SAINS TANAH – Journal of Soil Science and Agroclimatology

Journal homepage: http://jurnal.uns.ac.id/tanah

Enhancing beans (*Phaseolus vulgaris*) growth using zeolite-based growing media

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ARTICLE INFO

Keywords:
Cultivation
Electrical conductivity
Fertilization
Plant disease
Zeolite

Article history
Submitted: 2025-03-08
Revised: 2025-07-15
Accepted: 2025-08-08
Available online: 2025-10-28
Published regularly: December 2025

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ABSTRACT

Electrical conductivity (EC) spikes due to fertilization are harmful to plant. This shows the need for appropriate composition of growing media, such as Zeoponic, consisting of zeolite, cocopeat, and compost, to support plant development. Therefore, this study aimed to determine the effect of zeolite-based growing media and the addition of fertilizer on growth of bean (*Phaseolus vulgaris*) cultivated in polybags. The experiment was conducted on beans in three different media with a completely randomized design (CRD) in factorial arrangement, with three levels type treatment (zeoponic, media A, and B), and three levels of fertilizer dosage (0 g kg^{-1}, 1 g kg^{-1}, 1.5 g kg^{-1}). The parameters observed were plant height, number of leaves, beans weight, length, and disease intensity. The results showed that growth and production of beans in zeoponic tended to be higher than in A and B. However, the addition of fertilizer at 1.5 g kg^{-1} did not significantly affect growth and production of beans. The presence of zeolite caused EC of the growing media to remain low, and nutrients were released slowly to ensure continuous availability to plant. Additionally, the use of zeoponic for cultivating beans in polybags has been shown to reduce the incidence of disease.

How to Cite: Oktariani, P., Suryaningsih, A. S., Suryaningtyas, D. T. (2025). Enhancing beans (*Phaseolus vulgaris*) growth using zeolite-based growing media. Sains Tanah Journal of Soil Science and Agroclimatology, 22(2), 370-376. https://doi.org/10.20961/stjssa.v22i2.100238

1. INTRODUCTION

Various plant growth media (PGM) are developed to address the problem of limited land. These alternatives support healthy plant growth and help achieve optimal yields. PGM play a significant role in seedling propagation, particularly in vegetable nurseries and greenhouses, by providing essential water, air, and nutrients, which serve as structural support for plant (Mathowa et al., 2017). As an essential factor, PGM must provide essential nutrients and maintain root moisture with sufficient water and oxygen availability to sustain plant metabolism and development (Febriani et al., 2021). The variety includes both organic and inorganic, such as sand, peat, perlite, rock wool, sawdust, cocopeat, and compost, which are widely used to support the cultivation of high-value crops comprising vegetables, fruits, and ornamentals (Sachin et al., 2020).

Despite the potential of PGM, not all nutrients are readily available for plant uptake, leading to deficiency issues. To address this challenge, nutrient availability can be sustained by supplementing PGM or plant directly with additional fertilizers to enhance soil nutrient content (Kihara et al., 2022). Nitrogen (N), phosphorus (P), and potassium (K) are the three main macronutrients that are crucial for plant growth and production. The need for these nutrients can be met by providing NPK compound fertilizers, although widespread applications influence soil properties, particularly pH and electrical conductivity (EC) (Theresa et al., 2020). Excessive application of NPK fertilizers can lead to high EC levels, which may negatively impact plant growth by disrupting water uptake and nutrient absorption (Song et al., 2022).

A high EC value shows elevated salt concentrations in PGM solution (Wibowo et al., 2018). Excessive salt levels can disrupt root function by inhibiting the absorption of water and nutrients, thereby suppressing overall plant growth and development (Suseno & Widyawati, 2020). Therefore, the use of a mixture of materials that have a high cation exchange capacity (CEC), such as zeolite, can be a preventive measure against spikes in EC values due to fertilization. The high

STJSSA, p-ISSN 1412-3606 e-ISSN 2356-1424
http://dx.doi.org/10.20961/stjssa.v22i2.100238

nutrient-holding capacity of zeolite materials has the potential to increase the buffering capacity against spikes in EC (Mpanga et al., 2020; Suwardi & Pangestu, 2004). According to Kusdarto (2008), zeolite is a hollow alumino-silicate mineral with a high CEC value, unique physicochemical properties, and good function as an absorber and ion exchanger. Due to the ordered crystalline and porous structure, zeolite is widely applied in large-scale industries such as agriculture (Kordala & Wyszkowski, 2024). In soybean cultivation, the addition of zeolite significantly increased the number of pods and seed weight compared to the control (Minardi et al., 2020). Meanwhile, in mustard green, tomato, and eggplant, the application of zeoponic increased plant height, root length, and shoot fresh weight (Suryaningtyas et al., 2023).

