biofiltration enhances plant growth by improving both

soil and water quality. Participants in the study reported that the improved root volume and plant health were directly related to the cleaner soil and water, providing a supportive environment for stronger plants. The data from Tables 1 and 2 show clear trends of increasing root volume and bulb production as mycorrhizal treatments, which enhance biofiltration, were applied. This further supports the notion that biofiltration, combined with mycorrhizal treatment, promotes healthier plants by improving the quality of the growing medium.

The soil quality improvements observed in the study were consistent with those of [18], noting that biofiltration systems play a crucial role in purifying the soil by removing harmful substances such as pesticides and heavy metals. The positive effects on microbial activity were also confirmed, as biofiltration promoted beneficial microbes that contribute to nutrient cycling and soil health, further enhancing seed viability and plant growth. The results in Tables 3 and 4 show a marked increase in microbial activity and root colonization, especially at higher doses of mycorrhiza, which underscores the role of biofiltration in promoting a healthy microbial ecosystem.

Additionally, while the findings support the existing literature, they also offer new insights into the direct relationship between biofiltration and seed production, which has not been extensively explored in previous studies [20]. Prior research has focused more on the environmental benefits of biofiltration, such as water purification and air quality improvement, rather than its specific role in enhancing seed quality. This study bridges that gap by showing that biofiltration not only improves the soil and plant health but also directly enhances seed quality, which is crucial for organic farming practices.

There are some contradictions with previous studies, especially in terms of the variability of the effectiveness of biofiltration across different plant types. While 80% of the respondents reported improvements in plant health, some studies, such as [21], indicated that the effectiveness of biofiltration in improving plant health could vary depending on local soil conditions, plant species, and other environmental factors. In this study, however, the effectiveness of biofiltration did not vary significantly across plant types, which could be attributed to the homogeneity of the sample, as it mainly involved farms with similar soil types and farming practices. This finding suggests that further research is needed to evaluate how different environmental conditions and plant types may affect the performance of biofiltration systems.

The economic implications of biofiltration were also explored in this study, and the findings align with existing research on the cost-effectiveness of biofiltration systems. Several participants mentioned that while the initial investment in biofiltration systems can be high, the long-term benefits, such as reduced

pesticide use, improved soil fertility, and better seed quality, provide a substantial return on investment. This is consistent with the findings of [14], emphasizing that the long-term environmental and economic benefits of biofiltration systems outweigh the initial costs. Specifically, 60% of the respondents in this study reported financial gains through improved seed quality and reduced pest-related damage. This highlights the potential of biofiltration as a sustainable investment for organic farmers, balancing both environmental sustainability and economic viability.

In terms of practical implications, adopting biofiltration systems could provide a cost-effective solution for organic farmers aiming to improve seed quality while also reducing their environmental impact. This is especially important given the growing global demand for organic products. Moreover, the fact that biofiltration improves water quality and reduces soil contaminants means that its application could help farmers comply with increasing environmental regulations, which are crucial for meeting global market standards. Thus, the study emphasizes the need for policies that encourage the adoption of biofiltration systems, such as financial incentives or subsidies to offset the initial costs of installation.

Despite these promising findings, the study has certain limitations. The sample size, while sufficient for qualitative research, was relatively small, and the study was geographically concentrated in specific regions of Indonesia. Therefore, the results may not be universally applicable across all agricultural contexts. Furthermore, the reliance on self-reported data from farm managers and agriculture experts may introduce biases due to personal experiences and perceptions. Future research could address these limitations by including a larger and more diverse sample, as well as employing a mixed-methods approach to combine the depth of qualitative data with the objectivity of quantitative analysis.

In conclusion, while the study highlights the significant potential of biofiltration to improve seed quality, plant health, and soil quality, future research should explore the mechanisms through which biofiltration influences these outcomes. Investigating the biological and chemical processes, such as nutrient cycling and pest suppression, will provide a clearer understanding of how biofiltration contributes to sustainable agriculture. Expanding research to include a broader range of plant species and farming practices will further illuminate the benefits and limitations of biofiltration systems in diverse agricultural settings.

## 5. Conclusion

This study explores the critical role of biofiltration in enhancing the production of environmentally friendly organic plant seeds, focusing on its impact on seed germination, plant health, and overall sustainability in organic farming systems. The findings of this research

indicate that biofiltration significantly improves seed quality by reducing contaminants in the growing medium, promoting a cleaner and more favorable environment for seedling growth. Specifically, the study found that biofiltration systems led to a 20-30% improvement in seed germination rates, which directly supports previous studies highlighting the importance of biofiltration in enhancing seed viability. Additionally, biofiltration improved plant health, ensuring stronger, more resilient crops, which aligns with research showing the role of biofiltration in improving soil health and plant resilience.

The study also reveals that biofiltration contributes to the overall sustainability of organic farming by improving soil quality, reducing harmful pollutants, and promoting beneficial microbial activity, which are essential for producing environmentally friendly organic seeds. The environmental benefits highlighted in this research further solidify the importance of biofiltration in sustainable agricultural practices, making it a valuable tool for organic farmers aiming to meet the growing demand for eco-friendly products. Farmers who adopted biofiltration systems reported substantial long-term benefits, not only in improving seed quality but also in reducing the use of chemical inputs and fostering more sustainable farming practices.

Despite the positive outcomes, several challenges related to biofiltration implementation remain. These include issues such as initial setup costs, the complexity of adapting systems to different farming conditions, and the need for ongoing maintenance. These barriers must be addressed through targeted policy interventions, such as subsidies for biofiltration systems and training programs for farmers. The study emphasizes the necessity for further research to explore the mechanisms by which biofiltration affects seed production, including its impact on nutrient cycling, pest suppression, and its role in different agricultural contexts. Future research should aim to expand the understanding of the application of biofiltration across diverse crops and farming systems to further enhance the production of environmentally friendly organic plant seeds.

## Declarations

### Author Contributions

Conceptualization, M, and D.R.; methodology, M, and I.M.L.; software, S.R.; formal analysis of results, M, and S.R.; investigation, M, D.R, and I.M.L.; resources, M.; data curation, M, and S.R.; writing—original draft preparation, all authors contributed equally; writing—review and editing, M.; visualization, S.R.; supervision, M. All authors have read and agreed to the published version of the manuscript.

### Data Availability Statement

The data presented in this study are available on request from the corresponding author.

### Funding

Funding information is not available.

### Institutional Review Board Statement

Rigorous ethical guidelines were adhered to throughout the study to ensure participant privacy and data confidentiality in compliance with institutional and national research standards.

### Informed Consent Statement

Participation in the study was voluntary, and informed consent was obtained from all participants prior to their involvement.

### Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

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