One of beans variety, namely *P. vulgaris,* is among the horticultural commodities from the legume group that is widely cultivated in Indonesia. This plant is valued for the edible pods, which can be consumed fresh, as dried seeds, sprouts, or young leaves (Setiyono et al., 2022). The pod is the primary edible part, offering numerous nutritional benefits, serving as a rich source of vegetable protein and vitamins (Dayan et al., 2019; Jemarut et al., 2023). As a key dietary component, beans provide an important protein source that complements carbohydrate-based staple foods, contributing to balanced nutrition (Smith & Rao, 2021). According to data from the Center for Agricultural Data and Information System (2022), the average per capita consumption of beans in 2022 was 1.067 kg cap^{-1} year^{-1}, which was higher than the per capita availability of only 0.74 kg cap^{-1} year^{-1}. Several methods can be attempted to increase the production of beans to meet the consumption needs of the community. These include independent cultivation using land and media available at home on a small or medium scale.

In line with the recent development, the use of alternative growing media has become a major strategy to support horticultural production in space-limited environments, such as polybag systems. Organic materials, including compost and cocopeat, improve water retention and nutrient supply, while zeolite contributes to increased nutrient buffering and EC stabilization due to the high cation exchange capacity. Although the agronomic benefits of zeolite have been shown in various crops (Suryaningtyas et al., 2023), there is limited information about the specific application of zeolite in *P. vulgaris* cultivation, particularly in polybag systems suitable for household and urban farming. This shows the need for investigation to enrich the literature on the formulation of alternative treatments that are efficient, environmentally friendly, and practical for small-scale and space-limited cultivation. Therefore, this study aimed to determine the effect of zeolite-based growing media and the addition of fertilizer on increasing growth of beans (*P. vulgaris*) in cultivation using polybags.

2. MATERIAL AND METHODS

This study was conducted at the Department of Soil Science and Land Resource, Faculty of Agriculture, IPB University, from June 2022 to January 2023. Media analysis was conducted at the Physical Land Resources Development Laboratory and the Soil Chemistry and Fertility Laboratory of the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University.

Plant material used in this study was beans of Gipsy variety (provided by BISI International company). Moreover, three types of PGM were used, namely media zeoponic (a mixture of zeolite, compost, and cocopeat), A (a mixture of compost, husk charcoal, and cocopeat), and B (a mixture of topsoil, compost, and husk charcoal). The field experiment was conducted in polybags (35 × 35 cm in size; filled with 5 kg of media per bag) using a two-factor completely randomized design, which included the type of planting media and the doses of fertilizer. The first factor served as growing media, which included three types, namely zeoponic (Z), A, and B. The second factor was the dose of NPK compound fertilizer, applied at 0 g kg^{-1} (0), 1 g kg^{-1} (1), and 1.5 g kg^{-1} (2). The combination of these two factors totaled 9 distinct treatments, each replicated three times, leading to 27 experimental units.

Before sowing, the seeds were soaked in a PGPR solution (Rhizomax, provided by WISH Indonesia) for 15 minutes and planted in trays filled with soil as growing media. This process was carried out to achieve uniform growth across all treatments before the seedlings were transplanted into the larger PGM. The seed trays were kept in a location away from direct sunlight. After 10 days, the seedlings were transferred to polybags containing approximately 5 kg of growing media, with 2-3 seeds placed in each bag. As planting area is an open location, watering was performed in the morning or evening, based on plant condition and the moisture level.

NPK compound fertilizers were applied twice during the vegetative phase. Each application was split into two portions, with half of the first dose being administered at 2 weeks after transplanting (WAT), while the remaining was provided at the age of 4 WAT. Plant maintenance included daily watering, weeding, and managing pests or plant diseases using yellow sticky traps and applying *Trichoderma* sp. biofungicide (Trichomax, provided by WISH Indonesia) at a dosage of 5 grams per polybag by direct sprinkling. Poles were installed for plant at four WAT to support their height.

Observations were conducted weekly from when plant was transferred to polybags until harvest. The parameters assessed were growth (measured by plant height, number of leaves, and fruit weight) as well as the presence of damping-off disease. Harvesting occurred when the pods were young, and the small seeds had not yet protruded from the surface of the pods, typically 2-3 weeks after flowering, or 55-70 days post-planting. This harvesting stage was consistent with national guidelines and agricultural practices in Indonesia, which recommended harvesting beans while the pods were still immature and the seeds remain flat. According to the Standard Operating Procedure (SOP) for beans (Directorate of Vegetables and Medicinal Plants, 2021), harvesting should occur approximately 38–45 days after planting, when "seeds in the pod are not yet protruding". Similar criteria were used in field trials, where beans were harvested around 48 days after planting, with pods measuring 20–23 cm in length, bright green in color, smooth-skinned, and containing flat seeds (Taslim et al., 2020).

Before planting, an analysis of growing media was performed to assess nutrient content. The parameters analyzed were pH, EC, ammonium, nitrate, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn). Soil pH was measured using the glass electrode method in a 1:5 soil-to-water suspension. EC was determined from the same extract using a conductivity meter to assess the concentration of soluble salts. Ammonium (NH_4^+) and nitrate (NO_3^-) were extracted using 1 N KCl. Available phosphorus was extracted using Bray I, while total-P was extracted using HCl 25% and measured with UV-Vis Spectrophotometer. Potassium (K), calcium (Ca), and magnesium (Mg) were extracted with 1 N ammonium acetate at pH 7.0 and measured using atomic absorption spectrophotometry (AAS). Micronutrients such as copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) were extracted using the DTPA method and analyzed using AAS.

Plant samples were collected for disease identification. The ANOVA test was performed to determine statistically significant differences between growing media, followed by a significant difference test at the 5% level using Minitab 19. The calculation of disease incidence was carried out using Equation 1 provided by Agrios (2005).

$$P = n \,/\, N \; x \; 100\% \quad [1]$$

Where P = percentage of disease occurrence; n = the number of infected plant; N = the number of plant observed.

3. RESULT

3.1 Analysis of growing media

As shown in Table 1, pH values of the three media ranged from neutral to slightly alkaline, with values between 7.2 and 8.2. According to the Indonesian Center for Agricultural Land Resource Research and Development (ICALRD), beans thrive best in media or soil with a pH between 6 and 7.8 (Magomere et al., 2024). Therefore, the pH values of both zeoponic (Z) and media A were suitable for beans cultivation. Media B had the highest EC value at 4.21 mS cm^{-1}, followed by A at 3.02 mS cm^{-1}, and zeoponic at 1.11 mS cm^{-1}. According to soilless media guidelines provided by the Missouri University Extension (2010) and the Oklahoma State University Extension (2017), EC values between 1.0 and 3.5 mS cm^{-1} are considered optimal for most horticultural crops. Based on these classifications, the zeoponic medium (1.11 mS cm^{-1}) was within the optimal range at the lower threshold, indicating sufficient nutrient availability with low risk of salt accumulation. Medium A (3.02 mS cm^{-1}) also fell within the optimal range but near the upper limit, suggesting relatively high nutrient availability. In contrast, Medium B (4.21 mS cm^{-1}) exceeded the optimal range and was categorized as high, implying potential risks of excessive soluble salts.

According to Eviati et al. (2023), the nutrient levels in each growing medium were classified based on national soil analysis standards. In zeoponic, nitrate was 67.86 ppm and ammonium was 9.0 ppm, which were considered sufficient to support healthy vegetative growth. Total phosphorus levels were high in all media, showing 175.61 ppm, 344.57 ppm, and 232.8 ppm in zeoponic, A, and B, respectively. However, the available phosphorus was recorded only as trace amounts.

Table 1. Analysis of plant growing media

Media/parameter	Zeoponic	Media A	Media B
pH	7.2	8.2	7.6
EC (mS/cm)	1.11	3.02	4.21
C-Org (%)	13.87	19.03	25.50
NO_3 (ppm)	67.86	98.70	49.40
NH_4 (ppm)	9.0	7.2	9.0
Available P (ppm)	tr	tr	tr
Total P (ppm)	175.61	344.57	232.8
K (cmol$^{(+)}$/kg)	7.69	35.89	17.94
Na (cmol$^{(+)}$/kg)	15.27	10.90	13.09
Ca (cmol$^{(+)}$/kg)	26.73	18.29	15.09
Mg (cmol$^{(+)}$/kg)	7.22	11.04	10.84
Fe (ppm)	1.7	5.9	2.9
Cu (ppm)	0.4	0.9	0.8
Zn (ppm)	1.3	1.8	0.5
Mn (ppm)	15.6	11.2	5.1

In line with the guideline, all media were categorized as very low in available P, which could limit plant uptake despite high total P content. The results showed that P was highest in Media A at 35.89 cmol(+) kg^{-1}, followed by B and zeoponic at 17.94 cmol(+) kg^{-1} and 7.69 cmol(+) kg^{-1}, respectively. These values were more than the guideline threshold of >1.0 cmol(+) kg^{-1}, causing nutrient imbalances by interfering with the uptake of calcium and magnesium. Calcium levels were also high with values of 26.73, 18.29, and 15.09 cmol(+) kg^{-1} in zeoponic, A, and B, respectively. Zeoponic exceeded the very high threshold (>20 cmol(+) kg^{-1}), while the other two were in the high range. Magnesium concentrations were also elevated across all media, with values above the very high threshold of >8 cmol(+) kg^{-1}.

For micronutrients, iron levels ranged from 1.7 to 5.9 ppm, which was below the commonly accepted sufficiency level of 15 ppm. Zinc levels 0.5 to 1.8 ppm were also low, while manganese was adequate, indicating a 15.6 ppm within the acceptable range for most crops. This suggested that the growing media showed balanced macronutrient availability and optimal EC. However, micronutrient deficiencies, particularly iron and zinc, should be addressed to support optimal plant health.

3.2 Plant growth

Measurement of growth parameters was carried out from the time plant was transferred to polybags until 9 WAP (Fig. 1a). Plant height began to increase rapidly in the second week after transplanting. The highest growth was recorded in treatment Z1 at week 5, reaching 77.2 cm. In comparison, the lowest growth was observed in treatment A0, with a maximum height of only 36.9 cm. After the fifth week, height started decreasing as plant entered the generative phase, showed by flower formation.

An increase in the number of leaves was observed starting from the second week after transplanting (Fig. 1b). Treatment Z1 showed the highest production, peaking at 33 leaves per plant in the sixth week. This outcome showed the superior performance of Z1 in supporting vegetative development, particularly in enhancing both foliar growth and plant stature.

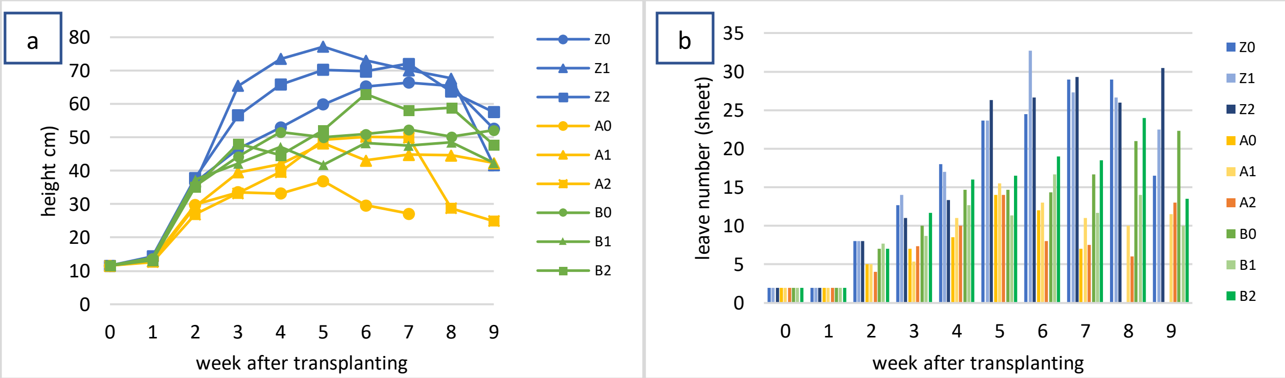

Figure 1. Plant height (a) and plant leave number (b) after transplanting

Table 2. Result of plant growth parameters

Treatment	Average height (cm)	Average leave number (sheet)	Total harvest (g)	Average bean length (cm)
Z0	45.60[abc]	13[ab]	3.26	12.37
Z1	54.22[a]	16[a]	2.93	11.85
Z2	52.69[ab]	16[ab]	2.91	11.86
A0	28.25[c]	4[b]	-	-
A1	31.82[bc]	6[ab]	0.65	6.80
A2	29.90[c]	5[ab]	-	-
B0	42.33[abc]	12[ab]	2.40	11.20
B1	39.76[abc]	10[ab]	-	-
B2	41.65[abc]	10[ab]	-	-

Remarks: Means followed by the same letters in the same column are not significantly different according to the Tukey HSD test at $p < 0.05$

Based on Table 2, beans grown in Z1 showed the highest height, with an average of 54.22 cm, which was statistically significantly different from the others. The Z2 treatment (52.69 cm) showed a similar performance and was not significantly different from Z1. However, the value remained higher compared to treatments A0, A1, and A2, which reached only 28.25 cm, 31.82 cm, and 29.90 cm, respectively.

As shown in Table 2, the highest average was also observed in Z1 and Z2, with 16 leaves per plant, suggesting the consistent positive effect of these treatments on plant development. Treatments A0 and A2 showed significantly lower numbers, with only 4 and 5 leaves, respectively. At harvest, the total weight and length of beans were measured (Table 2). Beans grown in zeoponic produced the highest overall yield. Although the plant in Z0 treatment had a lower average height and fewer leaves (45.60 cm and 13 leaves) compared to Z1 (54.22 cm and 16 leaves) and Z2 (52.69 cm and 16 leaves), Z0 achieved the highest total harvest weight (3.26 g) and the longest average pod length (12.37 cm). The composition and nutrient content of growing media have a significant influence on plant growth, as evidenced by differences in vegetative development and final yield across treatments.

3.3. Plant disease

Disease observations were carried out from the first to the seventh week after transplanting. The results showed the presence of damping-off disease, characterized by symptoms such as stem wet rot, followed by plant wilting and the appearance of brown lesions on the leaves (Fig. 2). Disease

Figure 2. Damping-off disease found on beans

intensity was calculated using Equation 1 on all growing media (Fig. 3). Initial symptoms were observed in the first week and continued to increase until the seventh week. Among all treatments, A0 showed the most severe disease progression, reaching 100% intensity by the sixth week. A2 had a sharp increase in intensity starting in the fourth week and reached 100% by the seventh week, showing that both A0 and A2 were the most susceptible treatments.

In comparison, treatments Z0, Z1, and Z2 consistently showed low disease intensities throughout the observation period. Z1 maintained the lowest levels of disease intensity, suggesting effective suppression of development due to the beneficial physical properties of the growing medium. By the seventh week, 100% of plant in treatments A0 and A2 were completely infected and died due to severe disease incidence,

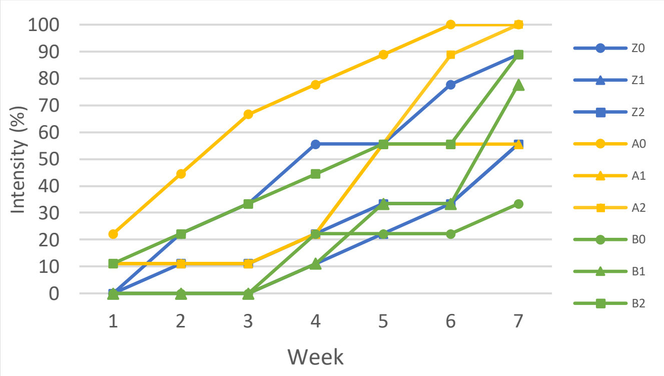

Figure 3. Disease intensity of bean (*P. vulgaris*)

leading to total crop failure. Treatments B1 and B2 also showed high disease intensity, which contributed to plant mortality and the absence of harvest data, as presented in Table 2.

4. DISCUSSION

The results showed that zeoponic significantly enhanced plant performance, as indicated by higher plant height, number of leaves, and yield components. These outcomes support the hypothesis that zeoponic substrates with unique physicochemical properties can provide a more favorable environment for bean cultivation under controlled conditions.

The improved growth observed in treatment Z1 was in line with previous studies. Suwardi et al. (2024) reported that zeolite-based substrates helped maintain ionic balance and reduced nutrient leaching, thereby promoting better plant development. As shown in Table 1, zeoponic had the lowest EC value (1.11 mS cm^{-1}), while A and B recorded significantly higher values of 3.02 mS cm^{-1} and 4.21 mS cm^{-1}, respectively. Elevated EC levels are associated with salt accumulation in the root zone, which can cause osmotic stress and inhibit water and nutrient uptake (Mota et al., 2016). This was shown in Table 2, where plants grown in zeoponic reached an average height of 54.22 cm, markedly higher than those in A (28.25 cm) and B (42.33 cm). These results show that the lower EC in zeoponic contributed to a more balanced nutrient environment, supporting improved vegetative growth.

In addition to balanced EC levels, nutrient absorption appeared more efficient in zeoponic. As shown in Figure 1b, plants grown in treatments Z1 and Z2 produced an average of 16 leaves, substantially higher compared to A0 (4 leaves) and B0 (12 leaves). This consistent and controlled nutrient availability minimized the risk of nutrient toxicity or deficiency, supporting steady vegetative growth and contributing to higher yields (Table 2). Similarly, Mpanga et al. (2020) showed that zeolite-based media improved nutrient uptake and promoted shoot development by minimizing nutrient loss and maintaining a stable root-zone environment.

An essential contributor to the superior performance is zeolite's high cation exchange capacity (CEC), which facilitates nutrient retention and gradual release. Mpanga et al. (2020) and Suwardi et al. (2023) stated that zeolite enhanced the ability of media to store essential nutrients and prevent abrupt EC fluctuations that may cause plant stress. In this study, controlled nutrient release was shown by increasing the fertilizer dose by approximately 1.5 g kg^{-1}. This did not significantly improve growth, suggesting that zeoponic already provided sufficient nutrient availability to support optimal plant performance.

The effectiveness of growing media is further supported by Irawati et al. (2023), who identify the optimal EC range for plant growth to be between 1.5 and 1.8 mS cm^{-1}. Although the EC of zeoponic in this study was slightly below the threshold (1.11 mS cm-1), a stable nutrient environment was maintained, promoting steady vegetative growth. Choi et al. (2017) reported that EC levels exceeding 3.0 dS m^{-1} could negatively impact fruit yield by causing salt-induced osmotic stress, which disrupted nutrient uptake and plant physiological processes. These results showed that excessive EC, as observed in A and B, could inhibit plant growth.

Other physicochemical properties in Table 1 further support the superior performance of zeoponic, with a pH of 7.2 falling within the optimal range for bean growth. Meanwhile, A and B had a pH of 8.2 and 7.6, respectively, which could limit micronutrient availability. The influence of media composition was also supported by Nurmegawati et al. (2019), who found that cow manure compost significantly increases soil pH, exchangeable cations (K, Na, Ca), and base saturation.

Zeoponic showed favorable nutrient profiles, with the highest calcium concentration at 26.73 cmol(+) kg^{-1}, compared to 18.29 cmol(+) kg^{-1} and 15.09 cmol(+) kg^{-1} in A and B, respectively. This contributed to stronger cell wall development and improved plant resilience (Naz et al., 2024). In terms of potassium, zeoponic contained 7.69 cmol(+) kg^{-1} while A showed an excessively high level (35.89 cmol(+) kg^{-1}), which could cause nutrient imbalances and antagonism with other cations.

Media A and B posed specific challenges that hindered plant growth. The high moisture-retention capacity of media A, due to the composition of compost, husk charcoal, and cocopeat, created anaerobic conditions in the root zone. These unfavorable conditions induced root stress, increasing the plant's vulnerability to soil-borne pathogens. By the seventh week, all plants in A0 and A2 showed 100% disease incidence (Table 2), which led to severe stunting and complete crop failure. Similarly, Labeda and Koesriharti (2022) reported that high moisture content in PGM promoted fungal proliferation.

Although the application of *Trichoderma sp*. biofungicide reduced damping-off symptoms by the fifth week, the late application in the fourth week could limit effectiveness, allowing disease intensity to peak by the seventh week. Theresa et al. (2020) stated that early application of biofungicides was more effective in suppressing pathogen development. This suggested that future studies should investigate the optimal timing and delivery methods for *Trichoderma* sp. application across different media compositions to enhance early-stage disease resistance.

In comparison to previous reports, this study offers a more holistic understanding by integrating physical (EC, pH), chemical (CEC, nutrient concentrations), and biological (disease incidence) variables. Previous reports have often investigated these parameters in isolation (Irawati et al., 2023; Labeda & Koesriharti, 2022; Mpanga et al., 2020), few have assessed the combined influence on bean growth. This integrative perspective highlights the potential of zeoponic cultivation as a sustainable and resilient strategy, particularly in systems that require careful nutrient and disease management.

5. CONCLUSION

In conclusion, zeoponic significantly improves growth performance, yield, and disease resistance of *P. vulgaris* compared to conventional organic media. Plants cultivated in zeoponic media show greater height, a higher number of leaves, and yield, alongside a delayed onset and lower intensity of disease symptoms. Moreover, the application of NPK fertilizers at concentrations of 1.5 g kg^{-1} shows no significant improvements in growth or productivity. This suggests that zeoponic provides sufficient nutrient availability to support optimal plant performance. Despite the valuable insights into the effectiveness of zeoponic for bean growth, this study still has several limitations. First, the experiment focused on one plant (*P. vulgaris*) and its application in small polybags, thereby limiting the generalizability of the results to other plants. Second, this study was conducted over a relatively short period, and the long-term performance of growing media was still unknown. Therefore, further studies should investigate the long-term nutrient dynamics and effects of zeoponic on various types of plants to fully understand the potential and limitations.

Acknowledgements

The author gratefully acknowledges the support from the Institute of Research and Community Empowerment, IPB University, through the Young Lecturer Research Grant Scheme for funding this research.

Declaration of Competing Interest

The authors declare that no competing financial or personal interests may appear to influence the work reported in this paper.

References

Agrios, G. N. (2005). Plant pathology (5th ed.). Elsevier - Academic Press. https://doi.org/10.1016/C2009-0-02037-6

Center for Agricultural Data and Information System. (2022). *Statistik konsumsi pangan 2022* [Statistics of food consumption 2022]. Secretariate General - Ministry of Agriculture Republic of Indonesia. https://satudata.pertanian.go.id/details/publikasi/407

Choi, G. L., Yeo, K. H., Choi, S. H., Jeong, H. J., Kang, N. J., & Choi, H. G. (2017). Effect of EC level of irrigation solution on tomato growth and inorganic ions of root zone in soilless culture of tomato plant using coir substrate. *Journal of Bio-Environment Control*, *26*(4), 418-423. https://doi.org/10.12791/KSBEC.2017.26.4.418.

Dayan, H., Subagiono, & Setiono. (2019). Karakter morfologi tanaman buncis (*Phaseolus vulgaris* L.) terhadap pemberian limbah kulit kopi. *Jurnal Sains Agro*, *4*(1). https://www.ojs.umb-bungo.ac.id/index.php/saingro/article/view/245.

Directorate of Vegetables and Medicinal Plants. (2021). *Standar Operasional Prosedur (SOP) Buncis*. Directorate General of Horticulture, Ministry of Agriculture of the Republic of Indonesia. https://repository.pertanian.go.id/handle/123456789/13714

Eviati, Sulaeman, Herawaty, L., Anggria, L., Usman, Tantika, H. E., . . . Wuningrum, P. (2023). *petunjuk teknis analisis kimia tanah, tanaman, air, dan pupuk* (3rd ed.). Soil and fertilizer instrument standard testing center, Ministry of Agriculture, Republic of Indonesia https://repository.pertanian.go.id/handle/123456789/23044

Febriani, L., Gunawan, G., & Gafur, A. (2021). Review: Pengaruh jenis media tanam terhadap pertumbuhan tanaman. *Bioeksperimen: Jurnal Penelitian Biologi*, *7*(2), 12. https://doi.org/10.23917/bioeksperimen.v7i2.10902.

Irawati, E. B., Sasmita, E. R., & Padmini, O. S. (2023). Optimal EC value and pruning strategy for enhanced growth in hydroponic watermelon cultivation. *IOP Conference Series: Earth and Environmental Science*, *1242*(1), 012010. https://doi.org/10.1088/1755-1315/1242/1/012010.

Jemarut, S., Muddarisna, N., & Rositawati, R. (2023). Pengaruh konsentrasi pupuk organik cair NASA dan konsentrasi GA3 pada pertumbuhan dan hasil tanaman buncis baby (*Phaseolus vulgaris*). *Primordia*, *19*(2), 59-64. https://doi.org/10.37303/primordia.v19i2a136.

Kihara, J., Bekunda, M., Chimonyo, V., Kimaro, A., Kotu, B., Lyimo, S., & Mhango, W. (2022). Management of soil fertility through application of fertilizers. In *Sustainable Agricultural Intensification: A Handbook for Practitioners in East and Southern Africa* (pp. 48-61). CABI GB. https://www.cabidigitallibrary.org/doi/10.1079/9781800621602.0004

Kordala, N., & Wyszkowski, M. (2024). Zeolite properties, methods of synthesis, and selected applications. *Molecules*, *29*(5), 1069. https://doi.org/10.3390/molecules29051069.

Kusdarto. (2008). Potensi zeolit di Indonesia. *Jurnal Zeolit Indonesia*, *7*(2), 78-87. https://media.neliti.com/media/publications/219596-potency-of-zeolite-in-indonesia.pdf.

Labeda, A. G., & Koesriharti. (2022). Pengaruh tingkat EC (*Electrical Conductivity*) dan nutrisi terhadap pertumbuhan dan hasil tanaman pakcoy (*Brassica rapa* L. var chinensis) pada hidroponik sistem sumbu (*Wick System*). *Produksi Tanaman*, *10*(1), 10-18. https://doi.org/10.21776/ub.protan.2022.010.01.02.

Magomere, K. M., Nchimbi-Msolla, S., & Tryphone, G. M. (2024). Effects of soil pH levels on iron and zinc concentrations of common bean (*Phaseolus vulgaris* L.) genotypes. *African Journal of Agricultural Research*, *20*(7), 510-516. https://doi.org/10.5897/AJAR2022.15924.

Mathowa, T., Tshipinare, K., Mojeremane, W., Legwaila, G., & Oagile, O. (2017). Effect of growing media on growth and development of sweet paper (*Capsicum annum* L.) seedlings. *Journal of Applied Horticulture*, *19*(3), 200-204. https://doi.org/10.37855/jah.2017.v19i03.36.

Minardi, S., Haniati, I. L., & Nastiti, A. H. L. (2020). Adding manure and zeolite to improve soil chemical properties and increase soybean yield. *Sains Tanah Journal of Soil Science and Agroclimatology*, *17*(1), 1-6. https://doi.org/10.20961/stjssa.v17i1.41087.

Missouri University Extension. (2010). *Greenhouse media analysis*. Oil and Plant Testing Laboratory, University of Missouri. https://extension.missouri.edu/programs/soil-and-plant-testing-laboratory/spl-greenhouse-media-analysis

Mota, P. R. D. A., Fernandes, D. M., & Ludwig, F. (2016). Development and mineral nutrition of gerbera plants as a function of electrical conductivity. *Ornamental Horticulture*, *22*(1), 37-42. https://doi.org/10.14295/aohl.v21i2.533.

Mpanga, I. K., Braun, H., & Walworth, J. (2020). Zeolite application in crop production: Importance to soil nutrient, soil water, soil health, and environmental pollution management. https://repository.arizona.edu/handle/10150/669960

Naz, M., Afzal, M. R., Raza, M. A., Pandey, S., Qi, S., Dai, Z., & Du, D. (2024). Calcium (Ca2+) signaling in plants: A plant stress perspective. *South African Journal of Botany*, *169*, 464-485. https://doi.org/10.1016/j.sajb.2024.04.047.

Nurmegawati, Iskandar, & Sudarsono. (2019). Effect of bottom ash and cow manure compost on chemical properties of soil at new-established rice field. *Sains Tanah Journal of Soil Science and Agroclimatology*, *16*(1), 1-12. https://doi.org/10.20961/stjssa.v16i1.22366.

Oklahoma State University Extension. (2017). *Greenhouse growth media: Sampling, testing and interpretations (Fact Sheet HLA-6726)*. Division of Agricultural Sciences and Natural Resources, Oklahoma State University. https://extension.okstate.edu/fact-sheets/greenhouse-growth-media-sampling-testing-and-interpretations.html

Sachin, T., Thakur, N., & Sharma, P. (2020). Use of alternative growing media in ornamental plants. *International Journal of Chemical Studies*, *8*(6), 188-194. https://doi.org/10.22271/chemi.2020.v8.i6c.11079.

Setiyono, Pangestu, R. W., & Kusbianto, D. E. (2022). Aplikasi pupuk hayati (Biofertilizer) dan pupuk ZA terhadap pertumbuhan dan hasil tanaman buncis (*Phaseolus vulgaris* L.). *Agritrop : Jurnal Ilmu-Ilmu Pertanian*, *20*(1), 10. https://doi.org/10.32528/agritrop.v20i1.7124.

Smith, M. R., & Rao, I. M. (2021). Chapter 12 - Common bean. In V. O. Sadras & D. F. Calderini (Eds.), *Crop Physiology Case Histories for Major Crops* (pp. 384-406). Academic Press. https://doi.org/10.1016/B978-0-12-819194-1.00012-8

Song, Q., Fu, H., Shi, Q., Shan, X., Wang, Z., Sun, Z., & Li, T. (2022). Overfertilization reduces tomato yield under long-term continuous cropping system via regulation of soil microbial community composition [Original Research]. *Frontiers in Microbiology*, *Volume 13 - 2022*. https://doi.org/10.3389/fmicb.2022.952021.

Suryaningtyas, D. T., Nur Fatiha, Y. G., Oktariani, P., & Suwardi. (2023). Zeoponic, a plant growing medium from zeolite mineral. *IOP Conference Series: Earth and Environmental Science*, *1133*(1), 012020. https://doi.org/10.1088/1755-1315/1133/1/012020.

Suseno, & Widyawati, N. (2020). Pengaruh nilai EC berbagai pupuk cair majemuk terhadap pertumbuhan vegetatif kangkung darat pada soilless culture. *Agrosains : Jurnal Penelitian Agronomi*, *22*(1), 4. https://doi.org/10.20961/agsjpa.v22i1.32510.

Suwardi, Palupiningtyas, E., Galuh Nur Fatiha, Y., Hidayat, M., Tjahyandari Suryaningtyas, D., & Oktariani, P. (2023). Chemical and physical properties of zeoponic and their influence on growth of forestry plant seedling and horticultural crops. *IOP Conference Series: Earth and Environmental Science*, *1133*(1), 012019. https://doi.org/10.1088/1755-1315/1133/1/012019.

Suwardi, & Pangestu, M. B. (2004). Zeoponik sebagai media tanam pada budidaya tanaman hortikultura. *Jurnal Zeolit Indonesia*, *3*(1), 15-18. https://www.neliti.com/id/publications/219761/zeoponic-as-growth-media-of-horticulture-plants.

Suwardi, Suryaningtyas, D. T., Oktariani, P., Widjaja, H., & Randrikasari, O. (2024). Zeoponic: A breakthrough plant growth media for horticulture and seedling of plantation. *Agricultural Reviews*, *45*(3), 538-545. https://doi.org/10.18805/ag.RF-310.

Taslim, N., Akbar, Y., & Sabr, Y. (2020). Pertumbuhan dan hasil tanaman buncis (*Phaseolus vulgaris* L) akibat pemberian beberapa dosis pupuk organik cair keong mas (*Pomacea canaliculata* L). *Journal of Agricultural Science Development*, *4*(5), 1-14. https://jurnal.umsb.ac.id/index.php/agriculture/article/view/5628.

Theresa, K., Shanmugasundaram, R., & Kennedy, J. (2020). Effect of varied levels of NPK fertilizers on soil reaction and electrical conductivity. *International Journal of Chemical Studies*, *8*(1), 2632-2636. https://doi.org/10.22271/chemi.2020.v8.i1an.8669.

Wibowo, A. W., Suryanto, A., & Nugroho, A. (2018). Kajian pemberian berbagai dosis larutan nutrisi dan media tanam secara hidroponik sistem substrat pada tanaman kalian (*Brassica oleracea* L.). *Produksi Tanaman*, *5*(7). https://protan.studentjournal.ub.ac.id/index.php/protan/article/view/485.